An Ecological Approach to Sanitation in Africa

A compilation of experiences

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1. An Introduction: understanding the concept of ecological sanitation

For most people sanitation means sitting on a toilet and flushing away the excreta to waste or simply sitting or squatting on a pit toilet and letting the waste matter build up in a pit. In both cases the excreta is disposed of and forgotten in the quickest and most convenient way. To be frank, this is an entirely logical view - there are far more important things to concern us all. But in a world which is becoming increasingly polluted from excreta, and where many of the world's population do not have access to a decent toilet at all, it does make sense to look at excreta in another way. The fact is that excreta can easily be made safe and contains valuable nutrients which can be used for enhancing the growth of food. And the methods of achieving this are not complex or expensive. On the contrary, they can be undertaken very cheaply, with great benefit to those who try.

Ecological Sanitation concerns the recycling of human excreta to form products which are useful in agriculture. Those who believe in ecological sanitation see the human excreta, not as a waste but as a valuable resource. And a resource which is renewed every day! To put it simply… *ecological sanitation is* a *system that makes use of human excreta and turns it into something useful, where the available nutrients can be recycled in agriculture to enhance food production, with minimal risk of pollution of the environment and with minimal threat to human health.*

In fact processed faeces can turn into excellent compost. This material contains a well balanced mix of nutrients, such as nitrogen, phosphorus and potassium, which are easily taken up by plants. Urine also contains a similar range of nutrients, being particularly rich in nitrogen, which makes it useful for feeding green vegetables and maize. Even a combination of urine and faeces, when mixed in a shallow pit, with soil, wood ash and leaves, can turn into a sweet smelling and fertile compost. This pit compost is quite unlike the original matter from which it was formed, and when mixed with poor soil can greatly enhance vegetable production. Such a conversion is nothing short of a miracle of Nature.

But there are problems. Human excreta is odorous and unpleasant in the extreme. The excreted products, particularly the faeces, are known to carry a multitude of pathogenic organisms which carry disease. For most people they are best disposed of and forgotten as quickly and as effortlessly as possible. That means the use of a flush toilet or a pit latrine - out of sight and out of mind. And for much of the world's population the flush toilet and the pit latrine must continue to form the basic form of excreta disposal for a long time to come.

But there is a growing concern about the use of ever depleting fresh water supplies to flush away such wastes, which can often lead to greater pollution "down the line." Where there is a lack of space, even the ubiquitous pit latrine cannot easily be emptied to form space for another. And even deep pit latrines eventually fill up and must be abandoned. The problems faced in high-density urban areas are the most pressing and also the hardest to solve. And for much of Africa, the cost of an improved latrine may also be prohibitive.

Perhaps the answer may lie in applying the principles of ecological sanitation. Now there is an extended range of options that can suit a wide range of users – from the very poor to those who are well off. Slowly but surely the concept of ecological sanitation is broadening and rising to help solve these serious problems.

There is also a concern that valuable nutrients are being lost, in vast quantities, every minute of the day by the disposal of excreta in conventional ways. The nutrients available in processed excreta are ideal for use on the lands and in vegetable gardens – and yet these valuable resources rarely come anywhere near our gardens in most parts of the world. Where flush systems are used they fertilise our lakes and seas instead of our fields, with dire consequences.

Shallow pit systems

Two of the three main toilet systems described in this book process the excreta in shallow pits. The third system separates urine from faeces and these two products are processed separately. The methods using shallow pits are simple and relatively cheap to construct, and are thus more suited for uptake in the poorer countries of the world, where pit sanitation may already be the standard method of excreta disposal.

This approach has been undertaken for several reasons. The world of ecological sanitation has been broadened to include very simple and forgiving methods which are similar (if not identical) in their use to the standard pit toilet – the most commonly used excreta disposal system in the world. These systems have been given names – the ***Arborloo*** (a simple pit -toilet in which a tree is later planted) and the ***Fossa alterna*** (an alternating twin pit toilet which forms compost). Such methods are, in this account, seen as introductory or entry points into the world of ecological sanitation and the recycling of human excreta. They are particularly useful and appropriate for use in parts of Southern and Eastern Africa. The urine diverting system is seen as an excellent but more sensitive concept – its success depending greatly on meticulous use and regular maintenance. Thus the range of options is expanded to include methods which are more forgiving and thus less sensitive to misuse. Also there is a problem of cost to consider. Urine diverting systems are more complex and costly to build and may be beyond the scope of the less well off, which on a continent like Africa, may be most. However, there are many ways of collecting the valuable urine other than separating it in a pedestal or squat plate. Urine can be collected in containers, bottles, potties and stored and later mixed with water for application to the soil. There is much flexibility.

Urine diversion

There are many ways of putting ecological sanitation into practice – and it starts off with the use of an appropriate toilet. A huge range of ecological toilet designs exist from the very simplest to the most complex. Most ecological sanitation programmes throughout the world use a concept known as 'urine diversion' to separate the urine from the faeces. The faeces accumulate in one place and the urine in another. A specialised urine diverting pedestal or squat plate is used for this purpose. These are designed for sitting or squatting. Both faeces and urine are much more easily handled when they are separated. The smell is much reduced, as is the potential for fly breeding, common to most pit latrines. The urine can be contained, and then later:

a. Diluted with water to make a plant food particularly rich in nitrogen, or
b. Applied undiluted to the soil and watered in, or
c. Applied to the land without dilution, and then left, before planting, for soil bacteria to convert the urea into nitrate nitrogen for later uptake by plant roots.

In most urine diverting toilets, attempts are made to desiccate and sanitise the faeces. Lime or wood ash (and often dry soil or sawdust) are used for this purpose, being added regularly to the faeces which accumulate in vaults or containers. The combination of desiccated faeces and ash or lime turns into an alkaline, sterile product which in countries like Guatemala is known as "abono." This inert and inoffensive material can be stored in bags and is often applied to the land as a soil conditioner. Being very alkaline it is good for acid soils. When it contains much ash, this will help to increase the potassium level of the soil. In its dry state it is certainly quite a safe material.

Most practitioners of ecological sanitation feel the greatest value of excreta lies in the urine, which contains most of the nutrients, and a very high proportion of nitrogen. They see the dried faeces as a secondary product of much reduced value. Some advocate digging it into shallow pits or burning it. But this book promotes the view that compost derived from biologically processed (as opposed to dessicated) human faeces is far too valuable to burn or to dig into holes which are then abandoned. In fact this compost has a far better overall balance of nitrogen, phosphorus and potassium than urine alone.

The ideal is to use a combination of both composted faeces and urine in our gardens, taking advantage of the best qualities of each. Much has been written on the subject of urine diversion and reference should be made to the bibliography at the end of this book. This book deals mainly with the almost unknown range of non urine diverting methods, since they have been little researched and written about before. One chapter in this book is devoted to urine diversion and another to urine and its use.

Upgradeability

The concept of being able to upgrade from one system to another is also embraced here. It is for instance possible to start in the simplest possible way with an ***Arborloo,*** and then upgrade to a ***Fossa alterna.*** This too can be upgraded later to achieve a fully urine diverting system, when the concepts of recycling are fully understood and appreciated. Thus urine diversion is a system to aim for in a step-by-step upgrading process. In all cases the primary aim of ecological sanitation is to recycle human excreta in a simple, safe and effective way. Whichever method is used, the results should be obvious to the users and useful to them. For without a true value being perceived from the user's point of view, the ultimate aim of ecological sanitation can never be realised. To form a convincing appreciation, the compost formed in the "eco-toilet" must be seen to enhance the condition of the soil and actually lead to greater production of vegetables, food crops and trees. The urine must be seen to make plants grow larger and provide more food. Without such evidence, people will not be convinced.

The management of ecological toilets must also be simple enough to be achievable. The extra effort involved in managing eco-latrines must be repaid many times over in the end result – and in most cases this simply means more food to eat or trees to use as fuel or to provide fruit. Without this return, in the eyes of the user, ecological sanitation can never attain the position it deserves.

Recycling – the central issue

Ecological sanitation embraces far more than building eco-toilets. The toilet is important but it is only part of the system. The toilet fits into a concept of recycling compostable materials within the homestead as a whole and plays its part in recycling biological wastes from the kitchen as well as the garden. Obviously the "eco-toilet" is a central component, but the system also includes the processing of human excreta into products which are safe and valuable in agriculture. The aim is to show that the nutrients held in processed human waste can be recycled in a simple, safe and effective way to increase the production of food (both vegetables and fruit). This is known as **"closing the loop."** That means that food is consumed, excreta formed, excreta converted into compost and that this product (together with urine) can be used to grow more food which is consumed again. That is closing the loop!

The **practical demonstration** of the usefulness of the by-products of human excreta in agriculture is seen as an important component of all ecological sanitation programmes. Consequently the crucial step of linking toilets with a method of producing compost or urine for use in agriculture (or forestry) must be emphasised. It is this very important management procedure which is vital to the success of ecological sanitation. In ecological sanitation, success depends on proper management, and thus depends on user participation to a far greater extent than conventional sanitation systems. It is no longer a case of sit and flush or squat and deposit. Ecological sanitation embraces a philosophy which the users must belief in and practice daily. Such an understanding and practice takes time to fulfil.

Forming links with agriculture

Ecological sanitation has come at a most important time, not least because it is able, unlike most other forms of sanitation promoted before it, to form direct links with other important disciplines. The need to improve top-soils in a world where most soils are poor and unable to generate good crops is an important consideration. On a small scale, ecological sanitation can greatly assist this problem. The compost resulting from processing human faeces makes an excellent "soil conditioner", admittedly not in huge quantities at the family level, but certainly sufficient to enhance vegetable production in the back yard. The aim is to mix the compost formed in toilets with infertile and worked-out soil, thus making a "new soil" in which plants can grow far better. The urine can also be used to enrich the soil further, particularly for growing green vegetables, maize and even trees. Those practising ecological sanitation should also be familiar with the methods of making garden and leaf compost so that all these fertile materials can be mixed to form an enriched soil suitable for planting vegetables and other useful plants. Such compost, when properly used in agriculture, helps to improve food yields considerably and hence provides more food security and improves the nutritional status of the beneficiaries.

It is accepted that gardening and home based vegetable production may not be important to all potential users of ecological sanitation. But in the context in which this book has been written, which is for use in the urban, peri-urban and rural areas of Southern and Eastern Africa, food production in the home can be an important issue, and is taken seriously by most families. However, as we shall see, eco-toilets can solve other problems related to conventional sanitation, not least the saving of water or ease of excavation of shallow pits.

Thus important links can be made between sanitation and the worlds of agriculture and forestry. And also of importance is the link to permaculture, where methods associated with the best organic farming are emphasised. Permaculture emphasises the use of natural methods, where organic materials of all types are used to make valuable soil. The miraculous change of human excreta into compost is one of Nature's marvels. Without this natural process of "building up" and "breaking down" no animal or plant life could exist on Earth.

The living soil – humus is important.

The message contained in this book sees the converted faeces as a product of considerable value and no less important than the urine. The soil is placed at centre stage as a converter of excreta into compost. The ideal is a mix of excreta, soil, ash and leaves, which, within a year turns into a valuable compost within a shallow pit. Even with urine diversion, the separated faeces, initially mixed with some wood ash and soil in the latrine, can be moved to a "secondary composting site" where additional soil and leaves are added. The end result is also a nutrient-rich compost, not a sterile dust. The converter is the "living soil," greatly assisted by the presence of leaves and ash.

Global considerations

Perhaps there are broader objectives too. Turning a renewable waste product like excreta into a valuable product in which plants of all types can thrive has considerable merit in its own right. Even more so, in a world overlaid by depleted soils and barren landscapes. Saving valuable phosphorus, a vital nutrient in plant formation, is also vital – for world supplies are being depleted at an alarming rate. Human excreta is a most valuable source of phosphorus, and also of nitrogen and potassium – all vital elements to food production.

Letting Nature work so effectively for Man has supreme merit. *Nature at work* lies at the heart of the message provided by this book. The conversions are natural - the growth of plants a natural response to the fertile soil. The soil organisms of all types, beneficial bacteria, fungi, worms and insects, are seen to be at work throughout the entire process. The nutrients resulting from this process can work well for the benefit of Man. Whilst these processes of Nature take place, for the most part out of sight and out of mind, in combination they represent a great movement towards improving the fertility of the Land - something of supreme importance for the survival of Mankind on a planet which is fast being depleted of its natural resources.

Compost toilet built above a shallow pit

2. The answer lies in the soil

The theme which is central to this book about ecological sanitation is its link to the soil. Soil with its complex makeup of living organisms and nutrients is essential for the formation of humus. Even the recycling of urine is linked to the soil, for soil bacteria are essential for the conversion of urea and ammonia contained in urine to the nitrate - a salt of nitrogen which can easily be taken up by plants. When a mix of soil, leaves and excreta are combined, the organisms in the soil help to break down the excreta to form a type of compost. The excreta in return offers additional nutrients to the soil and also improves the soil's texture. Adding urine increases the nutrient content further. So the living soil is central to the process.

The various latrine systems and recycling methods described in this book have been so designed that the excreta which accumulates is converted into compost which is readily used by a great variety of plants – whether they be vegetables, crops or trees. In the case of the ***Arborloo***, a shallow pit latrine which becomes a tree, compost formation is encouraged in the shallow pit by the regular addition of soil, wood ash and leaves. Once the pit is almost full, the structure and slab are removed and placed on top of another shallow pit nearby. The used pit is topped up with leaves and more fertile soil and a young tree is planted in this soil, watered and protected. It is planted in the soil – not the excreta – plants do not survive when planted in fresh excreta. If the fates are kind, the young tree grows, at first in the topsoil, whilst the excreta below is turning into compost as it would in Nature. In this way the nutrients held within the pit contents are utilised by the growing tree, and when the tree matures, can be recycled to produce fruit (fuel or building materials). Much of the urine is absorbed into the mass of compost or leaves held within the pit, and the excess will be drawn up into the surrounding soil and converted into usable nutrients – which the tree can also use later in its life. The ***Arborloo*** thus travels on a "never ending journey" through the "lands" followed by a series of trees which may eventually form a woodlot or an orchard – or just simply shade trees scattered here and there. Sometimes a young tree will hesitate as it starts to grow. A few may die, but most grow strongly right from the start if well cared for.

The *Arborloo is* the simplest ecological toilet. Photo at Eco-Ed Trust.

In the case of the ***Fossa alterna***, the second simple eco-toilet described in this work, a similar process takes place in the shallow pit, with soil, wood ash and leaves being added as well as excreta. But the structure, which is portable, alternates between just two pits, which are permanently sited. Once the first pit is nearly full, the structure is moved to the second pit and the first topped up with a good layer of leaves and topsoil. After one year the contents will have changed their form into nutrient-rich pit compost which can be dug out and used on the garden. The structure is moved back on to the emptied pit. It moves from one pit to the other once a year, every year – a process which is fully described in this book.

A *Fossa alterna* in Epworth, Zimbabwe. The twin pit system makes humus

In the case of urine diverting toilets where the urine and faeces are separated, the faeces normally accumulate in a vault beneath the pedestal and the urine collects in an offset plastic container. There are many descriptions of urine diverting toilets in the international literature (see bibliography at the end of this book, notably *Ecological Sanitation* by Esrey et al. 1998). In the example described in this book, known as the '*Skyloo*" the faeces accumulate together with soil and wood ash in a bucket held within the vault. The soil and wood ash are added after every visit made to deposit excreta. This mix of faeces, toilet paper, soil and wood ash is removed within the bucket and deposited in a "secondary processing site" where more soil and leaves are added. Here the mixture changes its form into fertile compost for onward passage to the garden at a later date. Human faeces readily turn into compost if they are in close contact with a fertile soil and some form of plant life – and are kept moist and are well drained and aerated. The aim is enable the soil to form layers within the accumulation of faeces to effect the change. The mix of faeces, soil, ash and paper and preferably leaves can be added to shallow pits, trenches or containers such as cement jars and covered with layers of fertile soil. The change in form from a most obnoxious, foul smelling mass into pleasant smelling humus-like material is quite remarkable. It takes place in nature all the time, in the forest, for instance, where the wastes produced by animals turn into humus on the forest floor together with leaf litter formed from the trees. All the nutrients formed are recycled back into the forest. Humus like material formed from human excreta is rich in nitrogen, phosphorus and potassium – all essential for healthy plant growth.

The importance of humus

Humus is the dark crumbly material formed from decayed matter formed in nature from a constant supply of residues from animal and plant life. These residues are constantly converted in nature by the organisms present in the soil and also in the residues themselves. Moisture is required during the whole period during which the humus is being made and also abundant aeration is essential. Even in Nature, if too much water is present, the aeration of the forming humus is impeded and the process slows down or stops. If too little water is present, the activity of the micro organisms slows down and then may cease altogether if the mass becomes desiccated. Desiccated leaves can remain unchanged for decades or even centuries – but when they are moistened they decompose readily. Rainfall is an excellent method of watering since it is a saturated solution of oxygen. The conversion of the various natural products into humus is a result of activity by beneficial bacteria and fungi and also by a myriad of other micro organisms and small animals. Bacteria are essential to this process. Most bacteria present in Nature are beneficial to life and present no health threat. In fact by far the majority of bacteria are essential to the natural process of breakdown. Without this process of breakdown, followed by re-growth, life on this planet could not exist. The soil is the home of millions of beneficial bacteria.

Jar with a mix of faeces, soil and ash after 4 months composting. It is just plain humus.

Humus is essential to soil fertility and adds an important physical condition to the soil, making it more crumbly, more moisture retaining and physically capable of greater oxidisation, which is essential for the growth of all living organisms including plants. The best humus is derived by mixing the soil formed from excreta with other humus like soils and plant material like leaf compost. Thus good humus can be built up, in a series of generations by adding and mixing. The earth worm, the bacteria, the fungi, and a myriad of other micro-organisms of a benevolent character whose habitat is the soil are important actors in this process. The only way to farm or to manage a successful garden is to maintain the fertility of the land by adding humus – thereby preserving the living content of the soil. That living content of the soil is best maintained by the constant refreshment of further supplies of life

in the form of humus. Everything we see in nature shows the greatest use of every type of waste. In fact nothing anywhere in Nature is allowed to go to waste. Recycling is a central theme in Nature. Ecological sanitation also promotes this ideal.
These views, well expressed by Friend Sykes in his book *"Humus and the Farmer"* and other promoters of the humus theory (Howard, 1943 and Balfour, 1943) make a lot of sense (see bibliography). Others promote the use of chemical fertilisers as the best means of obtaining adequate crop yields on the land. The probable truth lies somewhere in between, in striking a balance between using natural and artificial fertilisation (Hopkins (1945). This wise concept is also discussed by Louis Bromfield in his book Malabar Farm. In his studies of the land, Bromfield found that chemical fertilisers were of very little use on soils devoid of organic material and of great immediate value upon soils high in organic content. Studies revealed in this book also show that the same holds true for the application of urine to the soil. Urine adds only chemical nutrients to the soil and no living material. Bacteria in the soil are essential for the conversion of the urea present in urine into forms of nitrogen (nitrate) which can easily be absorbed by plants. So the use of urine as a plant nutrient depends very much on the soil and its living content to be effective. Soil containing humus is far more effective at processing urine than soil deficient in humus, such as very sandy soil. So once again, the soil plays a central role, even in the use of urine.

The capacity of chemicals to burn out crops or to destroy bacteria, earthworms and other living organisms in the soil, Bromfield found, was largely determined by the amount of organic material present and of the moisture content which accompanies its presence in the soil. Nothing was so effective in trapping and holding rainfall and moisture as organic materials in every stage of decay. Thus it would appear that the value of humus holds true, whether or not artificial fertilisers are added, in what ever form they are used. This must also hold true even where diluted urine is the source of liquid feed. Plants will respond better to urine if the soil is more humus like and has water holding properties. Thus the recycling of both solids and the liquids of human excreta much depends on the presence of humus - the living soil.

One major difference between the process taking place in the garden compost heap and that seen in our shallow pit eco-toilets or the production of humus from excreta in bags, buckets, jars or shallow pits, is the relatively larger proportion of "manure" (human faeces) and the smaller proportion of vegetable matter. Vegetable matter in abundance is vital to the "Indore Process" of composting promoted by Sir Albert Howard. With less vegetable matter being present in the humus formed in shallow pits and jars containing human excreta, there is little rise of temperature – as compared to the compost heap where significant rises of temperature occur. The conversion of excreta into compost in this case does not depend on the activity of heat loving (thermophilic) micro-organisms (bacteria and fungi) but rather those bacteria and fungi which thrive at ambient temperature (mesophilic), that is close to the temperature of the surroundings. All manner of other beneficial organisms, including insects, worms, and many other life forms also thrive best at ambient temperatures. Not only do these animalcules and microbes digest the excreta but also inhibit, compete with, consume or otherwise antagonise those pathogenic organisms, such as bacteria, that carry disease. The process is an entirely natural one leading to the formation of humus and compost. The addition of fertile soils and leaves to excreta also help to absorb much of the moisture content of the excreta itself – a process which is associated with a reduction of the volume of the mass. The end result of this process is friable darkened humus, which when mixed with topsoil makes an excellent soil conditioner and nutrient enhancer.

The conversion of raw excreta into compost or humus, in the presence of adequate volumes of soil, leaves and ash, reveals a change of colour, odour and texture of the original faecal matter, which darkens, becomes pleasant to smell and handle and also become more friable. The activity of insects and their larvae may also be important in breaking up the faeces as well as bacteria, fungi and earthworms where they are present. Roots from trees and other plants also invade the highly organic layers in the eco-pits or containers where excreta is converting, and are very visible when the pit is being excavated or the jar is opened. Where plants grow into the organic materials held in pits or containers, their roots also convey oxygen into the body of the material, which greatly assists the decomposition process. In Nature, all living organisms and their products eventually end up in the soil and become part of it, only to be recycled again and again within a never ending process of building up and breaking down.

These descriptions of the humus and the important part it plays in the fertilisation of the land, together with the capacity of urine to increase the amount and availability of some essential nutrients, are in my view, central to our own promotion of the eco-sanitary process.

The top soils of many parts of Southern Africa are worn out and almost devoid of humus or nutrients. In Zimbabwe 70% of rural farmers work on a soil which is labelled as poor or very poor, holding less than 42ppm of phosphorus. Nitrogen is being lost at the rate of 30 kg per ha. and applied at only 3 kg per ha – a net loss of 20 kg per ha. Even when nitrogen is applied, heavy rain can leach out the nitrogen and drive it down to deeper layers where it is not available to plants. Most naturally occurring soils where people live are not only deficient in nitrogen but also in phosphorus and potassium and also many trace elements. Nitrogen, phosphorus and zinc, amongst other minerals are seen as limiting to meaningful agriculture in 70% of samples collected around Zimbabwe. Most soils are sandy and have a low pH. Few soils in the rural and even peri-urban and urban areas can sustain any form of healthy crop growth without meaningful inputs of both humus and nutrients.

Barren soils are a common site in Africa but can be enriched by recycling human excreta. The photo on right shows a series of trees growing on *Arborloo* pits in Malawi.

Since the soils of Africa are so depleted in nutrients there is an overwhelming case for using all methods available to restore both nutrients and fertility. The use of animal manure is widely used in those areas where cattle are kept and this technique forms part of a long standing traditional practice. But the great majority of people do not own cattle. In a world where commercial fertilisers are becoming increasingly unaffordable, there is an even greater need to harness any other form of humus or nutrient suitable for crop growth. It is in this context that processed human excreta must be considered. Whilst the volume of excreta produced by a family is not large, it is certainly enough, once processed, to sustain a family vegetable garden and that should be the initial aim. This means taking full advantage of whatever humus can be processed, and also urine and combining their best properties to increase the food crop.

The successful use of the specialised toilets used in eco-san depends to a large extent on the users understanding of the processes involved, and the potential benefits to be gained. Compared to pit latrines, which can provide an almost maintenance free service for a decade, ecological toilets require more attention and the advantages may not be immediately obvious. A tree planted in an ***Arborloo*** pit may take a few years to bear fruit. Two years are required before the first humus can be dug out and used from the ***Fossa alterna*** pit. Thus sound educational programmes and novel forms of demonstration must therefore precede programmes of construction – with ample evidence of the benefits to be gained. Most people simply do not believe that excreta can turn into "soil." And this "soil" together with their own urine can save them money that would otherwise have been spent on buying fertiliser. One needs evidence to believe and that means individuals seeing the proof with their own eyes – "ahead of time." ***Seeing is believing!***

Teaching people about toilet design and construction and also the potential of recycling nutrients from human excreta is an important part of the educational process. Annie Shangwa teaching a group of trainees in Kufunda training Village in Ruwa, Zimbabwe. This important aspect of ecological sanitationand its promotion is described in a later chapter of this book.

3. Modifications of the pit toilet

Man's most commonly used toilet, the pit latrine, has been used in some form, on most continents for thousands of years. This concept continues to be the simplest, cheapest and most favoured method of excreta disposal for most of Africa, not counting the towns and cities. But even in the towns and cities, pit toilets are used a great deal. Their relative cheapness, together with ease of construction, use and maintenance make them popular. Problems of odour and fly breeding can be largely overcome by fitting a screened vent pipe, or by adding generous amounts of soil and ash to the pit. Indeed a properly made pit toilet can be as comfortable to use as the best of other conveniences, although of course it must be built outside and very close to ground level. For these various reasons more people use pit toilets than any other form of excreta disposal, world wide.

The pits under most pit toilets are invariably dug about 3 metres deep, although in Kenya they may go much deeper. Most times, pits fill with a mix of excreta and garbage – the pit toilet is a convenient dustbin! Some pits are lined, others not. Most pits are covered with a slab made of wood or concrete, and the house above, made in a thousand different ways, provides privacy. The worst pit toilets are a menace, generating foul odours of the worst possible type and breeding flies in alarming numbers. Those in high water table areas in the denser settlements can also pollute underground water, and wells polluted in such places can carry disease. However, well constructed pit toilets can be a pleasure and comfort to use. They can be odourless and fly free. Well sited, they are not a threat to health in any way. By far the best are those built and used by a family, where they are generally kept clean and tidy. The vast majority of pit toilets are used until their vaults are full, and then they are abandoned, and new facilities built.

But in some countries and some communities, the value of the pit contents as a fertiliser has long been known. In several countries in Africa, and indeed elsewhere, trees are deliberately planted on old toilet pits because they are known to grow well, with the fruits growing large and tasty. Sometimes nature sows a seed in an old pit and a new tree will grow. Sometimes tomatoes or pumpkins will grow out of abandoned toilet pits, no doubt because kitchen scraps have been thrown there. There are some cases where the contents of old pit toilets, after a period of a few years, are deliberately dug out and used as fertiliser on the lands. So in these rather more isolated cases, the usefulness of the pit toilet extends far beyond its normal life. This book attempts to extend the logic of this concept and make it better known and understood. The usefulness of the pit toilet can indeed be extended far beyond its normal working life.

Some basic concepts about pit toilets

Once faeces and urine enter a pit, a process of breakdown begins. The end result is what may be termed pit compost. If the pit is filled with excreta and garbage alone, the composting process can take many years to complete, since there is little air in the compacted excreta and few suitable microbes. If the excreta is mixed with other materials like soil, wood ash and leaves, more air is introduced into the mix and also a complexity of microbes which are able to change the excreta into compost more efficiently. The end result is that the composting process is much accelerated. This shows the important effect the soil and its living content has on composting excreta. Perhaps the word compost or humus is not strictly correct as they convey the impression that the material has gone through a process of decay either by a heating process, as in garden compost or by natural decay where a large amount of plant material is available. This is not necessarily the case with pit compost. However the use of the word compost (or pit compost) and in some cases humus has been used for simplicity and convenience. The process may be called ambient temperature composting.

The process is best undertaken in shallower pits. In deep pits the contents become more compact, and once again contain less air. In shallower pits, which are less compact, there will be more air, particularly if there is a mix of ingredients. This is particularly so if leaves are added to the mix in addition to soil. Leaves help to reduce the density of the final humus and therefore increase the air content, which in turn makes composting more efficient. Shallow pits are also easier to dig out and further away from the underground water table. The eco-toilets described in this book use shallow pits which are rarely more than 1.5 metres deep.

However, shallow pits do fill up more quickly then deeper ones and it is necessary to strike a balance. If a mix of ingredients is added, the pits will certainly fill up faster, but not as fast as one would think, as much of the bulk of excreta is in liquid form which is partly absorbed by the soil and ash thrown down the pit, and partly leaches away into the surrounding soil. At least 70% of human faeces is made up of water, and when mixed with soil, the volume of composted faeces is much reduced. Actively composting excreta significantly reduces in volume over time. So a balance must be struck and a choice made. Deeper longer lasting pits need less attention, but eventually fill up and are usually abandoned. Shallower pits holding a mix of composting ingredients fill up more quickly, but the resulting humus can more easily be dug out, and used for growing vegetables or for growing trees.

The processes involved are simple and natural, and if care is taken the composted humus is considerably safer than hands soiled after anal cleansing. The increase in food production can be considerable, as this book reveals. This process adds a new interesting dimension to the rather dull story of building toilets. The worlds of sanitation and agriculture are now combined with a definite benefit being gained by the family in addition to the disposal of excreta alone. Food production can be enhanced. Also the eco-toilets, as they are best called, are relatively cheap and easy to make. With a little training it can all be done by the homesteaders themselves.

In this book we look at ways of building and managing the various simple eco-toilets designs. Then the important subject of using the recycled materials in agriculture is discussed and explained in detail with many working examples described.

Simple eco-toilet in Malawi.

4. The Arborloo - the single pit compost toilet.

The simplest of ecological toilets is called the ***Arborloo,*** the toilet that becomes a tree. But it differs in several fundamental ways in its design and the way it is used from the commonly used pit toilet.

A**ll the parts of the ***Arborloo, apart from the pit, are portable. This includes the "ring beam" protecting the pit head, the concrete slab and the superstructure. Each of these components moves on a *"never ending journey"* from one pit to the next at about 6 -12 monthly intervals. The toilet is literally picked up and moved, leaving the almost filled pit behind.

* ***Arborloo*** pits are shallow, - normally no more than one metre deep and they are not lined with bricks or other materials. The pit is normally protected at the head with a "ring beam" made of bricks or concrete which strengthens the pit head and reduces the effects of erosion and pit flooding from rainwater. In very sandy soils, a 200 litre drum may be used to make a pit lining. If the soil is very firm, no ring beam is required at all from a constructional viewpoint, but it helps to raise the toilet foundations on a ring beam to stop pit flooding during the rains.

*****Soil, wood ash and leaves are added regularly to the pit in addition to excreta. These aid the composting process considerably. The remarkable conversion from excreta into pit compost is normally complete well within 12 months of closing off the pit. The addition of soil and ash on a regular basis also reduce fly and odour nuisance.

* The ***Arborloo*** pit is NOT used as a dumping ground for rubbish like most pit latrines. The dumping of plastic, bottles and rags etc, is not recommended.

An *Arborloo* in Phalombe, Malawi

Once the latrine has been moved to the new site, a layer of leaves and fertile topsoil between 15cm and 30cm deep is added to the contents of the pit, which are first levelled off. The pit contents can be left for a month or two or more to settle or can be planted with a young tree straight away. Some people prefer to leave the day of tree planting until after the arrival of the rains. This is a wise move if water is scarce. But it is also possible to plant the young tree directly after topping up with soil. Trees will not grow in raw excreta - they must be planted in a good layer of soil placed above the excreta. Within a few months the layers containing the excreta will have changed into compost which the tree roots can then start to invade. So in effect the old latrine site becomes a site for a tree. Most trees will grow well in these shallow pits if planted properly and cared for. The young tree should be watered regularly, and protected from animals like goats and chickens like any other young tree. Covering the surrounding soil with "mulch" helps to retain water. With a combination of excreta, soil, ash and leaves in the pit the pit contents turn into compost which most tree roots can cope with easily and later will thrive on. Later on diluted urine can be used to provide additional nutrients.

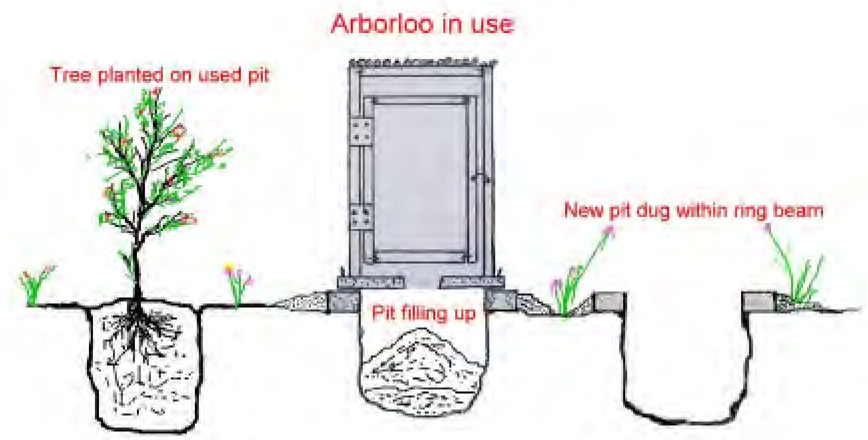
The ***Arborloo*** fulfils all the basic requirements of ecological sanitation. The recycling of human excreta is made as simple and convenient as possible. Natural processes are involved in a way that retains a simplicity of method and flexibility of design. The latrine is safe from a health point of view - the excreta is never touched by hand and contained below a layer of leaves and topsoil. Thus contamination of the environment is minimal. The pit is shallow and thus further away from ground water than any conventional pit latrine. The excreta (faeces and urine) combine with the soil and other ingredients to form pit compost which becomes an ideal medium for tree growth. Thus the odorous and potentially dangerous raw excreta are converted far more quickly into compost than in "deep pit" latrines. The combination of human excreta and soil, ash, leaves etc greatly enhances the nutrient levels found in the parent soil. This applies to all soils - whether they are rich or poor. The compost formed is more crumbly, with much elevated levels of all the major nutrients like nitrogen, phosphorus and potassium, which the trees can use. The ability of the "new soil" to retain water is also enhanced. Urine added to the pit is either absorbed into the pit compost or leaves or soaks into the side walls and base of the pit where some of its nutrients (particularly phosphorus) become available later, when the tree roots penetrate the soil. As the tree grows it absorbs more and more of the nutrients laid down earlier. Over time some nitrogen is lost, but this can be applied later with diluted urine.

The ***Arborloo*** also provides an excellent example of how the nutrients derived from human excreta can be recycled through the production of food - in this case fruit. The concept of "closing the loop." is well demonstrated. The fruits eaten from trees grown on older ***Arborloo*** pits, once processed by the human body, are reintroduced back into the ***Arborloo*** pit currently being filled. Over a period of time "woodlots" of gum trees or "orchards" of fruit trees will result and the general fertility of the land is improved. Trees also offer shade, leaf compost and stability to the soil.

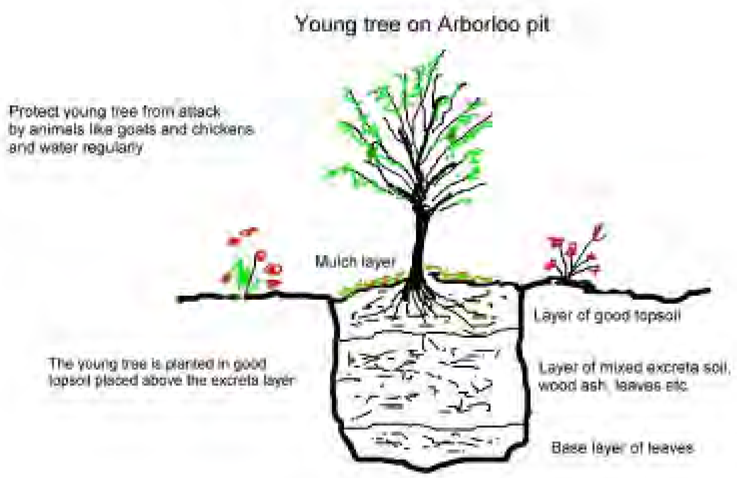
Remarkably, the mixing of barren topsoil and human excreta, results in a mix with enhanced nutrient value. If a fertile soil and leaves are also added, the resulting mix is even richer. It is into these soils that the tree roots will eventually grow. Tree growth into the pit contents represents only the first stage of root invasion - it continues into the surrounding soil which will also be nutrient enriched to a lesser extent.

Not surprisingly, a similar method of processing human excreta, has been used in the African traditional way of life for generations. In countries like Malawi, Mozambique, Kenya and Rwanda, villagers traditionally plant trees on disused latrine pits. And even nature uses the same principle - often the seeds of trees fall into disused and abandoned pits and germinate there. What better means exist to show that even human excreta, once changed into humus, can be an ideal medium for tree growth. The ***Arborloo*** is a refinement of this simple and well established principle. The physical structure of the latrine is designed to be portable, unlike more conventional latrines. Also the shallow pit is fed a mix of ingredients, deliberately, to ensure a more rapid conversion of excreta into pit compost and thus a better survival and growth rate of trees.

In practice the latrine is used until the pit is nearly full, which for a family should be between 6 and 12 months. Once the pit is nearly full, the structure, slab and ring beam are removed and the ring beam is placed on another suitable site nearby and a new pit dug within the beam - about one metre deep. The slab and superstructure are now placed on top of the beam and the latrine is put to use once again. The family may start off by using the toilet in any convenient place, but may then decide to place it within a specific piece of land set aside for an orchard or wood lot. Gum trees grow particularly well on these organic pits. However fruit trees are generally far more popular. In Malawi, citrus trees like orange and tangerine are the most popular trees because they have a commercial value.



The *Arborloo* moves on a never ending journey leaving behind a series of fertile pits filled with a mix of human excreta, soil, wood ash and leaves etc which provide a suitable planting medium for trees when composted. Nutrients in the excreta are used by the tree to enhance its growth.



The *Arborloo* - Stages of construction

Now we shall describe how to build and manage the simplest eco-toilet – the ***Arborloo***. The basic building components of both the ***Arborloo*** and ***Fossa alterna*** are the same, but the ***Arborloo*** is built with a single shallow pit about one metre deep in a temporary location. The ***Fossa alterna*** is built with two shallow pits which are deeper (1.2 – 1.5m deep), wider and permanently located. Generally ***Arborloo*** slabs and pits are made round to suit a more traditional type of structure, and ***Fossa alterna*** slabs and pits are made rectangular. But in fact whilst the building components of both these eco-toilets are basically the same, there is much variation in the way they are built. There are four basic components:

1. The shallow pit or pits
2. The component protecting the shallow pit (concrete or brick ring beam or brick lining)
3. The concrete slab
4. The "house" (superstructure).

To this can be added additional components like pedestals, vent pipes or hand washing facilities, which are optional additions. Low cost pedestals can be made very attractive by using standard plastic toilet seats in combination with a off-the-shelf 20 litre buckets. The method is described later in this book. Vent pipes (PVC or asbestos) help to ventilate the pit, providing a throughput of fresh air as well as removing odours from the toilet. Vents also remove excess moisture and condensation from the pit and composting materials. Hand washing devices attached to the toilet are essential if personal hygiene is to be improved.

Which slab and ring beam?

The ***Arborloo*** is normally made with a small round concrete slab and matching ring beam made of bricks or concrete. But there is much variation in the size and shape. Slabs and ring beams for the ***Arborloo*** can also be made rectangular (see chapter on ***Fossa alterna***). If a rectangular portable superstructure is to be used, the rectangular shape is preferred. If traditional poles and grass are to be used, the round shape may be better. Each has its advantages and disadvantages. Round slabs can be moved by rolling them, which can be a big advantage. This means that for the one metre diameter slab (and matching ring beam) a single person is able to move the slab and ring beam to the intended toilet site. Rectangular slabs and rings beams cannot be rolled so they need at least two people, and normally four persons to lift and move them. But rectangular pits are easier to dig and excavate than round pits. The pit linked to the one metre diameter slab is about 80cm wide, and this is not so easy to dig and re-excavate compared to the rectangular pit which provides more room for using the digging tools, and in the case of excavation, also for repeated excavation.

There are advantages in using a rectangular slab together with a rectangular movable superstructure. The superstructure just sits on top of the slab. The structure need never touch the surrounding soil and this can have its advantages. If part of the structure is made of timber, the termites are less likely to eat the wood if it is sitting on a concrete slab compared to being part dug in the ground. With round slabs, the structure is normally built around and outside the slab. This means that the soil must be raised around the slab. Generally round slabs are best for simple structures made from poles and grass.

Then there is a question of economy. A high strength round slab made with cement and river sand can be made one metre in diameter using ¼ bag of cement (10 litres) and 30 litres river sand (1:3) and 3 - 4mm reinforcing wire. This is a very strong and relatively light weight slab. It can be moved after 7 days of curing. The same size slab can be made with a mix of 5 litres cement (1/8th bag) and 30 litres river sand (1:6) and 3 – 4mm reinforcing wire. But in this case the cement and sand must be of the highest quality and great care must be taken at every stage of construction. 10 days of curing is required for this "economy slab." If care is not taken the economy slab will crack. If care is taken, it is as good as the high strength slab. The larger 1.2 metre diameter round slab can also be made also with 10 litres of cement and 50 litres river sand (1:5) and 3 – 4mm reinforcing wire. A 1.2m X 0.9m rectangular slab can also be made with the same mix of ingredients (see later). 8 litres of cement is provided in the "Compost Toilet Starter Kit" and is mixed with 30 litres river sand to make a 1metre diameter slab (see later).

The concrete ring beams linked to these various concrete slabs are made with the same mix of materials (cement, river sand and wire) as the matching slabs. All these alternatives are described in this book.

The ring beam is valuable since it helps to stabilise the head of the pit. In very loose sandy soil a ring beam may be inadequate, but in most places it works well. To lower costs ring beams can be made of local bricks. These can be mortared together with weak sand and cement for the ***Arborloo*** since they will be moved every 6 – 12 months. Termite mortar or clay can also be used to mortar the bricks together. Where the ring beam is made for the ***Fossa alterna,*** it will remain in position for long periods of time. So if it is made of bricks it is best mortared together with strong cement mortar. A concrete ring beam is ideal for the ***Fossa alterna***. If the soil is very loose and a ***Fossa alterna*** is chosen, then the shallow pit (dug down 1.2 – 1.5m) should be brick lined to the base.

Upgradeability

Since this concept of making humus in shallow pits for growing trees and vegetables is still evolving, there is still room for various ways of doing things. A family may decide to start by building an ***Arborloo*** using a one metre diameter slab and bricks as a ring beam. This slab may use a quarter bag of cement (or even an eighth of a bag with care for the economy model). Then the family may decide to make a concrete ring beam later. If well made, the concrete work will last almost indefinitely – it is just moved from one location to the next – there is no need to reconstruct it every time the toilet moves – and this can be an advantage. Then, later on, the family may choose to use the pit humus for use in the vegetable garden rather than grow trees. In this case the family can make two extra ring beams of bricks or concrete and rotate the toilet around the three permanent toilet sites and excavate the humus after one year of composting. Even the toilet which uses one slab and three rings beams will use only a single 50 kg bag of cement for the high strength concrete version or half a bag for the economy model. But care is required with using economy concrete. It must be made and cured properly with quality sand and cement. Otherwise it may crack, which is not such a good idea on a toilet. The family may decide to grow trees some years and make humus in other years. The options are open and available.

Protecting the pit – ring beam and brick linings

If the soil is firm and a light superstructure is used, and particularly for the ***Arborloo,*** it may not be necessary to protect the pit at all, since it will be used for a limited period of time (up to 12 months) and the chances of collapse are minimal. However, it is always best to lay the concrete slab above ground level to avoid erosion due to surface water flowing during the rains. Composting does not work very well in very wet conditions and it is best to avoid pit flooding. So it is desirable to build a ring of bricks around the rim of pit, on which the slab is mounted. Such a ring of bricks is called a "ring beam." But not all ***Arborloos*** are built with them.

These *Arborloos* built in Embanweni, Malawi, where the soil is firm, do not have any form of pit protection. The 0.8m diameter concrete slab is laid directly over a 0.6m diameter hole and the simple superstructure built on top. The pits are dug about 1.0m deep.

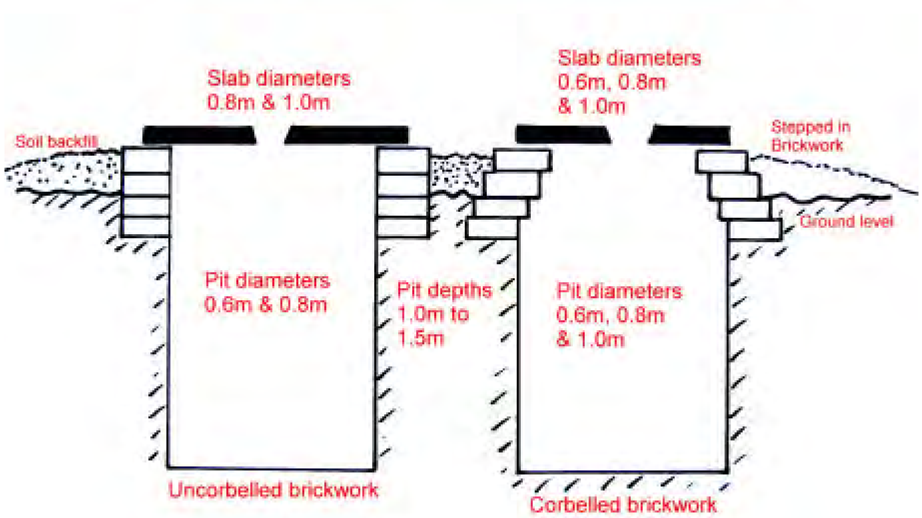
In most other cases where the structures are made of light traditional materials like poles and grass, it is best to mount the concrete slab on a "ring beam." This raises the slab above ground level and helps to reduce the chances of pit flooding during the rains and also stabilises the whole unit. This is true for both the ***Arborloo*** and the ***Fossa alterna.*** In most cases where the soil is moderately firm and stable, and the superstructures are not made of bricks, the ring beam may be all that is required for pit protection.

Only when the superstructure is heavy and built with bricks, must the pit be fully lined with bricks. But since most of the toilets described here do not use bricks, they do not require fully lined pits. In any case the ***Arborloo*** will rarely be made of bricks and is relocated once or twice a year and the pit may need little protection unless the ground is soft. In most cases a "ring beam" which is constructed in a round or square shape is made up of bricks or concrete and built around the pit head. Or rather the other way round! The ring beam is made first on the site and only then is the pit dug inside it. Then the slab and structure are mounted on top. There are several ways of protecting the pit with a ring beam.

Brick ring beams

These can either be made round, square or rectangular depending on the slab shape chosen. If made of bricks, it is often best to cut down into the soil about 0.3m and dig out an area large enough to lay cement or termite mortared bricks so that the internal measurement of a round pit is at least 0.6m across. The bricks are built up from beneath ground level and then at least one course above ground level. Ring beams for the ***Arborloo*** do not need to penetrate the earth so far, because the toilet will not remain in the site for more than one year. Many ring beams made for the ***Arborloo*** in Malawi are made to support slabs which are only 0.6m in diameter, but one meter diameter slabs can be placed over slightly wider pits which last longer.

METHODS OF PROTECTING A PIT WITH BRICK RING BEAM



The arrangement of slabs and upper brickwork protection of circular pits. The brickwork can be constructed vertically upwards or "stepped in" a little at each course (corbelling). The corbelling method is more complicated but allows for a slab to be added which is the same diameter as the pit. This is useful, as a slab of a particular diameter can be fitted on a wider pit with greater volume.

Arrangement of brick "ring beams" for the *Arborloo*

Arborloo pits in Malawi are dug round, and using a 0.8m diameter slab the pit is about 0.6m in diameter and about 1m deep with straight sides. The ring of bricks is cement mortared around the rim of the pit, preferably cut down into the softer topsoil and built up to at least one course above ground level. If a 0.8m diameter round slab is placed on top, the ring beam will give 10cm of support all the way round. If a 0.6m diameter slab is used, the pit can be dug to the same diameter, but the layers of brickwork in the ring beam must be stepped in (corbelled) to give sufficient support for the slab. If a 1m diameter slab is used, the internal diameter of the pit and ring beam (without corbelling) can be 0.8m diameter. A 1m diameter pit can be held up by a corbelled ring beam on a pit 1.0m in diameter. With less experience avoid the use of corbelling and use a 0.8m diameter slab mounted over a 0.6m diameter pit or a one metre diameter slab mounted over a 0.8m diameter pit.

The left picture shows the arrangement of bricks in the corbelled (stepped in) method of making a ring beam to protect the pit in Malawi. In the case shown four courses of bricks have been laid. Two courses are laid end to end around the pit and two courses with the bricks laid radially. This provides extra strength. The bricks are best bonded with cement mortar or traditional mortar made of special soil cut from anthills or from other sources. The brick protection usually starts beneath the ground and rises above ground level. On the right a concrete slab is mounted over the ring beam of an *Arborloo.* In this case both the pit and the slab are 0.6m in diameter. The pit was 1.0m deep below ground level. Soil cut from the hole is then placed back around the ring beam up to slab level and the structure then built on top. This makes a stable unit.

Another case in Malawi showing corbelled brickwork protecting a shallow pit of an *Arborloo.* Once again the diameter of both the pit and slab is 0.6m. Here the poles for the structure have been mounted in the ground before soil from the pit soil is placed back around the brickwork up to slab level.

A brick ring beam being built at Kufunda training centre, Ruwa, Zimbabwe. In this case two courses of bricks are laid on top of each other without any corbelling as this is considered easier for villagers. The bricks are mortared with local ant hill soil which resists erosion. The 0.8m diameter hole is dug inside the ring beam and the soil placed around the ring beam and rammed in place. The 1m slab is then fitted.

Making concrete ring beams

Making toilet components in concrete is usually a good investment. If well made and cured, concrete lasts for decades, and its services can be relied on for generations. Thus a well made concrete ring beam (or two in the case of the ***Fossa alterna***) should last indefinitely if cared for, and will not require reconstruction. This also applies to the slab which should always be made in concrete.

The concrete ring beam can be used in both the ***Arborloo*** and the ***Fossa alterna***. The ***Arborloo*** will use one ring beam, the ***Fossa alterna,*** two ring beams. This system of construction is used in some parts of Zimbabwe and ring beams and concrete slabs are either round or rectangular in shape. Normally round ring beams are used for the ***Arborloo*** and rectangular ring beams for the ***Fossa alterna***, but these are interchangeable. Larger ring beams use more cement but protect wider pits which have greater volume and last longer. The volume of a 1m diameter pit (using a 1.15m diameter slab) is 1.5 times the volume of a 0.8m diameter pit (using a 1m diameter slab). The 1.15m diameter slab uses only 2 litres more cement (10 litres) compared to the 1m diameter slab (8 litres). This small increase of cement use (for both the slab and the ring beam) must be seen as good value for money when equated with the extra pit life (1.5 times). Descriptions of how to make smaller and larger slabs and matching ring beams now follow.

Making a small round concrete ring beam for use with 1m diameter slab.


In this case a concrete ring beam has been made in a circular shape with a mix of 10 litres cement and 30 litres quality river sand. The mould is made from bricks over a plastic sheet. For the inner ring of bricks a mix of full and half bricks has been used. Spaces between bricks in the inner ring have been filled with segments of stiff plastic. The inner diameter of the concrete ring beam is 85cm and the outer diameter 115cm. This provides for a ring beam width of 15cm all round. Half the mix (5 litres cement mixed with 15 litres sand) is made up first and added between the two brick rings. Then one circle of 4mm wire is placed on the cement midway between the bricks. If in sections the ends of the wire should be slightly bent.


The second half of the full mix is then made up and added to the mould and smoothed off with a wooden float. Two handles are added, one at each side of the ring beam. The beam is then covered with plastic and left overnight. The following morning it is watered down, covered and kept wet for another 10 days before being moved. The fully cured ring beam is then taken to the toilet site and placed on the ground and levelled off. A hole is dug down within the ring beam down to a depth of between 1m and 1.5m. The removed soil is placed around the ring beam and rammed in place (right photo). The matching 1 metre diameter slab can now be fitted (see below and later). This is followed by the construction of the superstructure.


The one metre diameter slab fitted to matching ring beam.

Making a concrete ring beam with 1 metre internal diameter.

(for use with 1.15m diameter slab)


Lay plastic sheet on ground and make 2 circles of bricks. The concrete for the ring beam is laid between the two circles. The inner diameter should be 1 metre, the outer 1.4 metres. This makes the width of the ring beam 20cm. Pre-cut sticks can be used to make the measurement .


Make up a mix of 10 litres cement and 50 litres clean river sand and mix into concrete. Add half the mix to the brick mould and level off.


Add two complete circles of 3mm wire on the concrete. Then add the remainder of the concrete mix and level off with wooden float. Cure in the same way as concrete slab. When slab and ring beam have cured, move both on to toilet site. Place the ring beam on levelled ground and dig pit. Heap and ram soil around ring beam. Place slab on ring beam on bed of weak mortar.

Concrete slabs

The concrete slab is an essential part of any toilet. Once well made and well cured it should last almost for ever. So it is worth investing in the cement and good ingredients right from the start. Once a good concrete slab has been made, it can be fitted on various types of toilet including the ***Arborloo*** and ***Fossa alterna.*** The ingredients are fresh cement, clean sharp river sand and some 3 – 4mm diameter wire for reinforcing. Even better if granite chips can be found to mix with the sand, but it is not easy to find in most rural locations. The cement should be fresh, since over time its ability to make good concrete does fall off. Also the type of sand is important. Pit sand dug out of the ground will not do. Clean river sand taken from the river and washed is best. It should have a range of sizes of sand including some chips and very small stones. Also some reinforcing wire is required. It does not need to be thick steel bar. It can be wires between 3mm - 4mm in diameter. 3mm wire is fine. Concrete slabs are cast in a mould which is normally made of bricks or wooden planks depending on the shape. It is best to lay the concrete over plastic sheet, as this retains the ingredients and helps to improve the final strength The wire is placed inside the concrete half way up, so half the mix is added to the mould first, the wire is added, then the final part of the mix is added and smoothed down with a steel float. A hole is made for squatting and a special mould is required for this. It also helps to add handles, made from lengths of 8 - 10mm steel bar. These make lifting the slab easier. A most important aspect of making concrete is the curing. Concrete sets quite quickly and within a day can be quite hard. But it takes much longer to develop strength. The concrete cannot develop strength if it is allowed to dry out. So a curing slab must be kept wet at all times. Also the longer the curing time, the stronger the slab will become. So it is best to keep the slab wet and cure for at least a week before it is moved. For the more economic slabs using a 6:1 mix, 10 days curing is recommended. It is also best kept the slab under a plastic sheet or at least under a layer of wet sand to keep it wet. If properly made, a well cured concrete slab will last indefinitely. It is a good investment in money, time and effort.

Concrete slabs are a very important part of the structure of all pit toilets. They are not difficult to make if the simple constructional details are followed. Making concrete components is a very good way of investing money for the future. If well made, concrete lasts almost for ever. Here school children make a concrete slab in Mombasa, Kenya

Making round concrete slabs

Round slabs suit the ***Arborloo*** and ***Fossa alterna*** principles very well. Very often round slabs are made in a dome shape in Malawi without reinforcing. But concrete slabs are easier to make flat with a little reinforcing. Reinforcing wires (3mm) are generally available in most local hardware stores. Some of the new generation round slabs are also made with handles for use in eco toilets so that the movement of the slab from one location to the next is made easy.

Making a strong 1 metre diameter round concrete slab


The mould is made from bricks laid on plastic sheet. This slab is 1 metre in diameter and made with a total of 10 litres cement (quarter bag) and 30 litres quality river sand. Four pieces of wire 3 - 4mm in diameter each 90cm long are used as reinforcing. The mould for the squat hole is placed slightly to the rear of centre. The same size slab can also be made with a weaker mix of 6 litres cement and 30 litres quality river sand (5:1). In this case the construction and curing must be undertaken carefully. 10 litres of cement mixed with 50 litres river sand can also be used to make a 1.15m slab (see below).


Half the mix is made first with 5 litres cement and 15 litre river sand in a wheelbarrow. The concrete slurry is added to the base of the mould and distributed evenly over the whole surface. The four wires are then added as shown at right angles to each other.


Another mix of 5 litres cement and 15 litres river sand is now made up as before and added to the mould over the wire reinforcing. The concrete is levelled with a wooden float and then finished off with a steel float. Two handles are placed on either side of the squat hole to make picking up easier and more hygienic. 10mm steel bar is best for the handle if it is available. The concrete is left overnight and the following morning watered down and then kept wet for about7 days. The slab is only 32mm thick, and relatively light to pick up or roll into place. The 3:1 mix is a very strong one. This slab is made to fit over the circular concrete ring beam shown earlier or over a ring beam made of bricks.

Making a 1.15m diameter slab for a 1m diameter pit.


Lay a plastic sheet on level ground and lay bricks in circle 1.15m in diameter to make a mould. Add a shaped bucket or bricks to make the squat hole.


Make a mix of 10 litres cement and 50 litres clean river sand. Add about half of the mix to the brick mould and level off.


Add lengths of 3mm wire across the slab as reinforcing. At least four 1 metre lengths of wire are required, 2 in each direction. Add more wire if it is available. Then add the remainder of the concrete mix and level off. The squat hole mould can be removed with care once the slab has started to harden. The slab must now be cured. This means allowing it to harden overnight, then covering and watering down. The slab must be kept wet for at least 7 days to cure. 10 days is better. It must not be allowed to dry out. When thoroughly cured and strengthened it can be moved to the toilet site. The ring beam is laid down first on levelled ground, the pit dug and the slab added.

Digging the pit

The pit is dug down inside the ring beam, the extracted soil being placed around the ring beam and rammed hard in place. The pit is dug down at least one metre and up to 1.5 metres deep. The deeper the pit the longer it will last.


Digging pit inside brick ring beam


Digging pit inside concrete ring beam.

IT IS IMPORTANT TO MAKE THE RING BEAM FIRST AND PLACE IN POSITION AT THE TOILET SITE BEFORE DIGGING THE PIT. THE PIT IS DUG INSIDE THE RING BEAM. SOIL TAKEN FROM THE PIT IS PLACED AROUND THE RING BEAM AND RAMMED HARD IN PLACE. THIS RAISES THE SOIL LEVEL AROUND THE TOILET SITE AND HELPS PROTECT THE PIT FROM EROSION CAUSED BY RAINFALL.

Sequence of fitting the circular concrete ring beam and slab.

The construction of a concrete slab with matching concrete ring beam using between one quarter and half a 50kg bag of cement (depending on the size and mixture used) is a good investment for the family. The advantage of the concrete ring beam, as opposed to the brick one, is that it is permanent, will last almost indefinitely and can easily be moved from one location to the next. The circular slab and ring beam are easy to move because it can be rolled.

Once the slab has cured properly it is removed from the mould, washed down with water and fitted over the ring beam at the head of the pit. It is a good idea to bed the slab in some weak cement mortar laid over the beam to allow the slab to settle properly (slabs and beams are never made perfectly level). Alternatively some anthill mortar can be used. Hopefully at this stage two sacks of dry leaves will also have been deposited into the base of the pit to help the composting process. Once this has been done, the time has come to fit the superstructure.


Round concrete ring beams and slabs can be made off the site and rolled into position as these photos show. In this case the larger ring beam (ID 1 metre) is being rolled onto site and fitted with a 1.15m diameter slab.


The ring beam has been embedded in levelled ground and the pit dug out to required depth. Soil extracted from the pit is placed around the ring beam. The slab is then fitted on the ring beam




The same sequence using the smaller 0.85m internal diameter ring beam and one metre diameter slab. The hole is dug inside the ring bean down to a depth of 1 to 1.5 metres. The excavated soil is placed around the ring beam and rammed in place. The slab is then embedded on a layer of clay, weak cement or termite mortar laid on the ring beam, Now the superstructure must be built around the slab.

Where the concrete ring beam/concrete slab combination is used as an ***Arborloo,*** the toilet is used for as long as the pit can accept the combination of excreta, soil, ash and leaves. Once full, the entire structure (ring beam, slab, house) is moved to the next location. The ring beam is put in place, the pit excavated within it, the slab mounted and the superstructure put in place again or reconstructed. At each full pit site soil is added to the pit contents and a tree planted.

But the system can also be used to make humus (like the ***Fossa alterna***) for the vegetable garden. Using these smaller ring beams and matching 1 metre diameter slabs, 3 ring beams and one slab can be made from between half and one 50 kg bag of cement, depending on the mix. In this case the 3 ring beams are made and located on site and remain in their original locations. The matching slab and superstructure rotates around them in sequence. Since the pits are smaller than the normal ***Fossa alterna*** pit, the slab and structure may need to be relocated every 6 months. But by the time the third pit has been filled, the humus in the first pit will have had adequate time to compost. The compost can be dug out and the slab and structure relocated on its original site. In this way there will be a never ending source of humus. If for some reason the ground starts to fail, the ring beam can be moved to a new site.

Optional pedestal

It is possible to fit a pedestal on to any pit or eco-toilet, but the slab must be made specifically for it – with a 30cm diameter hole, rather than the 30cm X 19cm squat hole. This includes the ***Arborloo***. Commercial pedestals are available, but expensive. It is possible to make a strong home made pedestal at much lower cost. As time passes pedestals are becoming more popular in several countries where squatting was once the norm. Those who are more elderly greatly appreciate them. Constructional methods for home made pedestals are described later in this book.

Home made pedestal placed on the slab. The pedestal is smart, cheap and durable.

Superstructures

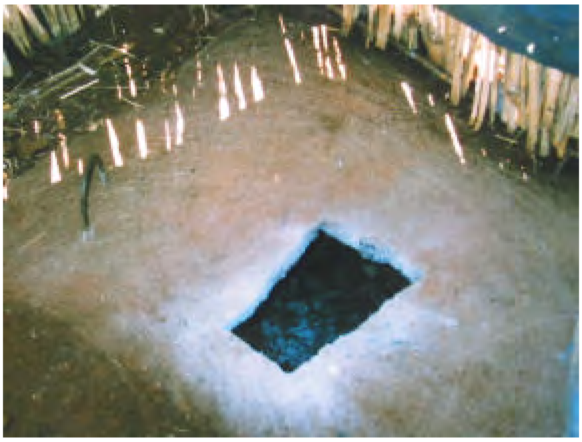
Toilet superstructures are built mainly for privacy, and protection from the weather. For the ***Arborloo***, they need to be portable or easily moved from one location to the next. A large range of materials can be used for the construction of the superstructure. These include poles and grass, frames made from poles, reeds, bamboo, wooden planks and steel etc with a variety of coverings for privacy. Coverings include grass, reeds, reed mats, plastic sheet, shade cloth, timber planks, iron sheeting, Hinged (using car tyres) or hanging doors may be fitted or the structure can be made without a door in a square spiral configuration. The type of superstructure chosen may depend on the availability of local materials. There is enormous variation in the type of structure which can be built, both for the ***Arborloo*** and the ***Fossa alterna.***

The Arborloo photo gallery


Left, the simplest superstructure – poles and grass – no door - no roof. Thanks to Jim Latham, Eco-Ed Trust. Right, more sophisticated pole and grass structure with door and roof. Durable door hinges can be made with cut sections of car tyres. Photo taken at Kufunda Village, Ruwa.


Left, simple portable structure made from poles and grass in Mozambique. This one has no door but has a roof, which has just been removed. The various sections are in panels and can be taken apart. Photo taken in Niassa Province. Thanks to Ned Breslin, WaterAid. Right, *Arborloo* structure built at Kusa Village, near Kisumu. Thanks to Osienala and RELMA


Woven basket superstructure from Malawi. Thanks to Steven Sugden and WaterAid.
Woven basket structure on *Arborloo* in Northern Malawi. The door is made from sacking. A neat and effective unit. Photo: thanks to Jim McGill, Embangweni eco-san project.

Arborloo **structure with low cost vent pipe. On the left the structure is made of poles and grass with low cost vent made with sacking and cement slurry. The interior is shown on the right. Thanks to staff of Mvuramanzi Trust. Zimbabwe.**


Structure made of bamboo and reeds. The four main bamboo uprights are anchored in the ground. They can be protected to a certain extent from ants with old engine oil or wood ash. The hinge for the door is made of old car tyre, as shown on the right. This material makes an effective and durable hinge.


Structure using small gum poles and old cement packets – also with a door Photo taken at Kufunda Village Ruwa. Thanks to Marianne Knuth. Moving an ***Arborloo*** **superstructure in Maputaland, South Africa. Note the wooden structure has legs. Thanks to Dave Still and Stephen Nash of Partners in Development.**

Two portable structures at Woodhall Road, Harare. One made of gum poles in sections which are wired together (right). The structure on the left is a steel frame covered with grass walling. Note hand washing device hanging from structure. All toilets should be provided with a hand washing facility. The structure made with steel frame and grass covering is easy to move. This is an excellent system where the frame is light and very durable and will last for many years. Less durable low cost walling materials like grass can be replaced when required. Photo taken at Fambidzanai, near Harare.

Photos of the steel frame *Arborloo* structure with grass walls and door made of sacking cloth. The vent pipe is a low cost home-made type made by wrapping plastic sheeting around a PVC pipe, then applying hessian and cement slurry. The structure has a door with car tyre hinge (see close up).

Simple *Arborloo's* at the Eco-Ed Trust, Mutorashanga, Zimbabwe. The pole and grass structure is easily taken apart and reconstructed from the original materials. The grass can be replaced every year if required. This type does not have a roof, but a roof is desirable to keep out rain. Thanks to Jim Latham,

Management of the *Arborloo*

Daily management of the *Arborloo*

The ***Arborloo*** is used like a normal pit latrine in that urine, faeces, anal cleansing materials (preferably paper) are added to the pit on a daily basis. In addition and in order to build up the mix of ingredients which assist in the conversion of faeces into pit compost it is important to regularly add dry soil and wood ash to the pit, preferably after every visit made for defecation. This material is best made up beforehand in the dry state, stored in sacks or bags and then added to a smaller container within the latrine. About four parts sifted dry soil and one part wood ash are mixed. Half a mug full of the soil/ash mix should be added after every visit made to deposit faeces. It also helps to add leaves to the pit – these improve the texture and nutrient value of the final compost.

It is wise to collect fertile soil in dry weather conditions and store this for future use in the latrine. It can be stored in bags or even in heaps in a part of the garden and covered with a plastic sheet during the rains. Wood ash should also be stored for future use. Although fertile soil is the best for use in the ***Arborloo*** pit (and also the ***Fossa alterna*** pit), the actual soil used will depend on what is easily available. The most obvious choice is to store the soil that was dug out of the pit during the initial excavation and put this back into the pit, every day. Sometimes wood ash may not be available or will be added separately. The most important ingredient to add is soil. Adding wood ash helps a great deal, especially in reducing odours and fly breeding and making the mix slightly more alkaline. Leaves improve the texture and also nutrient levels in the humus and also help to aerate the mass.

Experience over time, by the householder, will show that the best results are obtained when a mix of ingredients is put down the pit. This mix may include: excreta (urine and faeces), paper, topsoil, wood ash and leaves. The exact amount and mix must be judged over time. Clearly it would make no sense to add an excessive amount of soil, as the pit will fill too fast. As a rule of thumb the amount of soil added should approximately equal the volume of the excreta.

These additional materials help to improve the final texture and quality of the compost formed in the pit. It is also very desirable to add a sack full of dried leaves to the base of the pit before use and also a small sack full of leaves to the pit at 3 or 6 monthly intervals to increase the proportion of air and humus like material in the pit. The proportion of addition materials placed in the pit should be about equal to the volume of solids added. About half to a full mug full per visit after faeces have been added. In fact much of the bulk of the excreta will be absorbed into the dry soils and other dry materials (wood ash) added. It is important to add dry soil and dry wood ash to the pit, as these will help to absorb moisture from the excreta. Certainly some of the urine will be absorbed into the pit soil. Excess urine may also percolate into the soil surrounding and under the pit which will enhance it nutrient content prior to root invasion by the tree, even though some also nutrients will be lost.

No Garbage please !!!

It is also important to avoid placing non - biodegradable materials down the pit. These include rags, plastic sheets and bags, bottles, rubber objects and all manner of other objects that are often put down standard pit latrines. Whilst this part of the management is more important with the ***Fossa alterna*** where the pit contents are excavated (see next chapter) it is wise also in the case of the ***Arborloo.*** It is important that the pit is filled with good soil, not a pile of rubbish mixed with soil.

Flooding!

The conversion of excreta into compost will not take place if the pit is flooded with water. This means that only limited amounts of water should be added to the pit. Good pit drainage is very much dependent on soil type and area of soil in the pit available for drainage. Where the ring beam method of pit protection is used a large surface area of soil will be available for pit drainage. Pits lined with bricks or concrete rings do not drain so well.

Distributing pit contents

For the best results, and to ensure the best possible use of the pit volume, it pays for the user to look down the pit from time to time and level the contents. Since dry soil and ash when added to the pit tend to make deposits of excreta less fluid, the pit contents tend to rise up within the pit directly under the squat or pedestal hole. A central mound is thus formed – a process called "turreting." If the most economical use of the pit volume is to be made, it is very important for this mound to be flattened off from time to time with a stick. This flattening out of the pit contents and the occasional addition of a bucket of water helps to keep the contents moist and well distributed within the pit. These procedures will lengthen the life of the pit.

Relocating the *Arborloo*

When the ***Arborloo*** pit is almost full**,** the superstructure and slab are removed and put on one side. The ring beam is dug out and removed (or taken apart if made of bricks) from the old site and placed on a new site nearby. It does help to have handles fitted to the concrete ring beam in the case of the ***Arborloo***. This makes the movement easier and more hygienic. After the ring beam has been well placed and levelled on the new site, a new hole is dug down within the ring beam, as before, and the ring beam surrounded by soil taken out of the hole. The soil surrounding the ring beam is rammed hard in place.

The slab and superstructure are remounted on the ring beam as before. A seal is made between the ring beam and slab using a weak mix of cement and sand (1:20) or a clay like or termite soil made into mortar. The new location is chosen with care, taking note that the trees once planted will often grow large. Pits should not be closer than 3 metres apart. For trees which are known to grow large 5 metres may be a better distance. In a school setting or family homestead the ***Arborloos*** may be placed in an area which will turn into a wood lot or fruit tree orchard.

Preparations for tree planting

The contents of the used pit (filled with excreta, soil/ash/leaves etc) are now levelled off and topped up with fertile soil, at least 150mm deep. This soil can come from old compost heaps, fertile soil/leaf litter found under trees or any other place where the soil looks good. The aim is to plant the young tree in the topsoil so the roots come nowhere near the excreta layer. The more energetic can actually cover the pit contents first with soil and ram it into the mass with a pole, thus increasing the soil content of the pit. Ramming in soil actually promotes the conversion process. After ramming in extra soil into the pit contents, the final topsoil layer is added to completely cover the excreta lay and prepare it for tree planting. This final layer of topsoil should be at least 150mm thick.

Natural growth of trees in latrine pits

When a latrine pit is abandoned the contents contract in volume. Seeds of various types may fall into the depression formed and start to germinate. The kitchen wastes may also be thrown into such an abandoned pit. Pumpkin and tomato seeds will almost certainly germinate in such an environment. The same holds true for the seeds of trees that may fall into the old pit depression. The fact that this process occurs in Nature suggests that the medium found in these pits offers a suitable medium for plant growth.

A new latrine is being built to the left. On the right is the depression left from an old latrine pit. Close inspection reveals that an indigenous tree is starting to grow there. Photo a Kusa Village, Kenya.

The importance of trees

The most important aspect of the promotion of the ***Arborloo*** principle is that a link is made between the worlds of sanitation and forestry. The world lacks trees and they have such a beauty and value of their own which adds much to the world we live in. There is no part of the world that could not benefit by having more trees. This applies particularly to those barren parts of the developing world where trees may have been lost years ago and the resulting effects of erosion or reduced soil fertility are being felt. By linking the production of new trees with the reuse of human excreta we combine a problem (the disposal of human excreta) with a need for new trees and the many benefits they may bring forth. With each tree a story can be told. After ten years of use an ***Arborloo*** can leave behind a fine orchard of fruit trees or a wood lot of gums suitable for fuel or building. The tree is one of nature's marvels. It can be the provider of food, fuel, building materials, and medicine. It helps to stabilise the soil and offers shade. It provides leaf litter and thus provides additional fertility to the soil. It also provides beauty and richness to our environment. It helps to reduce erosion. The ***Arborloo*** is an elegant solution, which in the simplest possible way is able to provide an effective solution for low cost sanitation, adds greatly to the promotion of trees, and also offers an excellent example of recycling human excreta. Not surprisingly it is gaining popularity in many African countries.

Magnificent trees near Lake Victoria

The time has certainly arrived when we need to make the world of sanitation more interesting. And certainly one effective way of doing this is to make strong links between the sanitary world and that of agriculture in its many forms. Ecological sanitation has come at the right time, to offer us a practical way of doing this. That is what is good about ecological sanitation. It brings the worlds of agriculture, forestry, horticulture, food, fruit, herbs, natural medicines, fuel and many other things together.

Every means possible should be taken to grow more trees of all sorts, exotic trees and also indigenous trees. The links made between sanitation and the propagation of more trees is an important one. The value of the nutrients available in excreta, even if they exist below ground level, can be realised and witnessed with ease. Fruit trees grow very healthily on such organic pits if planted correctly, watered and protected. The fruits when tasted are delicious. What simpler and better way of demonstrating the concept of ecological sanitation and "closing the loop!"

The concept of the ***Arborloo*** is being promoted and tested in countries like Kenya, Mozambique, Malawi, Zambia, as well as Zimbabwe, where it is thought to have considerable practical application. The potential for its use throughout Africa is enormous. Because the method and concept is simple and yet retains the basic elements of ecological sanitation, it is thought of as a good first step along a route of increasing sophistication within the realm of ecological sanitation. It is, for instance, possible to upgrade the ***Arborloo*** and make a ***Fossa alterna***, moving quite simply from a series of single pits into a permanently sited alternating double pit system (***Fossa alterna***). By slight modification or replacement of the latrine slab (making a vent pipe hole), the system can be upgraded further to a VIP latrine. The ***Arborloo*** is the very best method of entering the world of ecological sanitation. The method is simple and cheap and there is no handling of processed human wastes. Many people may prefer to start off with this option. It is an excellent "entry point" for ecological sanitation.

Examples of *Arborloo* programmes

The *Arborloo* in Malawi

The ***Arborloo*** is very popular in Malawi perhaps because trees have been planted on old latrine pits for generations. Where the ground is hard the slab may be placed directly on the pit cut in the ground. In softer ground a ring beam or corbelled brick ring wall is built up from below ground level to above ground level and backfilled. Round slabs are very common in Malawi. As many as 8 slabs 0.8m in diameter can be made from a single bag of cement (left). Many domed slabs have no reinforcing. The one shown at left has 2 metres of 2.5mm wire placed in it. Photos taken in Phalombe district.

Most *Arborloos* in Malawi are of simple construction using poles and grass Photos taken in Embangweni (left) and Phalombe (right). Thanks to CCAP and COMWASH.

Making the 0.8m diameter round slab in Malawi

Making a round 0.8m diameter concrete slab in Malawi with sharp river sand and cement. When the river sand is of high quality, the addition of granite stones may be unnecessary. In this case a tin strip 40mm deep is formed into a circle 0.8m in diameter and supported by bricks. It is laid over a sheet of plastic. 4 wires are cut as reinforcing. In this case 2 metres of 2.5mm wire has been cut into 4 pieces (2 X 0.55m and 2 X 0.45m). 3mm or 4mm wire can also be used. The mix of sharp river sand and cement is 4 to 1(20 litres river sand and 5 litres cement). 8 slabs can be made from one 50 kg bag of cement using this method. High quality river sand and proper curing are important.

The sand and cement are thoroughly mixed and water is added to make a stiff moist concrete. The squat hole mould is added in the centre. Half the volume is added first, then the reinforcing wires, then the final part of the mix is added and trowelled flat and finished off with a steel float. The tin and squat hole moulds are removed and the slab covered with plastic sheet and left for 10 days to cure being kept wet throughout the curing process after setting. Photos taken in Phalombe. Thanks to COMWASH

The 1.0m diameter round slab in Malawi

Making a round 1.0m diameter concrete slab in Phalombe with high quality sharp river sand and cement. In this case a circle of bricks one metre in diameter is laid on the ground. Some sand is added to level off. A sheet of plastic is then laid inside the brick mould. 4 wires are cut as reinforcing. In this case 3 metres of 2.5mm wire has been cut into 4 pieces (2 X 0.7m and 2 X 0.8m). 3mm or 4mm wire can also be used. The mix of sharp river sand and cement is 3 to 1(30 litres river sand and 10 litres cement). The process is the same as for the 0.8m slab. Cure for 10 days and keep wet at all times after setting. 4 slabs can be made from one 50 kg bag of cement using this method. High quality river sand and proper curing are important. Thanks to COMWASH

A quality hand made 0.8m diameter domed circular slab made with a mix of stone chips, river sand and cement with footrests and handles. No reinforcing has been used. With this method 4 slabs can be made from a single 50 kg bag of cement. This is mounted over a circle of bricks laid as a ring beam for the *Arborloo* as shown on the right. Where the slab is used on a *Fossa alterna* it is mounted on a ring beam made of bricks (or concrete) at the top of the pit (where the soil is firm) or on the uppermost course of bricks in a fully lined pit which extends above ground level. The larger diameter one metre slab is best used on the *Fossa alterna* and the smaller 0.8m diameter slab on the *Arborloo.*


On the left a pole and grass *Arborloo* in the Phalombe plain. Thanks to COMWASH. On the right a brick *Arborloo* built in a peri urban settlement near Lilongwe, Malawi. Thanks to WaterAid, Malawi.

Sequence of building low cost *Arborloo* in Zimbabwe at Kufunda Village

Making the 1 metre diameter concrete slab

The circle for the 1 metre diameter slab mould is marked on levelled ground and bricks placed together in a circle

Plastic sheet is placed inside the mould and the concrete mix is made up in a wheel barrow (30 litres of good clean river sand and 5 litres of fresh cement. This is thoroughly mixed before and after adding water to make the concrete mix. Using this economy mix 8 slabs can be made with a single 50kg bag of cement.

A mould for the squat hole is made with a bucket or with bricks as shown here. Half the mix (about 17 litres) is added to the mould first and levelled off. The four 90cm pieces of wire (3 – 4mm thick) are added to make a wire square around the squat hole. Then the remaining concrete is added, levelled, tamped down hard and finished off with a wooden float and steel trowel.

Two thick wire handles are made up and inserted in the concrete on either side of the slab. A little extra cement can be added around the handles for extra strength. After an hour or two the mould for the squat hole is removed and the hole made neat with a trowel. The slab is covered with plastic sheet and left overnight. In the morning it is soaked in water and covered again. It is kept wet for 10 days under the plastic sheet. The longer it is kept wet under plastic sheet the stronger it will become.

Making the brick ring beam

A suitable site for the toilet is located, preferably on slightly raised ground. A circle is marked on the ground 80cm in diameter. A ring of fired bricks is laid on the chosen site around the mark to start making the ring beam. Anthill mortar is gathered, broken up and mixed with water to make a stiff mortar.

The brick ring beam is bonded together with anthill mortar, in between and above the bricks. Two courses of bricks are laid, one above the other and placed so that the upper bricks lay over the joint between the lower bricks. (note - if bricks are not available a concrete ring beam can be made instead).

The pit is dug out down to 1 – 1.5 metres and the extracted soil placed around the ring beam and rammed in place. The ring beam and surrounding soil will help to make the toilet stable.

The slab is then moved and placed over the ring beam embedded in a layer of anthill mortar to keep it steady. The superstructure is now built with locally available materials like wooden poles and grass).

Making a concrete ring beam

Two circles of bricks are laid over a plastic sheet. They are arranged so they form a mould in which the 6:1 mix of river sand (30 litres) and cement (5 litres) is placed. The open joints formed between the bricks of the inner circle of bricks can be filled with wet sand before adding the concrete mix. The mix is made in a wheel barrow and thoroughly mixed. Half the mix is added first to the mould. This is followed by a complete circle of 3 – 4mm wire. The remaining half of the mix is now added. The concrete is beaten down hard with bricks (see left photo) and smoothed down. The ring beam is then covered with plastic sheet and left over night. The following morning it is soaked in water and left to cure for 10 days. It is kept wet and under the plastic sheet throughout the curing period. After 10 days it can be lifted and placed on to the toilet site. A pit 1m – 1.5m is dug inside the ring beam. A sack of leaves is added and the concrete slab placed on top (in anthill mortar). The structure is then built around the slab. Soil, ash and leaves are added frequently to the pit contents to encourage the formation of good compost. For more detail see Appendix on low cost construction of *Arborloo.* Thanks to Marianne Knuth and Kufunda Village.

The Kufunda outreach programme in the villages

Trainees from Kufunda go back to their villages and show others how to cast simple concrete slabs and build the ***Arborloo.*** Whilst the cost of the cement is low (one 50 kg bag costing around USD8.50 can serve five families), most families prefer to spend their scarce resources on food or school fees. Consequently the concept of a “Compost Toilet Starter Kit” has been introduced. The Starter kit provides enough cement to make a one metre diameter concrete slab and also provides a young tree and simple instructions. The Kit contains 8 litres of cement (one fifth of a 50 kg bag), which is mixed with 30 litres of river sand to make the concrete slab. Some wire is also required. Both river sand and wire are available in most villages. Ring beams are normally made with local fired bricks bonded together with termite mortar. Structures are normally built in the simplest way at first – made from grass and poles. Often there is no roof at first. But even at this stage, a significant step forward has been made to the provision of sanitation in the village. The regular addition of soil and wood ash ensures significant reductions in both odour and fly breeding without the use of a vent pipe. Simple as it is, the construction of the ***Arborloo*** signifies a significant step forward in the provision of low cost and affordable sanitation.

Once the ***Arborloo*** has been made, the toilet can be upgraded at a later date, using the same slab with a more permanent concrete ring beam, and a more substantial house fitted with a roof. The family may choose to build a second or third pit and use the ***Fossa alterna*** (alternating pit) system in time, rotating the use of the toilet between two or three pits. This becomes a more obvious method, once the value of the humus formed in the pit has been seen by family members. The pit humus can significantly increase the production of vegetables and also maize, especially when combined with the use of urine. Such advantages become very apparent when a combination of humus and urine are used on very poor sandy soils – soils which are all too common in rural Zimbabwe and other parts of the sub-region. Once the effects of the humus on tree, vegetable or maize production have been witnessed, the popularity of the toilet system increases. Also once the method of making concrete slabs has been learned, the family may choose to make more slabs of its own.

The stage has not yet been reached when the enhanced growth of fruit trees has been experienced in this programme, which is in its infancy. Programmes in Malawi and Mozambique are more advanced. One thing is certain – families are very pleased with their own efforts in finally being able to construct their own toilet at minimum cost and without the use of artisans and labourers. Women are particularly proud that they can construct the system, normally the role of the men. In programmes promoted by Kufunda in Rusape, Ruwa, Mondoro and Zvimba, women are the most active participants and also the best instructors. During 2005, 100 compost toilets were built in Zvimba district

The Starter Kit concept, currently being tested, provides an incentive for the family member (often a woman) to start the process off. The Starter Kit also provides small trees (currently mulberry) which are planted, first in pots, at the same time as the toilet is built. Later, the partly grown trees are transferred from the pot to a generous layer of soil placed above the filled ***Arborloo*** pit. With watering, care and attention, the tree can grow into a considerable family asset later. All the instructions are provided in the Kit. It is an interesting and low cost method of promoting the uptake of low cost sanitation. Other excellent promotional methods are also being tried by WaterAid in Malawi and Mozambique and COMWASH in Malawi.


Participants at a "compost toilet workshop" in Mondoro are busy making the concrete slab. Instructions in the local language – Shona – are available. With the cement provided in the kit, a strong one metre diameter concrete slab can be built together with local river sand and some wire. The slab is flat and easy to construct. The importance of proper curing is emphasised. Cover with plastic sheet and after hardening keep wet for at least a week. The important aspect of this programme is that local villagers who are neither artisans or builders by trade acquire the skills. By far the greatest number of participants are women. In Mondoro, it is the women who train others to make the slab and toilet.


The ring beam is an important part of the structure, as it elevates the toilet slab above ground level and helps to the protect the unlined shallow pit. Most ring beams are made with local fired bricks and termite mortar. The slab sits on top of the beam and then the structure is built around this. On the right a group of villagers attend the compost toilet workshop in Mondoro.


A sack of soil near the home made slab on an *Arborloo.* The finished *Arborloo* made in the simplest way, provides a safe way of disposing of excreta. The facility offers privacy, with almost no smell or fly nuisance. It is an important first step in the provision of sanitation for low income families. These photos were taken in the Mondoro district.

Simple superstructures suitable for the *Arborloo, Fossa alterna*, urine diverting toilets and even VIP latrines can be made very attractive and serviceable using local timber and grass. This unit at Kufunda Training Centre, Ruwa, has been built on top of a rectangular concrete slab sitting on a rectangular concrete ring beam (see constructional details in chapter on *Fossa alterna*). The slab and ring beam each use a quarter bag of cement (10 litres or ¼ 50kg bag) together with river sand and some wire. The structure is portable, so when the shallow (1+ metre + deep) pit has been filled with the mix of excreta, soil, ash and leaves, the ring beam, slab and structure are moved to another site. Soil is added over the pit contents and a young tree can be planted immediately if the soil added is deep enough (at least 15cm). Alternatively the pit contents can be left to compost until the rains arrive, when the young tree is planted. For longer life the pit can be dug deeper up to 2m. Alternatively two rings beams can be made over two 1.5 metre deep pits and the toilet alternates between them at yearly intervals (see *Fossa alterna* – next chapter). The ring beam concept will work if the soil is moderately stable and the structure on top is light (ie not made of bricks or blocks). For more permanence the superstructure frame can be made of steel with replaceable grass walls and roof (see chapter on special techniques).

The simple *Arborloo* system can be upgraded by adding a vent pipe to control odours more (although the addition of plenty of soil and ash will help control both odours and flies). Also the squat hole can be upgraded by adding a pedestal for sitting. Also the system can be upgraded to urine diversion. This is easier on a pit system with a urine diverting pedestal with a urine off-take above the base (see chapter on special techniques). By diverting urine, the pit contents will become less moist which will also cut down on odours and flies. The urine can be led to a hardy nitrogen hungry tree like a banana. These various techniques are described in this book. The main point is that the simplest toilet systems can be upgraded over time. Low cost does not mean poor function. Some of the most effective toilet systems are low cost.

5. The Fossa alterna – the double pit compost toilet.

The ***Fossa alterna*** is a simple alternating shallow pit toilet system designed specifically to make compost suitable for agriculture. It is based on a twin pit system - the use of the toilet itself alternating between two permanently sited shallow pits. The toilet is managed in such a way that the conversion of human excreta into compost takes place within 12 months. After 12 months of processing the compost is dug out and used on the garden. The pit volume is calculated so that this 12 month period is less than the filling time of the pit when used by a small to medium sized family. This means that the ***Fossa alterna*** can be used continuously on the same site, almost indefinitely, simply by alternating between one pit and the second, with the compost being excavated once a year, thus making available an empty pit - every year.

The *Fossa alterna* is designed to make humus from human excreta. It has two shallow pits protected by two concrete ring beams, a single concrete slab and a superstructure, in this case made from gum poles and reed mats. This unit is also equipped with a low cost home- made pedestal, a vent pipe and hand washing device. The system is simple and can be made at low cost. Photo taken in Marlborough, Harare.

As in the ***Arborloo***, the conversion of excreta into compost in such a short space of time (12 months) becomes possible because extra ingredients, like topsoil, wood ash and leaves are added regularly to the pit contents. These extra ingredients alter the biological makeup of the pit contents, and also make it far more aerobic than would be the case with a deep pit latrine filled with excreta alone. Adding soil (especially fertile topsoil) and leaves brings into the mix a myriad of beneficial soil organisms such as beneficial bacteria, fungi, even worms and insects which excavate the soil and help to process the excreta. The addition of leaves (and other vegetable matter) increases the air content. Unlike solid excreta alone, this combination of ingredients readily converts into humus if sufficient quantities of the extra ingredients are added. The volume of soil, ash and leaves added to the pit should be about equal to the volume of faeces added. And it should be well distributed – in other words, the various ingredients should be added regularly. The conversion is improved if the soil itself is fertile and humus like. Adding clods of wet clay soil from time to time will not result in the desired effect. Neither will the occasional sprinkling of soil or ash on a huge volume of excreta held in the pit. The proportion of soil, ash and leaves should be significant and well distributed and should make up about half the volume of the pit. These important facts should be known to those people who are being introduced to the ***Fossa alterna***. In adding this combination of ingredients the process of decomposition within the pit is quite different to the one that normally takes place in the deep pit latrine. In the deep pit latrine, it is only excreta which enters the pit, together with garbage, and this combination may takes many years to convert into a useful compost, depending on the conditions. Under such an inefficient conversion - the alternate use of twin pits on a regular basis would be impossible. Thus the process of humus formation in the shallow pit systems used in the ***Fossa alterna*** is a significant departure from the system seen in conventional double pit latrines.

The ***Fossa alterna*** could be classified as a double vault pit latrine, but it is different in so many fundamental ways, that it has been given a specific name which distinguishes it from other twin pit systems.

* The ***Fossa alterna*** is specifically designed to make compost from human excreta (urine and faeces combined) in an efficient manner. This is achieved by the regular and generous addition of soil, wood ash and leaves together with the excreta.

* An important requirement of the ***Fossa alterna*** is to produce a relatively safe and valuable humus in the 1.2 – 1.5 meter deep composting pit within the space of 12 months. This is less than the time taken for a family of six persons to fill a shallow pit, which the ***Fossa alterna*** is designed to serve. This conversion from human excreta into compost could not be achieved within a year in a normal pit latrine, and the addition of the soil, ash and other ingredients into the pit is essential for this process. It is this feature which distinguishes the ***Fossa alterna*** from other double vault pit latrines. The aim therefore is to roughly match the rate of conversion of the excreta into compost in the one pit with the rate of filling of the second pit. When this is achieved it is possible to change sides once a year, with a regular out-put of compost being achieved each year. In practice a family should take a little more than a year to fill each pit and the conversion into humus is achieved in a little less than a year. So there is a safety margin built in.

***** The twin pits of the ***Fossa alterna*** are shallow, each about 1.2 meters deep, with 1.5 meters being a maximum. This makes excavation for the family relatively easy. The formation of compost takes place under reduced conditions of compaction (which would be the case in deeper pits). The excavation of compost is also usually easier than digging out the original pit. The shallowness of the pit also reduces the risks of contamination of underground water from the system, partly because the waste materials are contained further away from the water table and partly because the conversion of excreta into compost is accelerated.

***** The pit which has been filled with a combination of excreta, soil, wood ash and leaves is exposed in such a way that it is easy to excavate. It is important that the pit is topped up with additional soil and leaves and left to compost for 12 months. For safety reasons it may be covered with a wooden cover. Ease of excavation is important.

***** There is only **one** toilet slab used in the system. This is deliberate, so that only one pit can be used at one time. This avoids the problem seen in some other double pit systems which are equipped with two slabs - allowing both pits to be used simultaneously. The concept of the ***Fossa alterna*** cannot work if both pits are used simultaneously.

***** The system can be equipped with a portable structure, like the ***Arborloo,*** so that transferral of the superstructure from one pit to the other is easy and convenient. This is not an essential requirement however, and most ***Fossa alternae*** in Mozambique and Malawi house both pits within a single permanently sited superstructure.

* The ***Fossa alterna*** is designed to use the nutrients derived from urine and faeces in combination which are composted together with the soil entering the pit. The resulting compost is rich in nutrients, derived from both the urine and faeces (see later soil analyses). The ***Fossa alterna*** concept of producing compost in shallow pits can be used in combination with urine diverting pedestals, but this increases the cost and complexity of the unit. The urine diversion concept is best used in combination with above-the-ground vaults, but it will work on shallow pits as well

* The system is adaptable, - if overloaded by heavy use - a third or even fourth pit can and should be built and the single slab and superstructure can be used on a rotational basis between the series of shallow pits. The aim must always be to allow for at least one year of composting.

Fossa alterna **in Epworth near Harare. It has two shallow pits, a single concrete slab and single superstructure, made with a light steel frame covered with grass. The *Fossa alterna* was initially designed for per-urban use on medium sized plots, but can be used on smaller plots and also in the rural areas.**

Like the ***Arborloo***, the ***Fossa alterna*** attempts to fulfil all the basic requirements of a toilet used under the umbrella of ecological sanitation. The recycling of human excreta is achieved in a simple manner and the end product, in the form of compost, is relatively easy to excavate and introduce directly into the garden or into bags for future use or. An entirely natural process of "ambient temperature composting" takes place in the pit. Pit content temperatures rarely exceed 25 degree centigrade in Southern Africa. Where the ***Fossa alterna*** differs from the ***Arborloo*** is that the humus will be excavated from the pit, and hand contact will subsequently be made with it. Certainly when it is mixed with topsoil, and vegetables are planted, the material will be handled. Thus the health implications are important to consider.

After one year, properly composted pit compost is infinitely safer to handle than hands soiled in the toilet. It is important to wash hands after handling and this would be a normal procedure when handling garden compost before eating. **It is essential that the recommended materials (soil, ash and leaves) are added to the pit regularly and a full 12 month period of composting is allowed**. Without this method of management, where the excreta builds up without any, or very little additional material to help it compost, the excreta will not change in the desired way within the recommended 12 month period. Then, handling the resulting semi composted material may pose a health threat. Also ***Fossa alterna*** compost has not yet been fully investigated for the inactivation of viable helminth (round worm) eggs to date. Existing data shows that within 12 months the great majority of helminth eggs will have been rendered non viable for composted human sludge (Martin Strauss. 1990). Thus there is a small element of risk associated with handling the ***Fossa alterna*** humus, but this risk is infinitely less than handling many other sources of potential contamination in the environment in which the ***Fossa alterna*** was designed to work. Contact with the unwashed hands of another person who has attended the toilet or with a contaminated door or towel may constitute an infinitely greater health threat, than handling well composted excreta dug out of the ***Fossa alterna*** pit. The health threat is even greater if food is handled by the unwashed hands of those leaving a toilet. So the risks are relative. In very few aspects of human life, can one put a 100% guarantee that one will be safe and one's state of health can be assured.

The importance of placing a simple hand washing facility close by the toilet is an essential requirement if person health is to be taken seriously – and it must be. Regular hand washing is an essential component of improved personal hygienic behaviour. A number of low cost hand washing devices can be made in the home from locally available containers and materials and these are described in this book. The danger of handling ***Fossa alterna*** compost must be considered in relation to other potential contaminants related to the toilet, raw excreta itself being the most obvious.

If there is doubt about the safety of the excavated pit compost, for immediate transfer to the garden or vegetable bed, it can be transferred to sacks for storage for an additional length of time. Sometimes this method of "bagging" may actually be preferred by the family. In excavating and storing in bags, the material is turned and aerated, and this certainly helps to promote the composting process. This period of "secondary composting" in bags may be preferred because the time of excavating may not necessarily coincide with the time of planting vegetables. Some gardeners may on the other hand prefer to dig in the humus into the bed well before planting. Thus the humus will undergo further processing. The humus will nearly always be mixed with local topsoil before planting. Semi processed pit compost can also be placed in to pits which are covered with soil and in which trees will be planted.

The nutrient rich compost (see soil tests later in this book) excavated from the fully composted pit is far more fertile than normal topsoil, so by mixing the "pit compost" with existing topsoil the fertility of the topsoil is greatly improved. This is true for all the major nutrients, nitrogen phosphorus and potassium. Because the volume of pit compost derived from a family latrine is relatively small (about 0.6 cubic meters per year), most compost derived from the ***Fossa alterna*** is mixed with soils used in vegetable gardens in the back yard. A 2:1 mix of topsoil and pit compost is a useful ratio to use on small vegetable beds (see later). A 2:1 or 50/50 mix results in a considerable enhancement of the nutrient value of most top soils, which can lead to significant increase in the production of vegetables (see later). Thus the "close the loop" principle is once again achieved - and this is a central requirement of ecological sanitation. What is eaten goes back into the system and is recycled.

The ***Fossa alterna*** was originally designed for use in peri-urban settlements. The total area required for this toilet is quite small - about three square meters. Within this area it is possible to excavate two shallow pits lined wholly or partly with bricks or protected with two ring beams at the head of each pit. Time has shown that the simplest method – using concrete ring beams, is the most effective if the soil is moderately firm. This is because when a ring beam is used, there is maximum exposure of the pit ingredients to the surrounding soil. This improves drainage and also exposes the converting excreta/soil mix to the myriad of organisms present in the soil - and also, interestingly, of plant roots which are found in the topsoil. The conversion of excreta into compost takes place more rapidly in unlined or partially lined pits compared to those that are fully lined with bricks, or concrete rings.

The ***Fossa alterna*** also has considerable application in the rural areas as well. In Niassa Province, Mozambique (Ned Breslin, WaterAid, Mozambique) and in Thyolo District Malawi (Elias Chimulambe, COMWASH), for instance, the ***Fossa alterna*** is the preferred option because it offers a simple method of constructing a relatively permanent solution to sanitation. It is also relatively cheap to built, helps reduce flies and odours (even in the absence of a vent) and also provides a yearly supply of humus which can be used in a variety of ways

Much of what has been said in the preceding chapter on the ***Arborloo,*** applies equally to the ***Fossa alterna.*** The ring beam, slab and even superstructures can be identical in both units. The shallow pit receives regular additions of soil, wood ash and leaves in addition to excreta in both systems. The addition of garbage to the pit is not recommended in either system, but perhaps a tree will be more forgiving. It is no pleasure to excavate garbage like rags and plastic when the compost is being excavated. The difference is that in the one system the compost is left in place and a tree is planted in it. In the case of the ***Fossa alterna*** the compost is excavated, thus making available a "new" empty pit which can then be reused and refilled with a new mix of ingredients (urine, faeces, paper, soil, ash, leaves etc) again.

Perhaps the greatest asset of the ***Fossa alterna*** is its forgiving nature. It is no more than a pit toilet - and very simple to use, with the specific requirement that the users add soil and ash and leaves to the pit regularly, and do not add various other non compostable materials like rags, bottles, rubber, plastic and all manner of other garbage. The system still works if soil alone is added, but the texture and nutrient content of the humus produced is improved if leaves are added too. Also the conversion is far more efficient if humus like fertile soil is added compared to infertile soil or clay. Ash also helps to reduce odour and fly breeding and adds potash to the mix. The addition of dry leaves helps enormously, both as a layer at the base of the pit (two sacks full), and also throughout the filling process and also on closing off the pit. So the way a ***Fossa alterna*** is used and managed is a little different from the way a normal pit latrine is used and managed. However the differences are not great and should easily be managed by those who are familiar with the pit latrine. And in the world in which we live, this accounts for most.

Digging out pit latrines, though, is not commonly practiced in Africa, or in any part of the world. This is because the process is most offensive in the extreme. Consequently the first time users of the ***Fossa alterna*** are cautious at first about this part of the management. They will need convincing. The acceptance of this excavation as part of the procedure for using this system may not be immediate. The potential users will need to have seen other ***Fossa alterna*** pits excavated without difficulty and examined the compost for themselves. After a season of use however they will be convinced. Also they will be more convinced if they have seen evidence that the mixing of the humus with poor local top soils does actually enhanced the growth of vegetables. They will need to be convinced that the system is simple to build and simple to use, and also offers many benefits in addition to the conventional pit toilet. Potential users must be made aware, ahead of time, that for the system to work well, it is important to add soil, ash and leaves to the pit, regularly, and that they must also excavate the compost once a year. Thus projects involving the ***Fossa alterna*** require an effective component of education and demonstration. It does require more attention and effort than the use of a normal deep pit latrine. Indeed all solutions involving ecological sanitation require much more user participation than the standard pit or flush toilets systems demand.

Inspecting humus taken from the *Fossa alterna* in Mozambique.

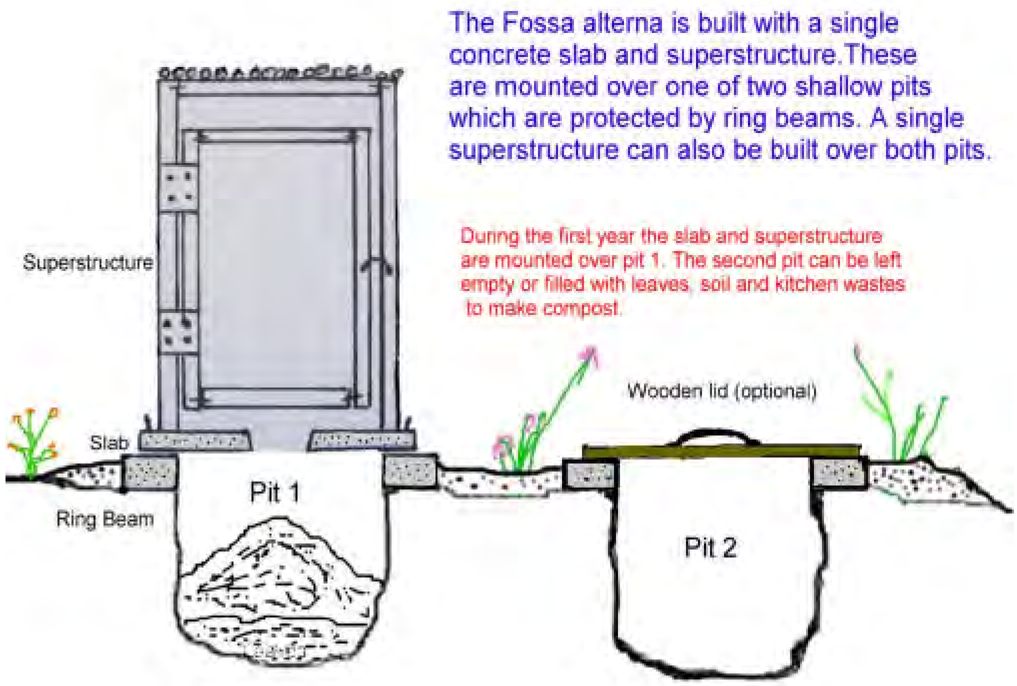
There is now much evidence that the pleasant nature and perceived value of the pit compost, with its ability to enhance soil fertility within the homestead, is encouraging people to excavate at the appropriate time. The excellent project in Niassa, Mozambique, which has studied various aspects of the uptake and use of the ***Fossa alterna*** has provided much evidence for the popularity of this system (Ned Breslin, WaterAid, Mozambique. See bibliography). A similar pattern of uptake is also seen in Malawi (Steven Sugden, WaterAid, Malawi). These are encouraging signs.

HOW THE *FOSSA ALTERNA* WORKS

There are two shallow pits close to one another and a single slab and superstructure. Both pits are dug and protected from the start. If this is not done, there may be confusion about how the system operates. The ***Fossa alterna*** concept cannot work with a single pit. If only one pit is dug and protected, by the time the first pit has filled the initial enthusiasm, drive or money for the latrine project might have gone. The message is simple - build the whole unit - with both pits - from the start with the slab and superstructure mounted over one of the pits. The second pit can be filled with leaves and covered with a lid for the first year.

As the first pit is being used it is filled with a combination of materials - not just excreta. These include faeces and urine and also soil, wood ash and leaves. The pit is used as if it was a composting pit filled from the top. The pit is used until it is nearly full, which for a family of up to 6 persons should be about one year or more.

During this first year period, the second (empty) pit may be covered with a wooden lid and left empty for the year. Alternatively it can be used as a “leaf composter” by adding leaves regularly throughout the year interspersed with thin layers of soil. The resulting leaf compost will be of considerable value in the garden (see nutrient levels in following chapters).



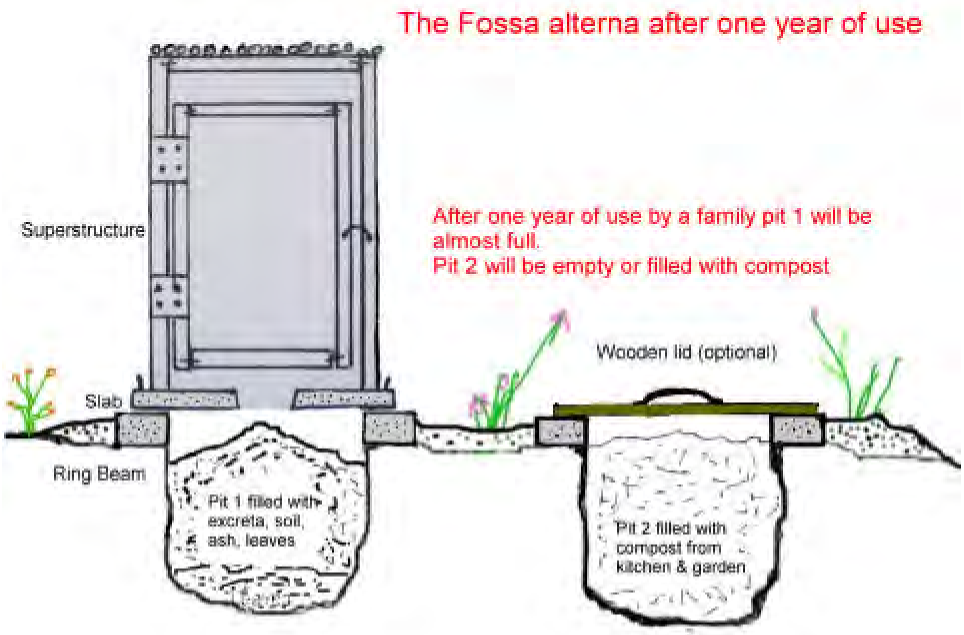
To start, two sacks of leaves are added to the base of the first pit. The slab and superstructure are fitted and the use of the toilet can begin. Buckets of dry soil, ash and leaves are placed inside the toilet. Every day, and preferably after every visit to defecate, some soil is added. Ash should be added too. Periodically leaves are added in addition.

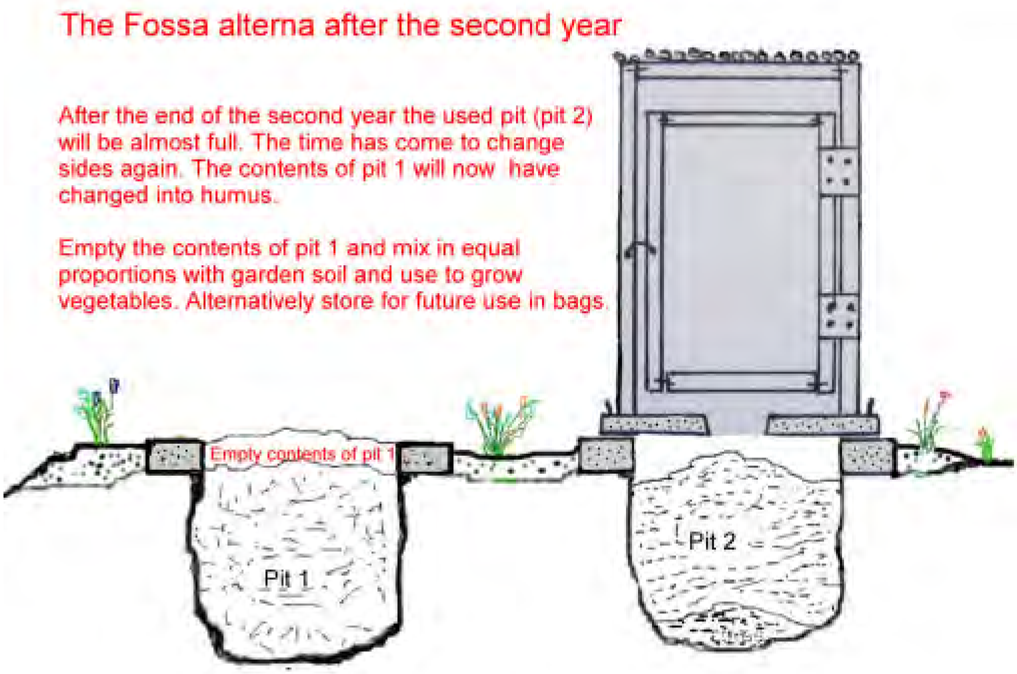
When the pit filling with excreta and other materials is nearly full (after about a year), the slab and superstructure are removed and placed over the second pit which should be empty. If it has been filled with leaves, the leaf compost is removed and used on the garden. Two sacks full of leaves are added to the base of the new pit before it is put to use. The first pit filled with the mix of materials is then "topped up" with leaves and a layer of soil at least 75mm thick and left to form humus over the following 12 months. If there is doubt about the correct proportion of leaves and soil being added to the pit, more soil and leaves can be added and rammed into the pit. The final covering layer of leaves and soil is then added. This process has the effect of increasing the proportion of soil/leaves within the mix and also distributing it more evenly throughout the pit.

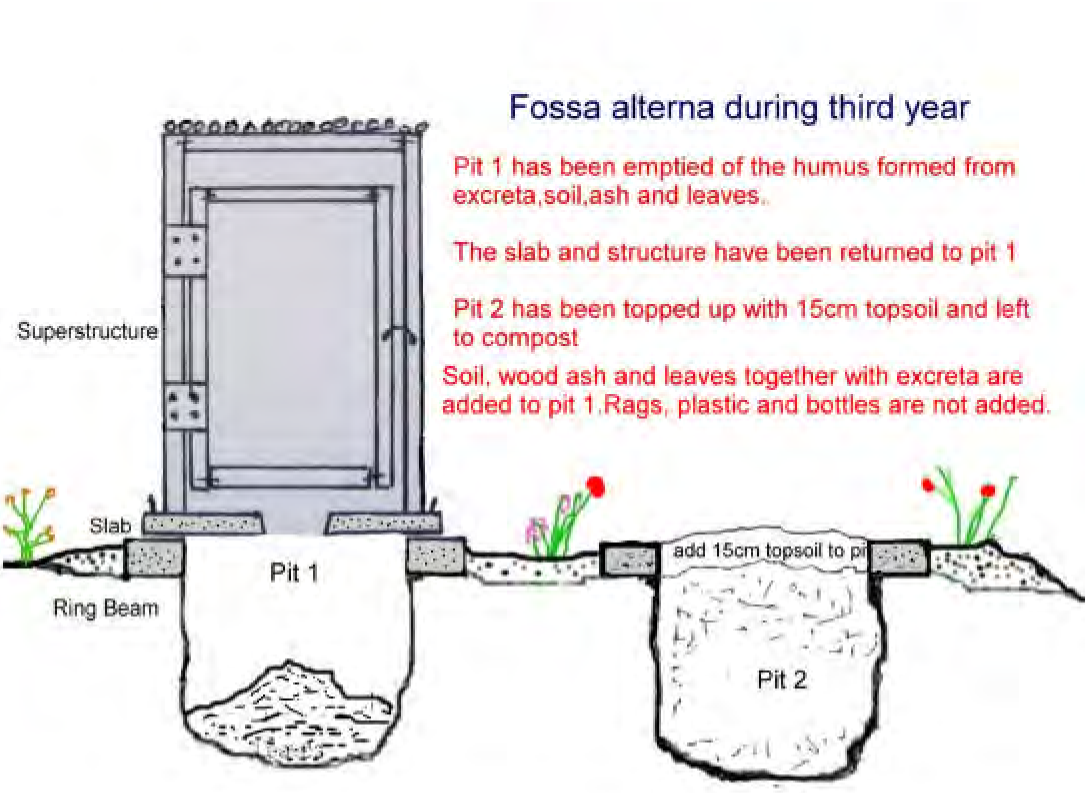
During the second year, the second pit will be filling with the mix of excreta, soil, ash and leaves whilst the first pit is composting. At the end of the second year the second pit will have nearly filled. By this time, the contents of the first pit will have already converted into compost which can then be excavated.

The excavated pit compost can be mixed with topsoil and dug into vegetable beds in preparation for planting (see later). Alternatively the humus can be placed at first in large sacks until the time comes to mix it with topsoil and grow vegetables. The excavated material can also be stored in a heap under the cover of a plastic sheet.

Once the pit compost has been excavated, the superstructure and slab are then returned to the original pit after more leaves have been added. The filled pit is covered with leaves and soil and the whole process is repeated again. Every year the process is repeated, possibly at the same time of the year. In Zimbabwe, the best months are during the latter part of the dry season (September – November). The process can in fact take place at any time of the year, but is normally easier to undertake during the dry season. The process will still work if leaves are not added, but the finally quality of the humus will be reduced. Leaves add air to the composting mix and improve the efficiency of composting. It is important to add leaves if they are available.







The *Fossa alterna* - Stages of construction

Siting the *Fossa alterna*

This will be very similar to siting the ***Arborloo,*** in terms of access and distance from a well, homestead etc. But there will be no future trees to consider in the siting procedure. In essence the ***Fossa alterna*** must be sited in the most convenient place for the family. It can backed on to a fence line. There should be room to move the structure from one pit to the next. Proximity to the vegetable garden may help but is not serious. The most important point in siting is convenience and privacy.

Methods of protecting/lining the twin pits.

Unlike the ***Arborloo*** the twin pits of the ***Fossa alterna*** are sited in permanent or semi - permanent locations. That is, they are sited in a place which may not change for some years - although of course it is very easy to re-site the pits at any time if there is space. Such pits may be fully lined with bricks or partly lined with bricks or fitted with ring beams of brick or concrete at the head of the two pits. It is an advantage that the ***Fossa alterna*** concept is adaptable and can use light and portable structures which impose a much reduced load on the soil around the pit, thus reducing the possibility of pit collapse. If a brick superstructure is used, as in Malawi, then it is essential to line both pits with mortared bricks to the base.

The ring beam method is the simplest and cheapest way of protecting the shallow pit with the ***Fossa alterna*** and also the most effective in terms of humus formation. So far this method has worked well in Zimbabwe even on moderately sandy soils under experimental conditions. But the experience of time alone will tell. With these types of structure with portable components, if there is any sign of movement, the parts of the latrine can be moved quickly to another site.

The decision as to which type of pit protection to use depends on local soil conditions. In very loose sandy soil, the pit will need lining with bricks to the base. If the soil is firmer a ring beam or part brick lining may be quite adequate, since a portable superstructure is not heavy. In most situations a ring beam will be perfectly adequate. It is also by far the cheapest and simplest method. If there is doubt about soil stability always line the pit with bricks to the base.

1. Ring beam method

Concrete ring beams

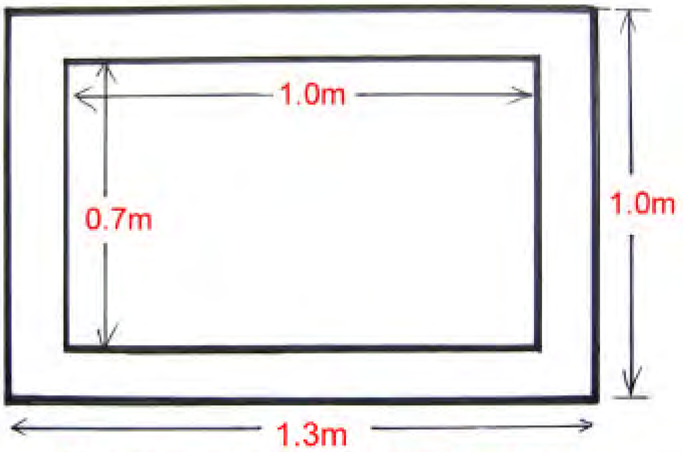
The best ring beam method uses a reinforced concrete beam which is strong and permanent. When well made, concrete structures like ring beams and slabs last almost indefinitely. They are a good investment in time and money. This is the recommended version for firm or moderately firm soils. A concrete ring beam can be laid on the surface of the ground in the same way as the ring beam for the ***Arborloo*** is laid (see previous chapter). If the ring beam is made of bricks, the soil near the head of the pit should be cut back down to about 150mm below the surface and the bricks can be built up from this level to one or two courses above ground level (see later). In both these cases the final pit is dug down within the ring beam to a depth of between 1.2 and 1.5 metres. This will provide an effective full pit volume of about 850 litres with a useable pit volume of approximately 650 litres.

Note here that the twin ring beams of the ***Fossa alterna*** can be cast in situ (ie in the final position) since they will not be moved. This is the preferred method. With the ***Arborloo*** the ring beam is best caste in another place and transferred on to site when it has cured. Since the ring beam of the ***Arborloo*** will be moved every year it must not be bonded too tightly too the soil as it may be difficult to remove at the time of the toilet migration. A tight bonding between ring beam and soil is desirable with the ***Fossa alterna***.

The internal measurement for ring beams used with the ***Fossa alterna*** should be around 1.0m diameter for round ring beams, or about 0.8m square for square ring beams or 0.7 X 1.0m for rectangular ring beams,. These will accept concrete slabs which are 1.2m in diameter, 1.0m square or 0.9m X 1.2m respectively.

Making the two concrete ring beams for the *Fossa alterna*

In those examples described here, the external measurements of the beam are 1.3 metres X 1.0 metres, the inner measurements (the size of the hole) being 1m X 0.7m. This ring beam is made for a slab measuring 1.2m X 0.9m. Wire reinforcing is used within the concrete mix, two strands of 3 - 4mm wire down each length, making a total of 8 pieces (total length approx. 9 metres). With the ring beam, the corners are a potential weak point.



Measurements for ring beam (metres)

When constructing the ***Fossa alterna***, the two ring beams can be cast on the actual toilet site directly on the ground, at least 0.5m apart and preferably at least 1.0m apart. A level piece of ground, preferably on a slightly elevated site is best. Alternatively the two ring beams can be cast away from the toilet site and moved on to site after curing. In this case a plastic sheet should be laid on the ground on which the ring beams can be made. The mould for the ring beam can be made with bricks as shown in the photo. Wooden shuttering can also be used as a mould, or a combination of bricks and wood. The ring beams are made 75mm thick, the thickness of a brick.

One 10 litre bucket of cement (weighing 12 kg) is mixed with five 10 litre buckets of sharp river sand to make each ring beam. If a 5 litre bucket is available the total mixture can be made in two batches. Half the full mixture is made first, that is 5 litres cement (6kg) and 25 litres clean sharp river sand (or if small stones are available, 5 litres cement, 15 litres sand and 10 litres small stones). A 5 litre bucket is useful for measuring, but 10 litre buckets are easier to find. Sufficient water is added to the mixture to make a thick slurry. Do not add too much water. This half mix is added to the lower half of the mould and spread out and tamped down with a wooden float. Then the wire reinforcing is added (4 lengths of 3 - 4mm wire in each direction). This is followed by the second half of the mix. If this square ring beam is used to construct the ***Arborloo***, four handles will help with the relocation. The four handles (if required) can be made from 4 steel bars about 8- 10 mm diameter and about 25cm long - four can be made from a one metre length of rod. These are bent and set in the concrete (see photo). No handles are required for the ***Fossa alterna*** ring beams as they remain permanently in position. The concrete is finally levelled off with a wooden float. The beam is covered with a plastic sheet if possible and allowed to set overnight. It is watered the following morning and kept covered and wet for at least a week before lifting. The longer it is allowed to cure the stronger it will become.

The ring beam shuttering can be made with bricks or wooden planks or a combination of both laid over a plastic sheet. Two ring beams have been cast within brick moulds over plastic sheet. After a few days the bricks can be carefully removed – watering continues. Note the handles inserted into the ring beam at the edges – these are useful if used with the *Arborloo*, but not necessary with the *Fossa alterna*, since the ring beams will never be moved. In practice handles are rarely used on the ring beam!

In the case of the *Fossa alterna* the two ring beams can be cast on the site where they will be used about 0.5m apart. In the case of the *Arborloo*, the ring beam is best made on one side and then placed in position as it will be easier to move later. Once the ring beam has been positioned and made level, the soil inside is excavated to the required depth. This is about one metre for the *Arborloo* and between 1.2 and 1.5m for the *Fossa alterna*. The excavated soil is deposited around the ring beam and rammed hard. This simple procedure will protect the pit in all but the loosest soils. Two bags of leaves are deposited on the floor of the pit before the slab is fitted. The leaves help to start off the composting process.

Here two ring beam for the *Fossa alterna* have been cast on site. On the right a completed *Fossa alterna* mounted on one of two permanently sited ring beams

Brick ring beams for the *Fossa alterna*

Ring beams can also be made from bricks which are bonded together with strong cement mortar. These beams can be built around the upper part of the pit. It is wise to start constructing the ring beam from below ground level and build up to one or two courses above ground level. The outer measurements are the same as for the concrete ring beam. However measurements for the both the slab and the ring beam are optional. A brick ring beam may be constructed from between 0.3m (shallow ring beam) to 0.5m (deep ring beam) below ground level. This leaves at least half the pit unlined but in most soils this is quite satisfactory for light weight structures placed over shallow pits.

Partly lined pits offer better drainage potential for the ***Fossa alterna*** compared to fully lined pits where the area of seepage is reduced to the base area only. There is a chance that this may become plugged if the water table does rise into the pit, or if too much water/urine is added. If the soil conditions allow for good drainage it may be best to fully line the pits. A generous layer of leaves (2 sacks full) added to the base of the pit helps drainage, as well as improving the efficiency of composting.

Deeper ring beams are normally constructed from 0.5 metres below the surface and rise to one or two courses above ground level. They can be made 100mm wide (single brick thickness) or 225mm wide (double single brick thickness) for extra stability.

If the "standard" slab size of 0.9m X 1.2m is used, the outer measurements of the brickwork for the single course should be just over 0.9m X 1.2m so the slab will fit neatly over the ring beam. Allow about 1 -2 cm all round - that is 0.95m X 1.25m for the outer measurements of the brick ring beam. In the case of the double course the outer measurements for the ring beam will be about 1.15m X 1.45m (pit excavation size about 1.2m X 1.5m).

The initial hole should be dug down about 0.5m below ground level - the hole size determined by the thickness of the brick construction (single or double course). The brick wall is build up from the base of this shallow 0.5m deep pit to one or two courses above ground level with strong cement mortar. The uppermost brick layer should be covered with a strong cement mortar for strength and protection. Once the mortar has hardened after a few days, the hole can be deepened to 1.2 – 1.5 metres within the brickwork. Two such partly lined pits are built about one metre apart. Since concrete slabs will be taken off and placed back on the ring beam/upper pit lining at yearly intervals with the ***Fossa alterna***, it is desirable that the working surface of the uppermost concrete/plaster layer be durable. This should be made of high strength mortar or concrete which is well cured. It should be well formed and left to cure under wet conditions under a cover for a week to develop a good strength. Often this final plaster layer is thin and made in weak mortar, just for appearances. The brick work of this vital working layer may fall apart when put to use if not properly made.

Arrangement of brick ring beams for the *Fossa alterna* with permanent structure

In Mozambique the slabs and pits are square and the brick ring beams are also made square and built up about four courses, three below ground level and one above. There is a little variation depending on the type of soil. In Mozambique, as in Malawi, the two shallow pits, which are dug up to 1.5m deep are "housed" within a single, permanently placed, non movable superstructure, made of grass and poles in Mozambique, and often bricks in Malawi (see later). In these cases the ring beams are built about 0.5m apart to conserve space.

Examples of brick ring beams for the *Fossa alterna*


Prototype *Fossa alterna* being built at Woodhall Road. Each ring beam was constructed with three courses of cement mortared brickwork. The two pits were only 0.3m apart. This distance was later increased to 1m. The experimental prototype had a shallow pit only 0.6m deep. Later pits are dug over 1m deep, and normally at 1.2metres. 1.5 metres is a maximum depth for the *Fossa alterna.*


***Fossa alterna* ring beams being constructed in Lilongwe, Malawi. Here the soil is firm. In this case the pit is first dug down to about one metre. The upper end has then been widened to allow for the 2 course brick ring beam to be constructed from one brick course below ground level. Two brick courses have been built above ground level. Soil taken from the pits is then built up around the two ring beams. This raises the site of the toilet above the surroundings, which helps divert rainwater from the site.**


On the left two brick ring beams have been built for a *Fossa alterna* in Lichinga, Niassa Province Mozambique. On the right two brick ring beams have been built in Kusa, near Kisumu, Kenya. The ring beams are permanently sited and are best bonded with strong cement mortar.


Brick ring beams for the *Fossa alterna* at the Friend Foundation in Harare. On the left three ring beams have been built in a line. This communal unit is heavily used and in order to attain the one year composting period, three pits, each one metre deep have been built. The slab and structure rotate between the three pits. On the right the brick ring beam is shown. It has been built with four courses of bricks. The pit is first dug down 0.5m and about 1.3m X 1m wide. The brick beam is then built up to one course above ground level. The brick mortar is allowed a day or two to cure and then the pit is dug down deeper to the required depth (1m – 1.5m). Note the layer of strong cement mortar covering the upper surface of the brickwork. This mortar is also extended outside the beam above ground level. This makes a strong and durable ring beam unit for the *Fossa alterna.* It is intended to last for many years.

Fully brick lined pits for *Fossa alterna*

These are required for the ***Fossa alterna*** if the soil is very loose. A full brick lining is used in all cases where a brick superstructure is built. Fired bricks and cement mortar should always be used underground. The brick lining is built up to at least one course above ground level. Always use cement mortar for bonding and fired bricks. When pits are lined from top to bottom with cement mortared bricks, it is only the bottom surface which allows for drainage. In clay soils the drainage will be poor and not entirely suitable for the ***Fossa alterna.*** The brick lining is built up to at least one course above ground level. The bottom should be cleaned of cement and a very generous later of leaves placed in the pit before use.


A fully brick lined *Fossa alterna* pit in Epworth close to Harare. The pit was 1.1metres deep. The soil is sandy and less stable. On the left the base of the pit is being cleared of cement mortar dropped during the brick work stage. On the right a layer of weak cement mortar is applied on the brick ring beam before the toilet slab is mounted on the ring beam. This weak mortar forms a good air tight base on which the slab can sit. This is important as it makes a good foundation for the slab and also an airtight seal for the best functioning of the vent pipe(when fitted), which draws air through the system, reduced pit humidly and also controls flies and odours. The ring beams in this case are about one metre apart.


On the left a permanent brick *Fossa alterna* structure is built around two brick lined pits in Thyolo, Malawi (COMWASH Project). The brick lined pits are shown on the right.

Proximity of twin pits/vaults

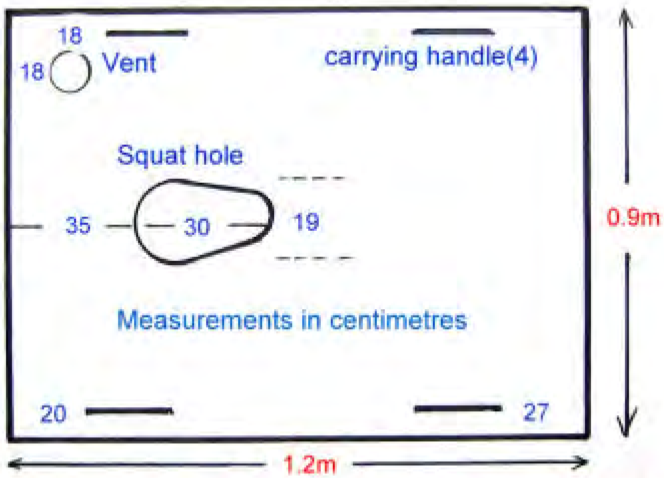
In the first prototype ***Fossa alterna***, built in June 1999, the two pits were placed side by side only 300mm apart. These pits were protected with brick ring beams. By placing the pits slightly apart the possibilities of seepage of digesting excreta from one pit to the other were reduced. If some space is available it is best to place the twin pits one metre apart to avoid any contamination passing from one pit the other. If space is really restricted 0.5m is adequate. The pits can be dug close together for convenience of movement of the superstructures, but far enough apart to reduce the potential of one pit being influenced by the other in terms of leakage of contents. Thus two separate pits, dug about one metre apart is recommended. If the two pits are located within a non portable structure, as is the case in Mozambique and Malawi, then the pits cannot be far apart. Normally 0.5m is adequate.

Making square or rectangular concrete slabs

These slabs are made with either a 3:2:1 mix of river sand, small stone and cement or a 5:1 mix of clean river sand and cement. They use the same amount of materials as the concrete ring beam described earlier – that is 10 litres cement (one quarter of 50 kg bag) plus the other ingredients. If small stones are available, then this will be stronger, but usually small stones are not available so river sand alone is normally used. The river sand should be clean and sharp, with little dust and small chips included. As with the ring beam, half the mix is made up first (5litre cement + 25litres river sand) and added to the mould and levelled off. The wire reinforcing is now added (same as ring beam – 4 pieces of 3 - 4mm wire in each direction – making a total of 8 pieces).The final half of the mix is now prepared and added, levelled and finished off with a steel float. Four handles should then be added, made from 8mm or 10mm steel bar and bent into shape.

The concrete slab described here is 0.9m wide and 1.2m long and about 40mm thick. The mould in which the slab is cast can be made with bricks or wooden planks or a combination as shown in the photos below. Most slabs are made with squat holes as this is the preferred position, but slabs can also be prepared for fitting a pedestal. In the case of the squat hole a suitable hole can be made by taking a 20 litre bucket, cutting off the bottom and bringing together the base into a pear shape with wire. A squat hole size of about 30cm X 19cm is required. If a pedestal is fitted the hole is 30 cm across and can be formed by a plastic basin. A hole can be made for a vent pipe also in the slab. This is made by inserting a short length of pipe (75mm long) in the slab at the appropriate position (see diagrams). The vent hole size should match the pipe which will normally have a diameter of 110mm. It is possible to make a low cost home made vent pipe using hessian and cement.

One 10 litre bucket of cement (weighing 12 kg) is mixed with five 10 litre buckets of sharp river sand to make each slab. If a 5 litre bucket is available the total mixture can be made in two batches. Half the full mixture is made first. That is 5 litres cement (6kg), 15 litres sand and 10 litres small stones (or 5 litres cement and 25 litres clean sharp river sand). A 5 litre bucket is useful for measuring, but 10 litre buckets are easier to find. Sufficient water is added to the mixture to make a thick slurry. Do not add too much water. This half mix is added to the lower half of the mould and spread out and tamped down with a wooden float. Then the wire reinforcing is added (4 lengths of 3 - 4mm wire in each direction). This is followed by the second half of the mix. The four handles can be made from 4 steel bars about 8- 10 mm diameter and about 25cm long - four can be made from a one metre length of rod. These are bent and set in the concrete (see photo). The concrete is levelled off with a wooden float and finished off with a steel float to make smooth. The slab is covered with a plastic sheet if possible and allowed to set overnight. It is then watered the following morning and kept covered and wet for at least a week before lifting. The longer it is allowed to cure the stronger it will become. 10 days is even better.



Measurements for 1.2m X 0.9m concrete slab

Where generous quantities of soil and wood ash are added regularly to the pit contents, there may be little need to fit a vent pipe, as these additions greatly help to reduce fly and odour nuisance. But the vent does help to reduce any odours that are present and controls flies as well if the required volume of ash and soil is not added. Vents also carry away excess moisture from the pit, which will almost certainly help the composting process. They also ensure that a fresh supply of air is being circulated through the pit, which will also help composting. Because the slabs of both the ***Arborloo*** and ***Fossa alterna*** will be moved at approximately one year intervals, it helps greatly to fit four carrying handles to the slab. These can be made by cutting 4 lengths of 8 - 10mm steel rod each about 25cm long and bending them and inserting in the fresh concrete towards the edges. The concrete is levelled off with a wooden trowel and finally smoothed down with a steel float. Once the concrete has begun to harden, the moulds for the squat or pedestal holes and the vent pipe hole can be carefully removed. The slab should be covered with plastic sheet if possible and left for a week to cure. During this period it should be kept wet continuously. If plastic is not available it can be covered with sand which is kept wet. For all concrete work, good curing is essential.

Photo of slab mould made of bricks and wooden shuttering. The eight pieces of 3mm reinforcing wire have been cut and laid on the plastic ground sheet. Four carrying handles have also been prepared. A 10 litre bucket with the base removed has been shaped by drawing in the two sides with wire. A 75mm length of 110mm pipe has also been cut to make the hole for the vent pipe. Thus all has been prepared for the addition of the concrete.

The addition of concrete is complete. Half the mix is added first, the reinforcing wire is laid, followed by the remaining concrete which is smoothed down. The handles are added by pushing them into the concrete mix. A little extra cement can be added around each handle to increase the strength of the concrete at this point. Finally the slab is smoothed down flat with a steel float and left to cure.

In many latrines, the slope of the slab is made so that washing water will flow into the squat hole. However if no roof is fitted to the structure the slab will act as a rainwater harvester and water will collect in the pit, which is undesirable. It will be remembered that for the natural breakdown of excreta into humus suitable for tree growth, the pit contents should not be too wet, but should be moist. It is undesirable therefore to have too much water entering the pit. One option is to make the slab flat or to slightly raise the central area around the squat hole including the foot rest area. In this case most drainage water from the slab will flow onto the ground around the slab. This might undermine the ring beam or pit head during the rains. However since the slab will move from one pit to the next, undermining of the ring beam within in a season may be unlikely. The simplest method is to make the slab flat – most rainwater will run away from the squat hole. The ideal is to fit the toilet structure with a roof.

Preparing the pit before use

Before the slab is fitted it is a very good idea to add two sacks full of dried leaves to the base of the pit. This will help the composting process from the moment fresh excreta is added. This composting process will take longer if the excreta falls on barren soil at the base of the pit.


Adding dry leaves to the base of a pit helps the composting process A full sack full or even two sacks full works well. The pit is ready – ring beam in place and leaves at bottom

Adding the concrete slab

The concrete slab is now mounted on top of the ring beam. It is wise to bed down the slab on the beam in a layer of very weak cement mortar (20 parts pit sand + 1 part cement). This makes the slab firm and stable. If a vent is fitted to the system it is very wise to seal any gap between the beam and the slab. This will improve venting of the pit and fly control. If there is a gap between the slab and the ring beam, odours may be released and this attracts flies. Also the efficiency of venting is reduced. A very weak mix of sand and cement can be used as a sealer (20:1) or soil cement or termite mortar. If cement is not available at the time, termite mortar could be used. The slab is now fitted centrally over the ring beam.


Adding a layer of weak cement mortar for the slab to rest on. This helps the slab to rest on the ring beam without strain. Also if a vent pipe is used, the pit should be air tight, thus allowing the suction of the pipe to draw air down the squat hole or pedestal. This leads to odourless conditions in the toilet. On the right a slab is mounted over the ring beam. This stab has a larger hole intended for a pedestal caste in it.


Adding dry leaves to the base of the pit in Epworth



The concrete slab is bedded into a layer of weak cement mortar on the ring beam. The photo on the left shows one being fitted at Epworth. The photo on the right shows the prototype fitted in Woodhall Road. Carrying handles are useful when moving the slab from one pit to the other

Superstructures for the *Fossa alterna*

Fitting the superstructure (with optional vent pipe and pedestal).

A great variety of superstructure designs are suitable for the ***Fossa alterna***. The main purpose of the structure is to provide privacy – the functioning of the ***Fossa alterna*** is not much influenced by how the structure is made. However a roof is very desirable, as this helps to control flies and helps to keep rain out of the pit. Very wet pits do not compost well. The various photos in this chapter and the previous chapter on the ***Arborloo*** show the great variation in superstructure design. Not all ***Fossa alternae*** are built with a single portable superstructure however. Most of those in Mozambique built under the WaterAid and ESTAMOS programmes, and also in Malawi under the WaterAid, CCAP and COMWASH programmes use a single larger permanent superstructure which surrounds and is built around both pits. The WaterAid funded work on promoting ecological sanitation in Mozambique and Malawi has been very successful. The ***Fossa alterna*** concept has become very popular because the regular addition of meaningful quantities of soil and ash to the pit have noticeably reduced fly and smell nuisance. The permanent location of the twin pits is attractive to the users since it seems to offer a longer term solution to their sanitary problems. Equally as important is the realisation that within a year, excellent humus can be extracted easily from the shallow pits (up to 1.5m depth). The value of this humus when applied to vegetable gardens is thought to be considerable. All these features make sense to the users. For once the toilet has a value of its own, apart from the disposal of excreta. The ***Fossa alterna***, like the ***Arborloo***, may have come at a time when the sanitation world is in need of a new approach.

Examples of *Fossa alterna* superstructures

On the left the prototype *Fossa alterna* used a wooden structure and two shallow pits with brick ring beams. On the right a *Fossa alterna* in a low density suburb in Harare. This unit used two concrete ring beams, a structure made with a steel frame overlaid by grass and a 75mm PVC vent pipe.

***Fossa alterna* at Woodhall Road, Harare. Note hand washing facility, waste water falling into a flower pot. Second pit during the first year was filled with leaves and compost. It was also used to grow comfrey (see later). Inside a home made pedestal has been fitted. The yellow bucket contains a mix of soil and wood ash and a dispenser. Leaves are also added occasionally.**

Fitting the portable superstructure to one of the twin *Fossa alterna* pits in Epworth, close to Harare. During the first year the second pit was filled with leaves and thin layers of soil to make leaf mould. After 12 months the leaf mould was dug out and the slab and structure moved to the second pit (as shown). The pit filled with excreta, soil, ash and leaves has been topped up with soil (see right of picture).

***Fossa alterna* in Niassa Province, Mozambique built under the WaterAid funded programme. The twin pits are enclosed in a single pole and grass superstructure which is permanently located. A washing area is also constructed as part of the system. These are very popular units, as they are almost odour and fly free, unlike many earlier toilets built in the area. They are also relatively low cost. The pits are each 1.5 metres deep and protected by brick ring beams. Here one of the pits is being excavated for humus.**

On the left a *Fossa alterna* with portable structure being constructed in Kusa Village, Kisumu, Kenya. On the right a permanent brick and thatch *Fossa alterna* built at Kufunda Village, Ruwa, Zimbabwe

Management of the *Fossa alterna*

1. Daily management

Add soil, wood ash and leaves regularly

Two sacks of dry leaves are added to the pit base before use. Then the ***Fossa alterna*** is used much like a normal pit latrine. Urine, faeces, and anal cleansing material, preferably paper are added every day. In addition and in order to build up the mix of ingredients which assist in the conversion of faeces into compost, it is important to regularly add dry topsoil and wood ash to the pit, preferably after every visit made, and also leaves from time to time. At the very least a small cup full of the soil should be added after every visit made to the deposited faeces. It is unnecessary to add the extra ingredients after urination only - this may result in the pit filling up too quickly with soil. If this soil is mixed with ash the resulting mixture will improve, as it will be slightly more alkaline and some potash will be added. Wood ash also helps to reduce odour and flies. The final texture of the compost formed in the pit will be improved greatly if leaves are also added regularly. At least a sack full should be added before the pit is put to use. These compact a great deal and the volume of leaves added should be generous. The leaves may have a considerable nutrient value of their own, as described for leaf compost in the gardening chapter. So they will improve not only the texture, but the overall nutrient value of the final humus. The final quality and usefulness of the pit compost will also be improved by the addition of organic vegetable matter from the kitchen like fruit skins and vegetable peelings. However this will increase the volume of added materials and a balance must be struck between volume added and final quality of the compost. The more soil and vegetable matter (like leaves and vegetable/fruit cuttings, the more crumbly and valuable the product will be in agriculture.

Ideally a premix of soil and wood ash can be made in the dry state and stored for use in bags. Such a mix is best prepared in the dry season. Dry leaves, even when crushed, do not mix well with soil as the heavier soil tends to fall deeper into the mix with the lighter leaves being concentrated on top. Hence the leaves must be added separately to the pit – taken from a separate container, like a sack, within the toilet. The dry soil and wood ash can be mixed beforehand - mixing 4 parts of dry soil to one part of wood ash. This is best mixed in bulk, stored in a larger container or sack and then brought to the latrine in smaller lots. Similarly the dried leaves are stored in bags and also brought into the latrine in smaller lots. The leaves once dry can be crushed to reduce their volume before storing in bags. They can be crushed by treading, by beating with a stick or rake, so that the leaves break down in to smaller units. The volume of dry leaves can be reduced considerably in this way and make for more efficient storage. The leaves will compact a great deal once in the pit and the soil will provide microbes which greatly assist the conversion of the excreta.

Pit filling rates

A little mathematics is required here. The volume of soil and ash added to the pit should be thought out beforehand and a suitable container such as a mug, or the upper part of a plastic milk bottle, with handle attached used for dispensing the soil/ash mix. If a family of 6 persons defecates once a day each into a pit and adds soil/ash after each deposit is made, it is possible to roughly calculate the resulting volume of soil. In a pit of cross section 0.7 X 1m X 1.2 m deep the volume to the top is 0.84 cu.m. or about 850 litres. The actual available space may be slightly less, since the upper part of the pit will not be used. If each member deposits 0.2 litres of soil/ash per day that means that approximately 1.2 litres of soil/ash will be deposited each day into the pit. That amounts to 450 litres of soil/ash per year. The leaves (about a hand full) should also be added, but once composted they will occupy a very small volume indeed - but they will be absorbed into the soil to improve its texture and also add more nutrients. The initial volume of faeces added by the family of six to the pit will be at least equal to this volume if not more - say 600 litres. That is 100 litres per person per year. But about 80% of this initial volume is water. After composting and absorption into the soil, the resulting solid fraction of faeces from a small family may amount to about 250 - 300 litres per year. A much greater volume of urine will be deposited in the pit. Some of this will be absorbed into the pit soil and leaves and later into the resulting compost, but much will seep away into the surrounding ground. This loss of potential nutrients from the urine, particularly nitrogen, must be accepted in shallow pit systems of sanitation like the ***Fossa alterna***. That is unless the excellent practice of storing urine, by urinating into containers is also carried out by the family (see chapter on urine). Such storage of urine is highly recommended. In the ***Arborloo*** not all the nutrients available in the urine are lost from the "loop" as they are absorbed into the surrounding soil and will later be taken up by the tree which is planted on the pit. The accumulation of the stable phosphorus in these shallow pits is particularly valuable.

Thus the combined annual volume of ingredients added to the pit may approximate 450 litres soil/ash/leaves plus a processed volume of faeces amounting to 250 - 300 litres, plus urine which will be absorbed into the compost and leaves or drain into surrounding soil. Thus an annual total of approximately 700 – 750 litres of compost can be expected. In practice a 1.2 metre deep pit will fill up in about one year for an average family. A 1.5 metre deep pit provides more latitude and should be aimed for.

It is accepted that in the real world such additions may not follow these recommendations exactly. In practice the soil may be added less frequently, resulting in a lower proportion of soil to excreta. The concept will still work quite well if soil alone is added without ash, but will not work so well if wood ash alone is added. The combination of human excreta and "any" soil will make a "new" soil which is greatly enhanced in terms of nutrients. The addition of a rich topsoil makes a better product than poor sandy or barren or clay like soil. Leaves provide extra nutrients, but equally as important they improve the texture of the final product considerably and also allow more air into the mass which helps the composting process. Also urine combines well with leaves to make compost. So the best is fertile topsoil, wood ash and leaves in combination. This combination will turn into excellent compost.

However the easiest way may be the only way at first - and this will be to use the soil which has been excavated from the pits or surrounding topsoil, whatever is available. Such soil may be very poor - both in texture and in nutrient content, but remarkably, once combined with excreta, the nutrient levels of the soil rises significantly (see chapter on soil tests).

Sources of fertile soil and compost in the garden

Sources of fertile soil can be found in most gardens to add to the used pit and also to add on top of the leaves which are added to the second pit. A good place to look for fertile soil is under trees where leaves may have fallen and begun to make "leaf compost." Leaf compost is the final product of decomposed leaves. Look around the garden for places where compost may have been made before and vegetables grown. Often the soil is barren in dry areas. Therefore the search for fertile soil will be more difficult. It is always a good idea to start making a compost heap to enrich the garden soil for planting vegetables. Sometimes it may be necessary to import some compost or fertile soil (on a Scotch cart for instance) from some other place where the soil is more fertile. Once the ***Fossa alterna*** is working properly, a yearly supply of compost for the garden will be available within the homestead from the composted pits. It is worth making the effort in the early years. The greater the proportion of these compostable materials added to the pit, the better will be the final humus excavated.

Finding fertile soil or leaf litter in barren environment

The question will be asked: where do we find fertile soil in a barren environment? The answer lies in looking under trees where humus may have been accumulating - or even going farther a field to find it and bring it back to the homestead in bags. Leaves may accumulate in pockets or depressions and may have partly converted into leaf mould over the seasons. The search for a living soil will often come up with something. The best soil which is available should be used first time around. Second time around the humus excavated from the first pit can be added to the second pit which will now be filling

No garbage please!

Since the compost will eventually be dug out, it is doubly important to ensure that garbage (rags, plastic, bottles, wire, glass, rubber, etc) is not tossed down into the pit. Such garbage can make later excavation tedious, difficult, unpleasant and even embarrassing. Thus plastic, rags, bottles and various other non compostable items should be disposed of elsewhere, like shallow garbage pits. They should NOT be placed down the ***Fossa alterna*** pit.

Not too much water either!

The conversion of excreta into compost will not take place if the pit is flooded with water. This means that only limited amounts of water should be added to the pit. Good pit drainage very much dependent on soil type and area of soil in the pit available for drainage. Where the ring beam method of pit protection is used a large surface area of soil will be available for pit drainage. Where the walls of shallow pits are lined with bricks to the base - only the base will be available for drainage. There will be a lot of variation depending on soil type, pit volume, pit protection type and the material content of the pit. But it is wise to add some water to the pit from time to time to keep the content moist. It is an excess of water that is not required. **So eco-latrines should not be used as bathrooms.**

Take a look from time to time!

For the best results, it pays for the user to look down the pit from time to time. One feature of adding soil and ash into the pits of eco-toilets, which is rarely mentioned, is the formation of mounds of excreta rising directly beneath the pedestal/squat hole. This is the result of adding dry soil/ash to the excreta directly after defecation. A pile of material results, which can look like an ant turret - it can be called "turreting." When this happens, any soil or ash added tends to fall to the sides of the turret and the best mix of excreta/soil/ash cannot result. Thus it is advisable from time to time for the user to take a stick or pole and try to level off the pit contents so that more of the available pit space can be used. Normally this involves moving the pile forwards towards the "front end" of the pit to level out the pit contents. This will help to some extent to mix the ingredients and assist the conversion process. This is very desirable in the ***Fossa alterna*** so that the greater part of the pit can be occupied with excreta/soil mix – and pit life can be extended. This means "spreading the load" a bit. The family should aim to fill the pit up in a year or more, and not less than a year. Thus the spreading out of the pit contents is an important part of routine ***Fossa alterna*** management.

Adding more soil and leaves to pit contents.

The routine of adding soil and ash after every visit, and preferably leaves as well, is important. This will help the conversion process. The soil mix is best stored in bags and then placed within the toilet in smaller containers for daily use.

The ratio of soil/leaves to excreta is increased by adding of leaves to the base of the pit before the concrete slab is fitted. This layer helps start off the composting process. It may also help to add an additional 30 litre bag of leaves to the pit half way through its one year cycle. Thus a good layer of "living soil" can begin to act on the raw excreta during the filling stage. Once the pit is filled and the slab and structure moved over, the final layer of leaves followed by fertile soil is added to cover the excreta. Once again the process is helped along if extra soil is rammed into the pit contents. A good layer of leaves followed by topsoil should be left on top of the pit contents and even these can be covered with leaves again. The overall aim is to get as much living soil and leaves into the pit mix as possible to help the conversion.

Effects of venting

The dry soil, wood ash and leaves do help to remove excess moisture from the excreta and this is desirable, since the conversion of excreta into humus will not take place in wet conditions. The addition of a vent pipe also helps to circulate air through the toilet system and also assists in the removal of excess moisture and condensation from the pit chamber. Vent pipes help to remove odour and if fitted with a corrosion resistant fly screen, reduce fly nuisance as well. However the production of compost will not take place in very dry conditions either. Toilet paper and leaves for instance will remain little changed in a very dry vault. The composting process needs some moisture, just as a compost heap requires moisture. So washing down with water will help from time to time.

Management of the second pit in the *Fossa alterna*

It is essential to dig and protect both ***Fossa alterna*** pits during the initial building stage. Whilst the second (and as yet unused) pit can be left empty and covered with wooden lid, it can also be used to the best advantage, whilst the first pit is filling.

The second pit can be used to make leaf compost by the addition of leaves, interspersed by thin layers of soil which is watered regularly. Since ecological sanitation concerns recycling in all its aspects and the development of a recycling habit within the homestead, it makes good sense for the concept of "pit composting" to be introduced. The aim is to develop the interest of composting as a sound gardening practice in combination with the use and management of the eco-toilet. The ***Fossa alterna*** system makes this possible. Even adding leaves and some local soil to the second pit during the first year of operation can be very valuable. The leaf compost formed in a second a pit in Epworth near to Harare was considerably more fertile then the surrounding soil and proved to be valuable in growing vegetables and maize. At times of heavy rain it is best to cover a composting pit to avoid flooding. If the second pit is not used for growing plants like vegetables or comfrey, it should be covered with a wooden lid.

On left, comfrey being grown on second pit of *Fossa alterna* during the first year. Comfrey is rich in potassium and makes an excellent mulch for vegetables, especially tomatoes. On right leaf compost being made in the pit – a mix of leaves and a little soil – should be kept moist.

Time to change sides!

"Changing pits" on the *Fossa alterna*

Once the used ***Fossa alterna*** pit is nearly full the time has come to change pits. For a family this should be after one year or more. If the latrine is heavily used, and the pit filling time is less than 12 months, it is best to make an additional ring beam and use 3 pits which are filled in rotation. If the pits are used more heavily 4 pits may be necessary. The time of conversion of excreta into compost is dependent on several factors which include moisture content, temperature, mixture within the pit etc - the more topsoil and leaves the better. The pit must not flood, neither should it be very dry. Temperature will depend on altitude and season. In warm/hot areas under the right conditions, compost can be formed in a few months. The higher the ratio of soil/ash/leaves in the pit the more effective the conversion will be. Also the more varied the ingredients - the higher the fertility of the humus will be.

If the second pit has been filled with leaf compost during the past year, this should be emptied - thus making available the empty pit. The excavated compost can be used on the garden, but it is also usefully added to top up the pit filled with excreta and soil etc. The same material can be used to add to the new pit as it fills up.

Changing sides involves first remove the superstructure and slab and placing these to one side. Add plenty of leaves into the empty pit. Now place the slab on the ring beam above the empty pit and also seal this off with a weak cement mortar or termite mortar. Now add the superstructure back on the slab (and any pedestal if used). The procedure for toilet management is now started on the second pit, just as before.

Dealing with the pit filled with excreta etc.

The pit filled with excreta/soil/ash/leaves etc is now levelled off and fertile soil is added. The best results are obtained if extra soil and leaves can be rammed into the body of the pit with a gum pole. This ensures that more soil and leaves are added and well distributed. This may appear to be a most unpleasant task at first. But it pays off. In any event, even if new soil is added just to cover the existing pit contents, this will break down within the year. A layer of about 100mm - 150mm is best. The soil is best fertile and can be taken from the compost pit or from a layer of good topsoil if available. A final layer of leaves can also be added as leaf mulch. The pit is watered a little to make the contents moist. The pit can now be left to convert for one year. Occasional watering is required, even if plants are not added to keep the contents moist. The pit must never be flooded.

Excavation of the pit compost

After one year of composting the pit compost can be removed. The pit contents will have considerably shrunk after one year, perhaps to about two thirds of the volume, as the water content of the faeces is absorbed by the soil and into the walls and floor of the pit. Normally this pit compost is easy to excavate and usually much easier to remove than the original soil when the pit was first dug. A shovel and pick are used. The pick can be used to loosen up the compost, especially nearer the bottom. The compost should be quite dark in colour, but the colour and texture of the material depends on what has been added to the pit.

The compost removed from the ***Fossa alterna*** pit is best stored in bags at first, where it will get more time to compost further. It can also be dug into the garden soil, also in preparation for planting. The process of biological breakdown will continue. It can also be mixed with local topsoil and placed in containers or shallow trenches for growing vegetables or pits for growing trees. These methods are described in another chapter. As with all gardening practice, it is wise to wash hands after doing the gardening and handling compost from these shallow pits.

After the pit has been excavated and the compost stored in bags etc, two sacks of dry leaves are added to the base of the pit and the process is repeated. The slab and structure are moved onto the empty pit. The pit filled with of excreta, soil, ash and leaves is topped up with soil and leaves and allowed to compost for another year.

This same process is undertaken once a year, every year. Excavating a shallow pit does not take long (about 45 minutes) and if the right ingredients have been added through the year the process should be easy and not offensive in any way. It is quite remarkable how the foul human excreta can change into a pleasant material. It will change into compost if there is enough soil, ash and leaves in the mix to help the process along. Seeing it for the first time most people are very surprised to see this miraculous conversion of Nature.

Ephraim Chimbunde excavates humus from a *Fossa alterna* pit in Hatcliffe, a project of Mvuramanzi Trust. The compost is placed in bags for storage and later transported to the vegetable garden of choice.

The "long cycle" alternating compost VIP toilet

In the ***Fossa alterna*** unit so far described the period of alternating is about 12 months. The pit is relatively shallow (max 1.5 metres) which has several advantages. These advantages include ease of digging, reduced compaction, better composting, more distant from water table etc. However it is also possible to build a pit toilet of this type where the pit is a little wider or deeper (max about 2 metres) so the period of alternating pits can be extended to between 2 and 5 years depending on usage. Composting is encouraged as before by the generous addition of leaves to the base of the pit before use and then regular addition of soil, ash and leaves during use. When fitted with a vent pipe, this becomes a variant of the VIP toilet.

Where the alternating period is longer, recyclable superstructures made of brick can be used. These are best linked to a steel frame fitted with "sprags" which are bonded into the brickwork. Such frames can be fitted with hinges made of car tyre rubber. Also the option of fitting lighter doors mounted on the door frame is possible. In this case the bricks are mortared together with a weak cement mortar (20 parts pit sand to 1 part Portland cement). Experience has shown that such brickwork can hold firmly for years, but is also easy to take apart and rebuild. Roofs and vent pipes are best built in materials which will last for a very long time and can cope with being dismantled and reconstructed. The ideal is asbestos. Asbestos vent pipes last much longer that PVC pipes. With good bricks and asbestos roofing and vent, a brick superstructure can be recycled periodically for many years.

Pit volume can be increased by enlarging the cross section of the pit from 0.7 sq.m. (in the model described earlier) to 1.2 sq.m or more. A pit with an upper cross section of 1.2 sq.m. and a depth of 2m will have a total volume of 2.4 cu.m. This is nearly three times the capacity of a pit with a cross section of 0.7sq.m and a depth of 1.2m (0.84 cu.m.). The larger ring beam (external measurements 1.2m X 1.4m and internal measurements 1m X 1.2m) will require a larger and heavier slab. This will have dimensions of 1.2m X 1.4m and will be 1.5 times as heavy again as the smaller slab(1.2 X 0.9m) and will use 1.5 times the volume of cement and sand to make (15 litres cement + 75 litres river sand). Experimentation is required.

Once again the type of superstructure mounted over one of the two pits is optional. But where the recycling time is longer, bricks can become a serious option. Where the steel frame version with sprags is used, the entire structure can be taken apart, bricks cleaned, slab relocated and structure completely rebuilt within 6 hours by an artisan. This relatively easy process is possible because the entire brickwork is mounted on the slab itself and no separate foundations are required. The brickwork for this system is built on edge, to reduce weight and the number of bricks required. A steel frame superstructure covered with any suitable material (such as grass) to provide privacy is also a good option. Where heavy brick structures are used both pits must be lined with bricks to the base. A good ring beam is probably adequate for lighter structures. It is desirable to dig and line both pits at the same time, using one immediately and retaining the other for future use. The second, as yet unused pit can be filled with leaves to make leaf compost. Whilst this procedure (digging and lining both pits at the same time) may seem unnecessarily laborious, experience has shown that if both pits are not built at the time of the toilet programme, a second pit may never be dug and lined, or dug and lined poorly. For the ***Fossa alterna*** concept to be successful it is essential that both pits be available for use from inception.

Photos of a fully recyclable "alternating compost VIP toilet"

Durable and yet completely recyclable!

For long life, the vent pipe and roof are made of asbestos. Inside, a home made pedestal using a plastic toilet seat and plastic bucket. For those who do not use pedestals, the squat hole is equally as effective. A bucket of soil easily available. A cup full is added to the pit after use. Wood ash should also be added and plenty of leaves. With a good vent pipe in place the facility should be almost odourless.

Sequence of building, dismantling and rebuilding the recyclable brick superstructure.

One of the two pits is dug and lined with cement mortared fired bricks. The steel frame (with door frame) is erected at the "door" end of the slab and the brick walls are built. "Sprags" of steel welded to the frame link the steel component with the brick and mortar work.

The roof is fitted after completion of the brickwork and door fitting. An asbestos pipe will also be fitted. Photo on right shows first stage of dismantling. The pipe, pedestal and roof have been removed. Now the brickwork is taken apart.

All the brickwork has been taken apart. The bricks are cleaned up. This is easy because the mortar is weak (20:1 sand and cement). On the right the same slab, having been removed from the original pit, is relocated on the second pit and mounted over a bed of weak cement mortar.

The steel frame is mounted again on the slab and the same bricks are used to rebuild the structure.

After the brickwork is complete, the roof, asbestos pipe and pedestal can be put back in place. The operation takes about 6 hours. If the pits are changed once every 3 – 5 years, this is not a huge expenditure of time and effort. Everything is recycled, even the material in the pit, which is dug out once the time has come to change sides again.

Closer views are parts of the frame. In this case the frame is made from 40mm X 40mm X 5mm angle iron. In this case the hinges are steel, but a more durable hinge can be made from car tyre. This is shown in the chapter on special construction techniques later in this book.

Potential problems of the *Fossa alterna*

No account of the ***Fossa alterna*** would be complete without a discussion of problems that may be encountered and how they can be overcome**.**

1. Pit overused.

Use of three or more "alternating" pits!

If the "family" size is very high (including visitors, lodgers and tenants etc) a 1.2m deep pit will fill up in much less than a year. Under these conditions the rate of composting will not keep pace with the rate of new additions to the pit. It will be essential in this case to dig another pit or even another two pits to cope with the loading. In this case the structure rotates around the three or four pits, thus allowing each pit of contents more time to "convert." Making each pit deeper, say to 1.5m will also help. By doing so the same conversions can take place in the pits, but the need to evacuate a pit "ahead of time" will be unnecessary. There will be more time for the full formation of humus. The longer the period of compost formation the higher the quality of the end product, and also the safer it will be to handle. So with a little extra space being allocated for the inclusion of a third or fourth pit there will be increasing flexibility. This may be the preferred option in some locations where there is some space but where the households are very full and the "family" is extended. Thus a family of 6 will find the double alternating pit entirely suitable for its needs at the pit depth of 1.5m. But if the number of users rises to 15 or 20, two shallow pits or vaults will not be adequate. A third or fourth must be built.

This *Fossa alterna* is actually used in a heavy duty communal setting. Three pits have been built to cope with the use.

2. Inadequate soil added to the pit.

Adding soil into a pit is not the most natural way of using a pit latrine. Many users may think the pit will fill up very rapidly and may reject the idea. In fact much of the volume of excreta is made up of water and a proportion of this can be absorbed into the dry soil which is added. ***Fossa alterna*** pit filling rates are often less than anticipated by users unaccustomed to these ecological latrines. If too little soil (or no soil at all) has been added to the pit, the conversion from excreta into compost will take a long time - even years. Adding just a small sprinkling of soil from time to time will not help the process at all. Fortunately it is possible to compensate by adding bulk soil/leaves/humus from time to time to the pit. And soil can be rammed into the pit at the time of changeover to increase the proportion of soil to excreta. These various methods help. It is far better, however to add the soil, ash and leaves as the pit is filling up.

3. Right type of soil

The best soil to add is crumbly humus like soil which is fertile and healthy. This will contain a high content of living organisms like beneficial bacteria and fungi which will help to break down the faeces. Less fertile soil like sand or clay will not be so effective at converting the excreta. During the first year of operation it is wise to look around for good soil to add to the pit. After this period, some of the compost taken out of the first pit can be used to help convert future pits. However it is accepted that for most areas where the ***Fossa alterna*** will be put to use, the soil will be naturally poor. This is where the addition of leaves will help. The best ingredients for the ***Fossa alterna*** pits are excreta, soil and leaves. Ash also helps to control flies and odours and adds potash.

4. A good distribution of soil

The soil should be added often so it is well distributed in the pit and some soil is near to the excreta wherever it may be in the pit. By adding lots of excreta without soil and then adding a bag of soil later is not the ideal. Add soil often to get a well distributed mix.

5. Pit Flooding

This can happen if rain flows into the pit if there is no roof on the structure. In this case a roof will solve the problem. It can also happen if the water table rises very high in the ground on a regular basis. In this case the problem may be solved by building the pits above ground level. That means basically converting them into brick lined vaults. This method involves raising the vault completely above ground level as shown in the picture below. In this case the above-the-ground vault is used in the wet season and the latrine is placed on a ring beam placed at ground level during the dry season. Two above-the-ground vaults might also be used. It is not the ideal - then areas which are permanently flooded are not the best for human occupation, let alone the proper functioning of toilet systems.

Vault above ground and pit below the ground – used alternately.

6. Too much bathing!

Too much water from bathing can also lead to flooding of a pit. In fact it is not recommended that either the ***Arborloo*** or the ***Fossa alterna*** be used as a bathroom as this adds an excessive amount of water in to the pit, which disrupts the composting process. If bathroom facilities are attached to the eco-toilet, the wash water should be drained away to a separate soak pit.

7. Adequate pit drainage

Adequate drainage is important to the ***Arborloo*** and ***Fossa alterna*** concepts. The conversion of excreta into compost will not take place in flooded conditions. Where flooding is known to take place regularly, shallow pit methods of eco-san may not be suitable. If the soil has a high clay content and the seepage of water and excess urine from the pit will be slow, a difficult situation is created. The addition of larger amounts of dry soil and leaves from above will help. But if the pit is permanently wet with water or urine, a "dry system" like the urine diverting method (described in the next chapter) may be more successful.

8. Climate

The ***Fossa alterna*** was designed to work in a warm climate and specifically for countries in East and Southern Africa. Its operation does depend on ambient temperatures in the pit being in the range 15 – 24 degrees Centigrade for most of the year. In colder climates the rate of humus formation will be slowed down and the system may not be effective. As always when a new technology is used for the first time in a new country, it must be built somewhere on an experimental basis and examined closely for a period of at least one year, and preferably more. Only after successful trials in a new country should more wide spread promotion begin.

A sunny climate is ideal for the *Fossa alterna*

Examples of the *Fossa alterna* from different countries

The *Fossa alterna* in Kenya


Delegates at eco-san workshop in Mombasa construct concrete ring beams within wooden frames for *Fossa alterna* at the Mtomondoni Primary School (left). On the right the two pits of a *Fossa alterna* are lined with coral limestone blocks from the base in very loose sandy soil near a beach site at Mombasa.

School children at the Mtomondoni Primary School learn how to make concrete slabs for eco-toilets


On the left adding semi composted "makuti," the leaf of the palm tree, to the base of a *Fossa alterna* to promote composting. On the right a finished *Fossa alterna* at Bengala Village. Both pits, dug down to 1.5m are fully lined with coral limestone blocks in loose soil. The second pit has been left empty and covered with a tin lid. The addition of soil, wood ash and leaves to excreta promotes composting in the pits. It is this promotion of the composting process which makes the *Fossa alterna* concept possible.

The *Fossa alterna* in Malawi

The ***Fossa alterna*** is becoming very popular in Malawi and is being promoted by WaterAid in Salima and also in Embangweni by CCAP with WaterAid Assistance. It is also being promoted by COMWASH in Phalombe and Thyolo districts. The Malawians as well as the Mozambicans have chosen to enclose both ***Fossa alterna*** pits within a single permanent superstructure rather than move a portable superstructure from one pit to the other. All these units use round slabs and ring beams or pit linings mounted over circular pits. In Embangweni and Thyolo the soil is firm, whereas in Salima and Phalombe the soil is loose and unstable. These areas require different approaches to construction.

Round concrete slabs are commonly used on pit latrines in Malawi and the *Fossa alterna* also uses a round slab. Many of these are domed and use on reinforcing. Some are flat and use a small amount of reinforcing. The flat slab on left is 1 metre in diameter using a 3 to 1 mix of sharp river sand and cement and 2.5mm or 3mm wire as reinforcing. It is left to cure for 10 days. The twin pits are normally lined with fired bricks and bonded with traditional mortar. Photo taken in Phalombe district. On the right two pits dug prior to brick lining. Photo taken in Thyolo district. Thanks to COMWASH.

Simple grass superstructure for the *Fossa alterna* on the left in Njerema Village, Salima. On the right a view through the entrance showing one pit covered with a squatting slab and the second pit awaiting a cover. The *Fossa alterna* pits in loose sandy soils are lined from the bottom with bricks. Thanks to WaterAid.


On the left a grass structure for the *Fossa alterna* in Salima district with support from WaterAid. Both pits are placed within the superstructure. On the right a permanent brick structure is built over two pits lined with bricks in Thyolo.


The interior of the structure shown above on right showing the two brick lined pits within the brick structure. On the left a demonstration structure showing one pit covered with a squatting slab and the other covered with a plain slab. Photo on left taken in Thyolo, photo on right taken in Phalome. Thanks to COMWASH

Very neat *Fossa alterna* constructed in peri urban settlement near Lilongwe with support from WaterAid. The roof has still to be added. On the right a view of the interior with round domed slab.

Excavation of *Fossa alterna* pit in Embangweni. In this case the structure is a simple bamboo portable unit which is moved from one pit the other. The ground is very firm in this locality and no ring beam or pit lining was used. The pit took less than 30 minutes to excavate and the entire operation of excavating and moving the slab and structure to the newly excavated pit took less than one hour. On the right dried leaves are being placed down the new pit. These help to compost the excreta like the soil which is added.

Using the *Fossa alterna* humus. On the left the pile from the *Fossa alterna* has been brought to the vegetable garden. A shovel is used to spread the humus over the vegetable bed. On the right a hoe is used to dig in and mix the new humus into the topsoil prior to planting vegetables at the onset of the rains.

An example from South Africa

A *Fossa alterna* built at Mbaswana, Maputaland, Kwazulu Natal, South Africa, by Partners in Development. Thanks to Dave Still and Stephen Nash.

Some work on recycling the existing pit contents of VIP toilets is also being carried out in Maputaland. On the left a previously full pit toilet, to which soil and leaves were added from the top is being dug out three years later. Previously it would have been impossible to dig out by hand. In Maputaland and elsewhere in South Africa, large numbers of VIP toilets were built years ago and many are now full.

In a new series of experiments leaves are added to the bases of dug out pits and the users asked to put plenty of soil, ash and leaves into the pit as they use it. And not to use the pit as a garbage dump. It it thought that this refinement in the way pits are used will make hand excavation easy in the future. Where twin pits are used, the family alternates the use from one pit to the other. The pits under investigation are lined with concrete rings. Each concrete ring is 1m in diameter and 40cm deep. Up to 6 rings are used to line a pit. Pits of this size (1.8 cu.m.) can last a family up to 5 years.

An example from Zimbabwe
Changing pits in the Epworth peri-urban settlement near Harare

This ***Fossa alterna*** was constructed in September 2001. It is used by a family on a plot in Epworth, where the soil is very poor. When the toilet system was first built, the second pit was filled with leaves and soil to make leaf compost. In September 2002 the leaf compost was removed from the second pit and added to a trench in which maize was late planted. The slab and structure were moved from the almost full first pit onto the empty second pit. The pit filled with a mix of excreta, soil, ash and leaves was topped up with more leaves and soil. This was left for another 12 months. In September 2003, the second pit change was made. This involved excavating the composted excreta from pit 1, adding leaves to the base of this pit and moving the slab and structure from pit 2, which was almost full, back to pit 1. The second pit was topped up with leaves and soil in preparation for a 12 month composting period. The photos below show the sequence. The pit excavation took 30 minutes and was easy work since the composted pit soil was loose. Moving the structure and topping up the used pit with leaves and soil took less than 20 minutes. The whole operation was completed in less than on hour. This attention is required once a year. The humus removed was completely converted and is a valuable resource in places like Epworth where the soil is very poor. (see later plant trials and soil analyses)


Starting to excavate the pit which has been composting for 12 months. This pit was brick lined in loose sandy soil. It was 1.1 metres deep with a cross section of about 1m X 0.7m. The pit was filled with a mix of excreta (faeces and urine) together with local soil, some wood ash and some leaves. At first the soil and leaves added on top of the excreta is removed. Further down the soil becomes darker and richer as the effect of the excreta on the soil becomes more visible. On the right photo, the richer soil is being removed.


The used pit has now been fully excavated and the compost can be seen on the side. The now empty pit has a generous layer of leaves added to the base. This helps to start of the composting process in the new pit. The addition of leaves helps a great deal to improve texture and nutrient value to the final compost.


The layer of leaves at the base of the pit. Note that small roots have invaded the pit, even through the brickwork to find the nutrients available in the composting excreta. On the right, the superstructure is now moved from the now almost full pit and placed on one side. The home made pedestal can be seen.


The concrete slab is now removed using the four handles and this is immediately placed over the now empty pit nearby. The slab is levelled and best laid on a bed of weak cement mortar laid over the pit lining brickwork.


Finally the superstructure (with pedestal and vent pipe in this case) is placed over the slab. The toilet can now be put to use immediately. On the right the pit used during the previous 12 months is not yet full, but a 12 month cycle of change is easy to remember. The pit contents are now covered with a generous layer of leaves and then topsoil is added. The mixed contents of the pit are then allowed to make compost for a further 12 months, while the used pit fills up again with a mix of ingredients. The whole process is then repeated every year. With this technique the pits are re-used repeatedly and every year a valuable supply of humus is produced. It is a simple technique which has great value.

It is wise to leave some written instructions on the inside of the toilet to remind the users how to manage the *Fossa alterna*. The regular addition of soil is essential if the process is to work properly, and also some leave and ash help to improve the compost. It helps if the time of changing pits is earmarked for a particular month of the year. In this case it is September, a good month as conditions are very dry. On the right, the composted pit contents can be bagged in preparation for the rainy season and planting. Alternatively they can be dug into the soil of vegetable gardens. A mix of half pit compost and half local topsoil is best. This mix enhanced the growth of vegetables considerably.

Satisfied customers at Epworth!

The *Fossa alterna* - a summary

The ***Fossa alterna*** is a relatively new concept introduced into the world of low cost sanitation and experimentation is still continuing with this principle. Clearly there is still a lot to learn of the process of excreta conversion in shallow pits and also how this concept will be accepted by communities in Southern and Eastern Africa and possibly elsewhere. It is possible that the ***Fossa alterna*** concept may represent an important step forward in sanitation technology and a valuable addition to the eco-san concept. Whilst low in cost and simple and adaptable in concept, it provides a system that is easily built by the family. It controls flies and odours, and also reduces the risks of ground water pollution. Because the pits of compost are easily excavated it offers potential for a permanent solution to home sanitation, whilst at the same time providing an annual supply of valuable fertile compost for the home vegetable garden. The testing and application of the pit compost is described in a later chapter. For these reasons the ***Fossa alterna*** may have widespread application throughout Africa.

***Fossa alterna* or *Arborloo* ?**
The two concepts are related – both make humus to enhance the growth of trees or vegetables. Both are specialised pit toilets – the link has been made between sanitation and agriculture.

6. The urine diversion toilet

Urine diversion

In a third range of latrine designs, the concept of **urine diversion** is used. This is a well established method which is being used successfully in many parts of the world. Countries in Europe like Sweden, use it a great deal in the new era of ecological sanitation which is taking off in the northern hemisphere. It is being strongly promoted by the Swedish EcoSanRes group and also GTZ. The concept of **urine diversion** is also being used widely and successfully in Mexico, Central and South America (El Salvador, Guatemala, Ecuador), India, Japan and also in China, where the recycling of human wastes has been practised for generations. It is also being promoted on a relatively large scale in South Africa (Austin and Dunker, 2002) and Uganda by the Ministry of Water, Lands and Environment (MoWLE, 2003). The use of this method is well documented. A book entitled *Ecological Sanitation* (1998) first written by Esrey et.al. is particularly valuable and the second updated edition (editors Uno Winblad and Mayling Simpson-Hebert - 2004) is now available. For a list of suitable references see the bibliography at the end of this book.

Urine diverting toilets use a special pedestal in which the urine enters the front part of the pedestal and is then diverted through a pipe and is thus separated from the faeces. In China and a few other countries where the squatting position is favoured, urine diverting squat plates are used. These are very successful. The urine can either be collected in plastic or concrete containers of some sort, or it can be led into a soakaway system. Considering the value of the urine, to allow it to soak away, unless on to a mature tree like a banana, is somewhat wasteful of a valuable resource. The faeces fall down directly into a brick lined vault beneath the pedestal. Some dry soil and wood ash (or lime in some countries) is added to cover the faeces after every visit. This covers the deposit and helps to dry out the surface of the faeces and makes them easier to handle and transfer. The distinct advantage of this method is that the urine can be collected separately, making it available as a liquid fertiliser. Also the solid component, being in a semi dry state, is much easier to handle and is safer from the beginning, even if it does initially contain pathogens. Being semi dry, it does not smell so much and its potential as a fly breeding medium is much reduced compared to the mix of urine and faeces. Eventually the faeces become completely desiccated.

Semi dryness is essential for the success of the urine diverting system. There must be no malfunction of the urine diverting pedestal. In other words, urine must always go down the front and faeces down the back. If there is an error made in this use, the system can malfunction badly. Blocked pipes carrying urine need unblocking. It is possible that soil thrown down the pedestal may enter the urine pipe, and sometimes even faeces if used by children. Thus the pipes used must be wider rather than narrower, and easily washed out. Also if urine (or water) finds its way into the above ground "dry" vault, the result can be messy and unpleasant. Meticulous use is rather an essential component of the urine diverting concept. This is one reason why alternatives are also recommended in Southern and Eastern Africa, as they are simpler and cheaper, being more forgiving of misuse. The writer has used an above-the-ground single vault urine diverting toilet for several years in his garden and this experience is reported in this chapter. Both home made and commercially made urine diverting pedestals have been used. Initially urine was taken to a seepage area, but this was modified so that urine was collected in a 20 litre plastic container for use in the garden. This system has proved to be an excellent asset to the homestead and has given far fewer problems than the conventional water born system used in the house.

The single vault urine diversion system

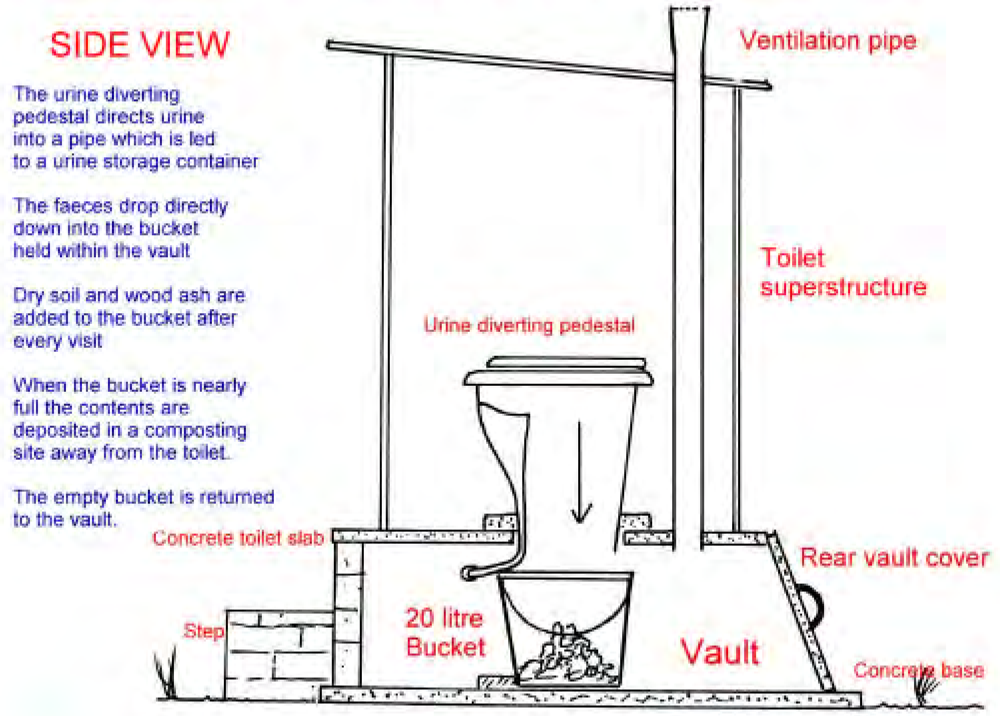
In this system (sometimes referred to as the ***Skyloo***) the faeces are collected in a single small vault built above the ground. Whilst faeces can accumulate directly in the single vault for periodic removal, the preferred method in this case, has been to contain them in a 20 litre plastic bucket (together with toilet paper, soil and wood ash). The bucket contents are held within the vault only for a relatively short period, until the bucket is nearly full. Then they are transferred to a "secondary composting site" for further processing. These sites may be in the form of cement jars or buckets or shallow pits or trenches and even garden compost heaps. In each case the formation of humus is encouraged by combining the various ingredients in the bucket with more soil and also some water to add moisture to the mix. Some leaves can also be added. The mixture of ingredients is converted into a pleasant smelling humus-like soil within a few months. This humus can be used to grow a variety of trees, vegetables and flowers. Nothing has gone to waste. Once again the recycling of human excreta is made as simple and convenient as possible. Natural processes are involved.

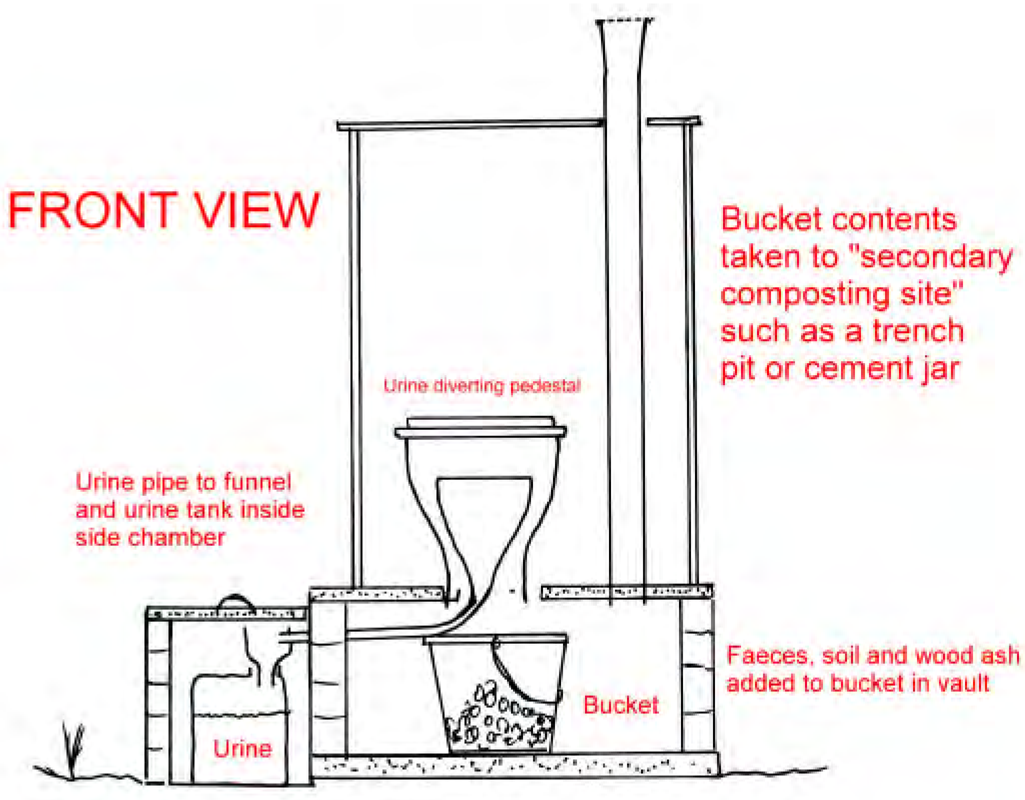
The humus resulting from composted human faeces makes an excellent soil conditioner and is rich in nutrients as the soil analyses revealed later shows. The important lesson that comes out of this experience is that human faeces, once composted into humus, have a considerable value of their own, not only in providing extra nutrients, but also by improving the texture of soil. The resulting humus can be used directly for growing trees, vegetables and flowers or it can be mixed with less fertile soils to improve the overall quality of the soil. The use of garden and leaf compost generated in the garden is also important so that a combination of these various plant growing media can be encouraged. Thus those practising ecological sanitation should also be familiar with the methods of making garden and leaf compost so that all these fertile materials can be mixed to form a good planting material. The human fraction enters the system and becomes part of it. Such humus when properly used in agriculture helps to improve food yields and also food quality and hence provides more food security and improves the nutritional status of the beneficiaries.

A general description.

The toilet is built upon a base made of concrete cast on the ground. Above this concrete base is built a shallow "vault' made of bricks and cement mortar. The vault only needs to be a little deeper than the bucket which will be fitted inside it - that is less than 40cm deep. A concrete slab is laid on top of the vault with openings for a vent pipe and urine diverting pedestal. An additional slab is made to fit on the rear of the vault for easy access into the vault and removal of the bucket. A urine diverting pedestal is fitted over the hole in the concrete slab. The urine pipe from the pedestal can direct the urine into a soakaway or preferably through the wall of the vault into another brick built chamber which contains a 20 litre plastic container to receive the urine. Next, a suitable superstructure is built or mounted on top of the latrine slab. This can be made of wood, bricks, plastic sheets attached to a frame or in any way that affords privacy. All hardware in direct contact with urine should be made of durable plastic – not metal - urine is very corrosive.

How the urine diverting toilet works





Stages of construction

Stage 1. Making the base slab

This is a concrete slab laid on level ground which will form the base of the toilet. This forms the foundation for the whole toilet. A concrete mix is made using five parts clean river sand and one part cement (or 3 parts river sand, 2 parts small stones and 1 part cement). The concrete is cast within a mould made of bricks, the dimensions being 1.35m long X 0.9m wide X 75mm deep. An area for the step is also made 450mm long and 335mm deep. Some steel reinforcing wires are placed in the concrete. It is left to cure for at least 2 days before any brickwork is built on top of it. It should be kept wet for several days to cure properly

On the left the brick mould for the toilet base slab. This is cast on level ground at the toilet site. The whole structure is built on top of this. On the right the mould for the toilet slab. This is cast with the same mix of ingredients as the base slab and is 1.2m long and 0.9m wide and about 40mm deep. Holes are cast in the slab for both the pedestal and the vent pipe. The exact method of making the concrete slab is described in the toilet construction chapter. In fact the same basic slab can be used to make an *Arborloo*, a *Fossa alterna* or this urine diverting toilet. Using the same slab it is therefore possible to upgrade the system over time. Money spent on making concrete slabs and other concrete structures is well worth while since they usually last for a lifetime and are a good investment in both money and time.

Stage 2. Making the latrine slab

This is made with a mixture of 5 parts of quality river sand and 1 part of cement or three parts river sand, two parts small stones and one part cement. It is reinforced with 3 or 4mm steel wire - 4 lengths in each direction. The slab is made 1.2 metres long and 0.9 metres wide and about 40mm deep. Holes are made for the vent pipe and the pedestal. The pedestal hole is made about 30-35cm from the rear end of the slab and the vent pipe hole (110mm in diameter) is made about 15cm in front the rear and side of the slab. The hole for the pedestal is made using a plastic basin or 20 litre bucket and this is laid in the final position. The hole size must match the pedestal being used. The vent hole is made using a short 75mm length of the pipe which will be used for the vent. This may be a PVC vent 110mm diameter. The slab is cast on flat ground on a plastic sheet. Bricks can be used as a mould, or timber. Half the mix is made first, then the wire reinforcing is added, followed by the remaining cement. The concrete work is made flat with a wooden float, then finished off with a steel float. About 10 litres of cement (quarter 50 kg bag) mixed with 50 litres good river sand (or 30 litres of river sand and 20 litres small stones) is a good mix . The slab is best cast in the late afternoon, left to harden overnight, then watered and covered with plastic sheet. It is kept wet for at least one week before moving. Whilst the slab is curing, the rest of the toilet structure can be built. Such a slab, well made will last indefinitely.

Stage 3. Making the vault, step and lintel

The vault is built up in fired bricks and mortar to the required height on the base slab. If a 20 litre bucket is used the vault should be about 40cm high. This will require about 4 courses of bricks built on edge or about 6 courses built normally. The walls are built so that the outer measurements of the top are 1.2m X 0.9m and the base 1.35m X 0.9m. This allows for the slope at the back of the vault over which the vault access slab at the rear will be fitted.


Stages in making the vault. The brickwork

Since the rear end of the latrine slab will not be supported on a brick wall it is desirable to make a reinforced concrete lintel which spans the rear end of the vault. This is made with 3 parts river sand and one part cement and reinforced with 3 or 4mm wire. It should be 0.9m long and be 225mm X 75mm wide. Once cured after 7 days it can be carefully mounted on the rear wall of the vault as shown in the photo above.

Stage 4. Making and fitting the vault access slab

This is made in thin high strength concrete using 2 parts river sand and one part cement with 15mm chicken wire as reinforcing and two wire handles inserted for lifting. The dimensions are about 90cm X 45cm high (the exact dimensions must match the vault). This is cured for a week and will be rested against the sloping rear side of the vault. A neat, almost airtight fit is required. This is made by applying strong cement plaster to the vault brickwork and grease to the adjacent cement panel side and bringing the two together. After curing the panel can be withdrawn leaving an exact impression on the vault. This is shown in the photo below. The concrete slab is then fitted and bonded on top of the vault in cement mortar.


The vault access slab and the toilet slab have now been fitted. The superstructure must now be made.

Stage 5. The urine diverting pedestal

Urine diverting pedestals can be home made (see chapter 13 for various methods of home made urine diverting pedestal and squat plate construction), purchased commercially or modified from commercial non urine diverting pedestals which are more commonly available. The toilet described in this chapter used a home made urine diverting pedestal at first. Later this was replaced by a urine diverting pedestal made from a commercially available non urine diverting pedestal. This was modified by adding a urine diverting wall and a urine outlet pipe.

Home made urine diverting pedestals can be made from off-the-shelf plastic buckets and cement. The photos below show one possibility. The plastic bucket forms the inner shell of the pedestal and it is surrounded with cement mortar. Another plastic bucket is cut and trimmed to fit inside the first. The urine is channelled down and led off through a pipe to a soakaway or preferably into a urine storage container.

Stages in making one "home made version" of a urine diverting pedestal. Urine in this case ran down through the hole into another plastic bucket held within the vault and then to a soakaway.

On the left the home made urine diversion unit is fitted over the slab. On the right the improved urine diverting pedestal, fitted with wooden seat. Note also the vent pipe fitted behind the pedestal to the right.

Stage 6. Mounting the pedestal.

Pedestals are mounted over the hole in the slab and cement mortared in position. It is important that this joint is watertight, so that any water falling on the slab (from rain or washing water) does not drip into the bucket below which must contain faeces, paper, soil and wood ash only – absolutely no water.

Stage 7. Adding a urine collector.

Urine is a valuable plant food and is best collected in a container. The best method is to build an extra brick side-chamber on one side of the vault. This will house a plastic container of about 20 litres capacity which will receive and store the urine. A plastic pipe is led from the urine outlet of the pedestal through the side wall of the vault into the brick side chamber so that the urine can be caught by a small funnel which directs it into the urine storage container. The brickwork of the side chamber is built up to enclose and protect the container and the piping. The chamber is covered with a concrete lid with handles. It is important to ensure that the plastic pipe leading from the urine outlet to the container falls continuously and does not pass through a loop which will act as a water trap or air lock. The side wall chamber must be big enough to house the container so that it can easily be withdrawn. Since urine is very corrosive, the piping and container must be made of stout plastic. Metal parts will corrode.

A plastic pipe is led down from the urine diverting pedestal through the side wall of the vault into a plastic container held within a small brick built side vault. A home made funnel is used to guide the urine into the container. The side vault is built up on soil so that any urine overflow can drain away.

Stage 8. Making the superstructure

Many types of superstructure are possible for urine diverting toilets. They are built in one location and thus can be made from bricks or timber, metal sheeting, asbestos sheeting, reeds, grass or of any material that offers privacy. In this case, the vent pipe is placed within the structure and the roof must have a hole made for the ventilation pipe to pass through. Structures are fitted with a door of some sort. A roof is essential as this prevents rain water entering the interior and the pedestal. Water must not be allowed to penetrate into the vault.

The superstructure


The superstructure in this case has been made from a frame of polyethylene pipe covered with plastic "shade cloth." This is not very robust, but has proved very adequate over a four year period. The urine diverting pedestal is smart and comfortable. A mixture or soil and wood ash (4:1) is stored in one container, with dispenser. Toilet paper is held in another container.


Finished structure with side vault for urine collection. The rear vault access door is neatly fitted. A 20 litre bucket has been fitted within the vault. Two bricks cement mortared to the floor locate its best position directly beneath the pedestal chute.

Stage 10. Finishing off

Make sure the rear access door fits well at the rear of the vault. The vent pipe will function better if the vault is well sealed. Two bricks can be mortared on the base slab to locate the best position for the bucket which is directly under the pedestal. The vent pipe is fitted into the toilet slab and through the roof. A latch is fitted to the door to hold it closed. A mix of dry soil and dry wood ash (4:1) is provided in a container. It is best to mix bulk dry soil and ash first and hold in a sack, or dust bin, then bring to the toilet in small lots.

Use and management of the urine diverting toilet

Since the faeces from the UD toilet will be used to make humus, it is essential that soil and wood ash are added after every visit to the latrine. The bucket then fills up with a mixture of materials which compost easily - faeces, paper, soil and wood ash. It is wise to premix the soil and the ash first (mix of four parts soil to one of ash), when these materials are in the dry state. This can be stored for use in a larger container or sack and brought and stored in smaller containers within the toilet. The ash and soil can be applied down the chute using a small cup or home made dispenser – the one used on the toilet is made from the upper part of a plastic milk bottle. Half a cupful of the mix is added after every deposit made. When the bucket of contents is nearly full, its contents are transferred to a "secondary composting site" for further processing. The rate of filling obviously depends on the number of users and the amount of soil/ash added. Weekly transferral may be required for a family of about 6. For a single user, the bucket may take 4 – 6 weeks to fill up. The urine accumulates in the plastic container until it is nearly full. This urine can be used in various ways as described later in this book.

Processing the faeces

The faeces (without urine) fall directly into the bucket, and it is wise to put some humus or leaves in the base when it is empty to avoid sticking and to help start the composting process off. In this unit the bucket is removed and its contents transferred to a "secondary processing site" quite regularly. The frequency of moving the bucket and its contents depends on how quickly the bucket fills up and this is related to the number of users. Fresh excreta does not remain in the toilet system itself for long. It may be just a few days or a week or two at most. However, at the ambient temperatures found in Harare (the temperature of faeces held in buckets hovers around 18 degrees C.), the combination of faeces, paper, soil and wood ash does start to degrade. Thus in practice the toilet can be considered the "primary processing site" (in so far that the ingredients are placed together and start to change their form) - but the period is brief. When the bucket is nearly full, the rear vault access slab is removed and the bucket withdrawn and its contents tipped into a "secondary composting site" nearby. Some soil is placed back into the empty bucket and then it is placed back in the vault beneath the pedestal. The rear vault slab is replaced and the toilet can be used again. This transferral of materials from primary to secondary composting sites is quick and easy.

The bucket is withdrawn from the vault and its contents tipped into a shallow pit composter or a split cement jar as shown above. The 30 litre split cement jar is ideal for processing human faeces. Fertile soil is added on top of the excreta and a strong lid placed over the top for protection. More deposits are made when the bucket fills again. After 3 or 4 months the contents are pleasant to handle. Naturally it is always wise to wash hands after handling humus of any type – including this variety. The conversion is a *Miracle of Nature*.

Secondary composting sites.

Several "secondary processing sites" have been tested over the last three years with the UD toilet. These are sites where the raw excreta is converted into a product which is best called humus. The humus has the appearance of loam like soil and smells pleasant. These sites include shallow pits (tree pit or fertility pit or twin shallow pits), trenches, compost heaps and also buckets or split cement jars where the composting process can take place. Plastic bags have also been used. The tree pit is a shallow pit covered with a lid into which the bucket contents are placed and then covered up with fertile soil. When the pit is almost full it is topped up with a good layer of topsoil and a young tree is planted in the topsoil. This works like the ***Arborloo*** **–** in fact this method preceded the ***Arborloo*** which evolved from it. A similar method is used with a trench, which is filled up in stages with buckets of the mixed composting ingredients.

What system to use as a secondary composting site?

This will depend on the number of users. If the number of users is small, a series of small jars described later is ideal. If the family is medium to large say between 5 – 10 persons or more it is best to build a twin pit composter where the contents of the bucket are added to one shallow pit until it is nearly full, then to a second shallow pit which fills whilst the contents of the first pit are composting. A composting time of at least 6 months should be allowed. A single user will completely fill a 20 litre bucket with a mix of faeces, paper, soil and ash in about 4 - 6 weeks. Thus a family of about 6 persons will fill a 20 litre bucket in approximately one week. This means that the bucket must be removed and its contents placed in a "secondary composter" every week. The actual rate of filling will be quickly established. In this case the best composter is the double shallow pit type. This can be built near the toilet.

Use of split cement jars as a "secondary composting site"

When nearly full, the bucket of contents (faeces, toilet paper, dry soil and wood ash) are tipped into the jar, levelled off with a trowel and covered with a layer of good fertile soil. The soil is full of life forms which digest and convert the excreta into humus. Two or three bucket loads may enter the jar before it is nearly full. After the last filling the excreta is levelled off again and topped up with about 5 cm layer of soil. This jar of contents should be watered, then covered with a lid and left to decompose. The various ingredients will decompose within three or four months to form humus which can then be removed and used much in the same way as the eco-humus taken from the ***Fossa alterna***. Tomato growing is the best option. The empty jar can then be reused time and time again.

When made properly, the cement jar can be used time and time again - being made of concrete. It is also cheap. The jar has a wider base than top so the contents held within it are well drained. That is important if a good conversion from excreta to humus is to be effected. During the period when the faeces are converted into humus, which may be as little as three or four months with this method, there is no (or very little) temperature rise within the jar. The conversion is rapid because the conditions seem to be ideal. There is a relatively high ratio of soil to excreta, and the conversion is made "in small lots" where no pocket of excreta is large and all excreta is relatively close to some living soil. As the mass is converted, it also contracts as the water content of the original excreta (which may be as high as 70%) is absorbed into the soil within the jar or drains away under the jar. In practice the level of the plug of soil held within the jar drops as its volume decreases. Also the diameter of the "plug" is reduced and this can leave a gap or small air space between the soil and the jar, which obviously retains its original dimensions. The soil near this air space is very active biologically. Thus the core of converting matter is moist, well drained, well aerated and close to the living soil - all ideal conditions for an effective conversion of faeces into humus.


Tipping the contents of the bucket from a UD toilet into a small shallow pit for processing. The shallow pit is covered with a concrete lid with hole which is itself covered. On the left three cement jars are shown. The one actively being filled is covered with an attractive painted concrete cover.

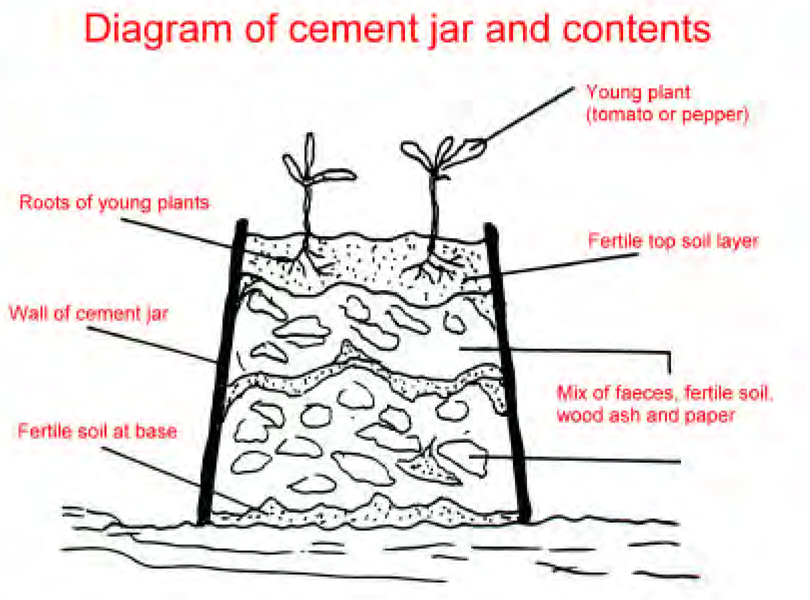
Biological activity within the jar

The contents of the jar are biologically very active during the conversion stage and thereafter. The process is aided by adding a layer of fertile topsoil to the container and planting young plants of various types into this upper layer. The conversion process whereby faeces are converted into humus is the result of the activity of bacteria and fungi present in the added soil which thrive under ambient temperatures (that is temperatures which are close to the surroundings). Many other beneficial organisms, including worms, insects and many other life forms also thrive at their best at ambient temperatures. These animalcules and microbes appear to digest the excreta and may also considerably reduce the number of pathogenic organisms, such as bacteria which carry disease. In tests carried out on jar humus, pathogenic bacteria such *Escherichia coli, Salmonella sp, Shigella sp, and Staphylococcus sp*. were absent after only 3 months of composting (From tests carried out by Clinical Laboratories, Harare - Frank Fleming. pers.comm.). This aspect is further discussed in the chapter on Health. Care is obviously required when handling any compost of this type.

The process is an entirely natural one leading to the formation of humus. The process may best be described as "*Ambient Temperature Composting*" since it takes place at a temperature close to the natural surroundings. The soil added should ideally be fertile and contain living organisms for the process to take place at its best. These fertile soils and leaf moulds also absorb much of the moisture content of the excreta, and the process is normally associated with a reduction of volume of the mass. Remarkably however the process still takes place where poor soils are added to the excreta, albeit less efficiently, and the final product may lack the texture of the best humus – but it certainly is high in nutrients, which come from the faeces.

In addition, the roots of the plants invade the body of the container as the plants grow and this provides an extensive biological structure within the decomposing materials which assists the process of converting the faeces into a friable and acceptable humus like soil. The extent of the root invasion depends on the plant type. Not all plants will send their roots down the entire depth of the jar. Certain types of flower are very effective at invading the contents of the jar (or bucket) and penetrate the entire space occupied by decomposing matter. The giant "*crackerjack*" marigold is a good example. Within 3 months its roots invade the entire contents of the jar or bucket and provide an extensive biological surface which assists in converting the faeces into soil. Obviously in doing this the flower is taking nutrients away from the humus.

The absorbing root-soil interface is called the rhizosphere. It is within this thin microscopic layer that surrounds the roots and root hairs that much biological activity takes place. There are many living organisms present in soil and around the rhizosphere - bacteria, fungi, protozoa, slime moulds, algae, soil viruses which together with nematodes, earthworms, millipedes, centipedes, mites, snails and other small animals, compete for water, food and space. The roots provide a multitude of surfaces for microbial colonisation. The roots also provide oxygen, essential for effective biological processes and also other nutrients that the micro-organisms require. These include carbohydrates, organic acids and many other substances essential to the life within the rhizosphere. The abundance of life in this active biological zone form micro-cavities where the micro-organisms live. In nature, decomposing vegetable matter within the soil helps to make conditions optimal for these organisms. The plant itself takes up water, nitrates, phosphates, potassium, sulphates, and many trace elements. Thus as the roots of plants invade the decomposing materials in the bucket, they greatly assist in the natural processes which lead to the conversion of faecal material into humus simply by generating enhanced biological activity throughout the root zone.



The final texture of the humus formed very much depends on the type of soil added. If the soil is a lifeless sandy soil, the final texture of the humus will be more sandy. If the soil added is fertile and humus-like itself, then the final product will be more crumbly and humus like. Thus the texture of the end product depends on the soil added. It is also possible to add leaves to the mix and this will greatly improve the texture of the humus. In all cases the combination of soil and human faeces considerably enhances the level of nutrients in the final soil produced. The increase in nutrient levels is dramatic and can transform even the most barren soils into soils which are fertile and able to sustain plant growth. The following charts show the levels of major nutrients in the 30 litre "secondary composting jars" combining human faeces, wood ash and soils.

The twin pit secondary composter

Stages of building a twin pit composter for single vault urine diverting toilet


Stage 1. Choose a level site near the toilet and caste two ring beams from concrete on the ground. The internal measurement is variable but in the case shown here the internal measurement was 0.8m X 0.8m. The width of the ring beam was 15cm and the depth 7.5 cm. A mix of 5 parts river sand and 1 part cement was used. The two ring beams were placed about 0.75m apart. The concrete was allowed to cure for a period of 3 days under plastic sheet. In the photo on the right the bricks and timber shuttering have been removed from the ring beam and each filled with water to loosen the soil beneath.


After a day and night soaking the soil is easier to dig. The photo on the right shows the two pits dug down to about 0.5m metres. The removed from the twin pits has been laid around the ring beams and rammed in place. This makes the pits more stable. The pit which will not be used first can be filled with leaves to compost, whilst the other pit will be filled with a mix of faeces, paper, soil and ash from the toilet. The area around the ring beams is smoothed down and made neat.


A wooden lid is made for the twin pit composter and placed over the pit which is being filled with excreta, soil, paper and ash. The almost full bucket is removed from the toilet vault and tipped into the shallow pit. The deposit is covered with more soil.


On the left a motivated pensioner tips his bucket of contents into the shallow pit. The photo on the right shows the first deposit made into the pit. Many more will be added until the pit is almost full. Since the excreta is close to the soil and is surrounded by soil and the additions are made in "small lots," the composting process is quite efficient. The pits are called secondary composting sites because the actual composting process starts off in the bucket itself and the process continues in the shallow pits. Leaves can also be added to the shallow pit. These add more air into the system and also further organisms which help to break down the excreta. The final humus is more crumbly in texture if leaves have been added.


Photo showing first addition (left pile) and second addition a month later (right pile) in the composter. The conversion to humus is already well advanced in the first pile. Note how the toilet paper has disintegrated. The new additions to the shallow pit are covered with a layer of soil and the wooden lid is laid over the pit for protection and safety. Water is added periodically to keep the composting ingredients damp. The two pits are used alternately. Once the first pit has filled up which should take rather more than 6 months, the second pit is used. When the second pit is full, the first pit can be emptied. And the process started again on the original pit.

Routine maintenance of the urine diverting toilet.

Routine cleaning and maintenance of the toilet is important for the best functioning of the unit. This is not an arduous task and can be carried out quickly once every month or two. Urine diverting pedestals have no means of flushing down the sidewalls and it is inevitable that some fouling will take place. Whilst the vent will carry any odours down into the vault and up the pipe, periodic cleansing of the chute is desirable. During normal use, the dry soil/ash mix will cover any side wall fouling, dry it out, and make it less objectionable.

The great advantage of the UD system described here, where the faeces are contained in a removable bucket and not a static vault, is that the system can be washed down completely once the bucket and the urine container have been removed. It is desirable that the vent pipe, pedestal and urinal pipe are washed down and cleaned from time to time. First the bucket and urine container are removed and put to one side. The vent pipe (which will normally be made of PVC) is also pulled out. Cobwebs which may have developed in the vault can then be cleaned out with a small tree branch. The whole unit can then be thoroughly washed down and cleaned out. The pedestal is cleaned entirely from top to bottom including the side walls. The urine pipe is also flushed out with water. The toilets floors and vault can also be washed down with water. The ventilation pipe must also be washed down and cleaned out from time to time to retain its efficiency. This is because spiders weave their webs inside the pipe and this seriously disrupts the air flow inside the pipe. Efficient ventilation is important and helps to reduce odours and also maintains a constant flow of air through the vault which reduces moisture. The toilet and its parts are then allowed to dry out and are all put back together (put back bucket, urine container and vent). The dry soil/ash container inside the toilet is constantly being recharged from a larger stored stock elsewhere.

During the wet season, it has been found that Culicine mosquitoes (which do not carry malaria) can hide in the vault and emerge up the pedestal chute during use. Attempts at controlling these mosquitoes have been made by introducing springs of the wild basil *Ocimum canum*, which is know to be a mosquito repellent. No flies have ever been seen.



The interior of the *Skyloo* can be completely washed down once the urine container and the bucket containing the faeces, soil and ash have been removed. In the middle the wild basil, *Ocimum canum*, can be used to chase mosquitoes away. On the right a spider – fortunately they rarely travel up the pedestal!


Flies have never been seen in the single vault urine diverting system (*Skyloo) described here,* but spiders and mosquitoes do invade during the wet season. Spiders do no harm but can block vent pipes. Mosquitoes in this case are the culex type and not malaria carrying. They look for dark places to hide – they do not breed there – there is no water. Effective fly and odour control is maintained by using a screened vent pipe (with corrosion resistant stainless steel or aluminium screen), and near airtight sealed vault, regular addition of a dry mix of soil and ash to the bucket, a water tight seal between pedestal and toilet slab (to stop rain or other water entering the bucket), and the toilet seat lid closed when not in use. The unit is "spring cleaned" three or four times a year by removing vent, bucket and urine collector. The vent is cleaned out and washed down. The pedestal is washed down, the vault washed clean and cobwebs removed. The urine pipe is flushed out with water. The bucket is cleaned and allowed to dry. The toilet slab is cleaned down. When parts have been cleansed they are fitted back together and allowed to dry out. The unit is then put back to use.

7. Upgrading the toilet system - *Start simple and improve over time*

The ***Arborloo*** is an excellent entry point for householders who wish to consider using ecological toilets and recycle their excreta. It is simple, cheap and the excreta is never touched. But the ***Arborloo*** can be upgraded to a ***Fossa alterna*** and this is a trend which is being followed in several programmes. Also toilets can be upgraded by fitting pedestals and vent pipes. The advantages of upgrading the ***Arborloo*** to a ***Fossa alterna*** is the permanence of location and a regular supply of compost. It is also possible to upgrade the ***Fossa alterna*** (or even ***Arborloo)*** to urine diversion. This brings with it extra cost and complexity. But the pit contents will be drier, with less potential for odour and fly breeding. Also the urine can be led to a sunken plastic container for collection. The urine can also be led to a seepage area planted with a nitrogen hungry tree (e.g. banana,) or a garden compost pit or some other seepage area. The pit contents will be drier which will be an advantage especially if the soil does not drain well. In those cases where a urine diverting pedestal is fitted to a shallow pit composting system, it is best that the urine pipe is led off above the base of the pedestal. Underground piping can be complicated to fit to pit structures. The same urine diverter (often using the same concrete slab) can be fitted to a brick vault where the toilet is constructed entirely above ground level.

This urine diverting pedestal has been fitted to a *Fossa alterna* system. The urine off-take is fitted above the base of the pedestal so that the pipe can be led above the slab to the most suitable place – like a container, compost-pit or tree. The 110mm vent pipe passes through a hole made in the slab and is fitted in this case inside the toilet house.

Example of upgrading the toilet system using the 1 metre diameter round slab and matching ring beam

The 1 metre diameter concrete slab and matching ring beam can be made cheaply and is normally used to construct an Arborloo. But the same slab can be used on a *Fossa alterna* system (see earlier chapters). The same concrete slab and ring beam can be used to make a urine diverting toilet, as this sequence of photos shows. The ring beam has been laid down on level ground and backfilled with soil. A round brick wall is then built up on the ring beam to form a vault, with an opening at the rear, and high enough to accept a 20 litre bucket for containing the faeces, ash and soil.


The one metre diameter slab has been fitted and bonded on top of the round vault in cement mortar and a urine diverting pedestal fitted. This could also be a squatting type urine diverting platform. The bucket is located in position under the urine diverting pedestal with some bricks.


A concrete vault access door has also been made and fitted to the rear of the vault


Toilet paper and is the dry soil/ash mix are held in separate plastic containers.


A simple structure is built around the vault for privacy and the urine pipe is led off to a banana plant close by. Structures can also be upgraded.

Example of upgrading the toilet system using a 1.2m X 0.9m rectangular concrete slab.


The 1.2mX 0.9m rectangular concrete slab has been used to build this Arborloo (left) and *the Fossa alterna* (right). Most Arborloo and *Fossa alterna* toilets use squat holes rather than pedestals. But they can be upgraded by adding pedestals and vent pipes. The vent pipe helps to remove smells and excess moisture from the pit


This *Fossa alterna* (using a 1.2m X 0.9m slab) has been upgraded first by adding a non urine diverting pedestal (left) and later by adding a urine diverting pedestal (right). When fitted to a shallow pit system the urine diverting pedestal is easier to install if the urine pipe lies above slab level.

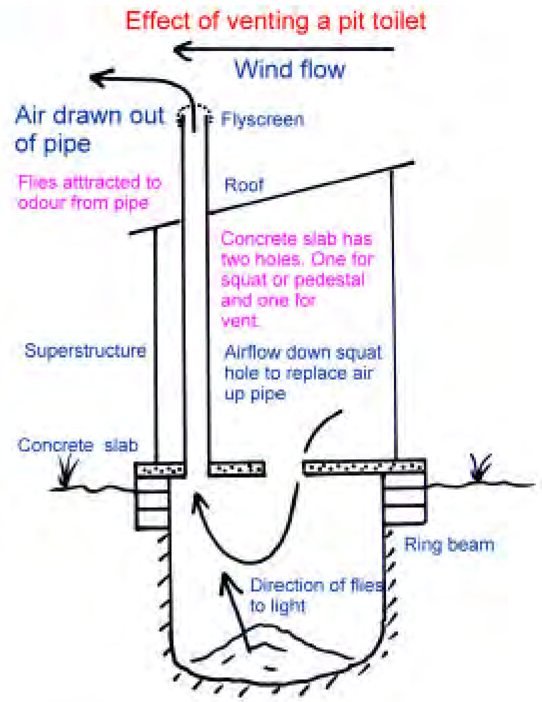

This urine diverting pedestal has been mounted on a 1.2m X 0.9m concrete slab mounted on an "above the ground" vault (see earlier chapter). In this case the urine pipe can be led off below slab level. The urine pipe is shown on the right leading to a plastic container. The two bricks which locate the bucket (not in place) which contains the faeces, soil and ash, are also shown.

8. Odour and fly control

The control of insects and odour are important issues to deal with in improved toilet facilities. The elimination of odours makes the toilet far more pleasant to use, and the control of insects, particularly flies is important for health reasons. Too many flies are also a nuisance.

Odour control.

A screened ventilation pipe can reduce odours and flies in all the compost making toilets described in this book. The vent pipe (e.g.110mm PVC) draws out air from the pit or vault, mostly by the action of air passing across the top of the pipe. The air that flows out of the pipe is replaced by air passing down the squat hole or pedestal. This is most efficient when the slab and pit collar are sealed and airtight and the head of the pipe is not surrounded by trees. Any foul odour from the pit or vault does not escape into the superstructure, but is diluted by air and passes out of the pipe into the atmosphere. The effect is that the toilet becomes almost odourless. The vent also helps to remove moist air from the pit or vault which helps to reduce the moisture content of the excreta.



Left: Diagram showing effect of vent pipe on controlling odours and flies. Right: A urine diverting pedestal with above slab urine take-off. This type is suitable for upgrading shallow pit composting toilets like the *Fossa alterna* to urine diversion. Pits under urine diverting pedestals are drier and this helps to control flies and odours.

Also a urine diverting pedestal which separates urine from faeces will also have the effect of reducing odours, since the faeces are drier when not mixed with urine. The drying effect is increased by adding wood ash or dry soil to the deposit. This will also control flies. But PVC pipes and urine diverting pedestals may be too expensive to fit to very low cost pit toilets. In this case the regular addition of soil, wood ash and leaves to the pit will help to reduce odour. Keeping the toilet clean and covering the squat hole can also help. It is possible to upgrade a simple pit toilet by adding a vent pipe or urine diverting pedestal or both at a later date. The urine diverting pedestal should ideally be one where the urine off-take is above slab level. This makes plumbing arrangements on pit toilets easier.

Fly control

In urine diverting toilets, the faeces are deposited separately and covered with dry soil and ash. Flies do not breed well under these conditions. But if soil and ash are not added, fly breeding can begin. However fly breeding is easier to control in urine diverting toilets, simply by adding more dry ash and dry soil to the deposit. It is essential that the urine diverting vault is not flooded with water or urine added. This will make things very messy. User education is required on the proper use and maintenance of UD toilets.

The method used in the VIP latrine effectively controls flies as well as odours if the conditions are met, such as fitting a screened vent pipe (corrosion resistant aluminium or stainless steel screens must be used). The toilet house must be kept in semi darkness (open doors allow flies to escape through the house and a roof is essential). Where the interior of the toilet is kept semi dark, flies will enter the pipe from the pit or vault and become trapped by the screen. This is because flies are attracted to light when they leave the pit and enter the pipe which is the most obvious light source. From the outside, flies are attracted by odours coming from the pit or vault and most of these are expelled through the head of the vent. If the head of the pipe is screened, flies cannot enter the pit (see diagram). This simple effect can dramatically reduce fly breeding in the pit toilet or vault and thus reduce the passage of fly-born disease. This is the principle of the VIP toilet (see diagram).

Fly breeding will also be reduced if the pit contents are drier. Thus adding a urine diverting pedestal to a shallow pit system will help reduce fly breeding. But for lower cost shallow pit composting toilets a vent pipe and/or urine diverting pedestal may be too expensive to fit. Then fly breeding, which is a natural phenomenon in pit toilets, must be controlled by some other means. This is because the mix of faeces and urine is far more fluid than faeces alone produced in urine diverting toilets. Flies breed most in pits which are moist and also during the warm wet season in Southern Africa (December – March). The liberal addition of wood ash is known to reduce the potential for fly breeding in pit toilets. But it may not eliminate them altogether. So if flies build up, it helps to add ash liberally if it is available, especially during the hotter wetter months when the fly problem is worst. The liberal addition of ash will also reduce odours. Where soil, ash and leaves are added in combination, the pit gets a mix of soil organisms, potash and composting matter which helps to make better pit compost for later use in agriculture and tree growing. So the more of these additional materials is added the better the final compost and the greater the degree of fly and odour control. Obviously pit filling time is reduced, the more soil, ash and leaves are added and a balance must be struck between adding too much or too little soil. In rural projects, homesteaders are often reluctant to add too much soil or ash at first, but soon learn that flies and odours are controlled better if more is added. Also a lid or cover added over the squat hole helps to reduce the entry of flies into the pit. If a superstructure is fitted with a door it is wise to also place a cover over the squat hole, in case the door is left in the open position. There is no fly control, even in VIPs if the toilet door is left open. If the toilet is also used as a washroom, a squat hole cover also prevents the soap falling down into the pit

In this pit, wood ash as been added over freshly deposited faeces to control fly breeding. During the hotter wet months it pays to add plenty of ash if it is available.

An Ecological Approach to Sanitation in Africa

A compilation of experiences

Peter Morgan

(2004)

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9. The Eco-toilet and agriculture

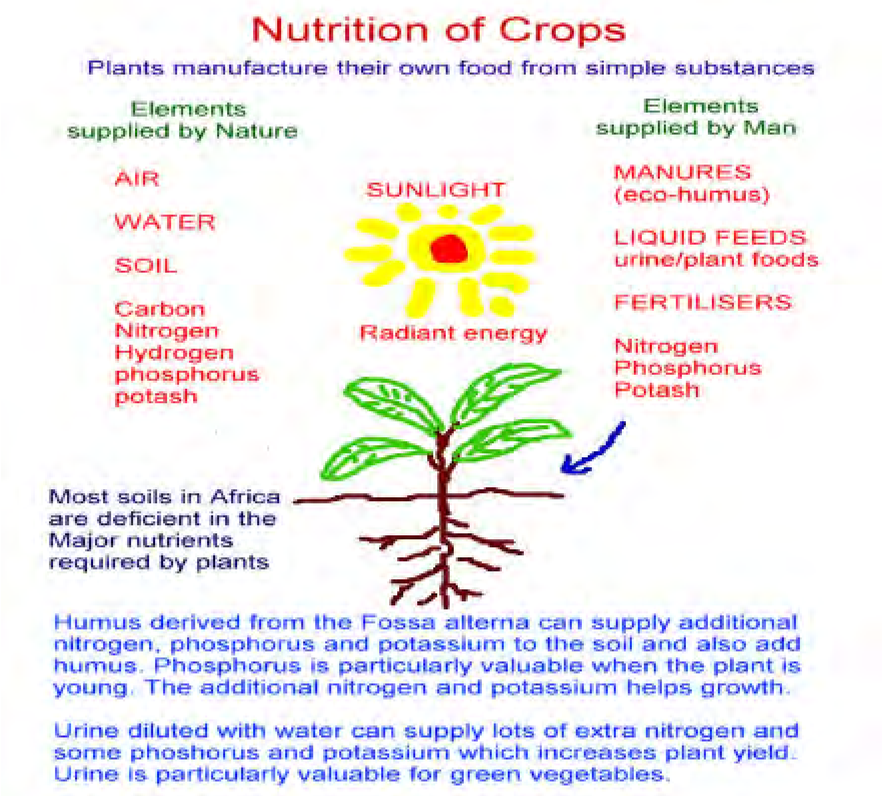
So far we have talked about toilets – how they are built and managed. We have arrived at the point where, in the Arborloo, we have a pit filled with composted excreta and soil etc ready for tree planting. In the case of the Fossa alterna we have arrived at the point where we have a pile of fertile humus which has been excavated from the shallow pit after a year of composting.

But at that stage we have only reached the first part of our story The best part is still to come! We must now plant trees to make use of the nutrients in the Arborloo pits and also use the Fossa eco-humus (and urine) to best advantage to grow better crops of vegetables.

The simple eco-toilets described here fit in well with the sound principles involved with organic gardening where organic materials of many types, like composted kitchen and garden wastes and animal manure etc, are recycled for the benefit of food and tree production. The use of eco-humus derived from human excreta is an extension of this idea, and there is nothing particularly new about it. Human waste, suitably composted, has been used by Man for a long time.

The importance of nutrients in plant growth

Plants require certain chemical elements for plant growth – these are called plant nutrients. Most of these are non-mineral elements such as carbon, hydrogen, and oxygen. These elements are mainly taken up as carbon dioxide from the air and water by the roots. Sunlight also plays a major part. Increasing the supply of sunlight, carbon dioxide and water through photosynthesis also increases the growth rate and crop yield of plants.



The nutrients are classified in two groups, macronutrients and micronutrients. The major uptake by plants falls in the macronutrient category. Macronutrients include nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and magnesium (Mg). These nutrients are mainly taken up from the soil by the plant roots in ionic form. Micronutrients include boron, copper, iron, chloride, manganese, molybdenum and zinc.

Each major nutrient, nitrogen (N), phosphorus (P) and potassium (K) plays a different role in plant growth and development. Each also plays a vital role, and plants grow best when there is a good balance of these essential nutrients. It is useful to record here the value of the different nutrients in plant growth and development.

NITROGEN

Increases size of leaves
Increases rate of growth
Increases final yields

TOO LITTLE - Poor pale green or yellow leaf
TOO MUCH - Delays ripening, causes lush but soft growth. Can block uptake of potassium.
VERY GOOD for green leafy crops and maize

PHOSPHORUS

Stimulates early root and shoot growth
Hastens leaf development
Encourages early maturity

TOO LITTLE - Poor growth
TOO MUCH - No harmful effect
VERY GOOD - All plants need generous supply

POTASSIUM

Improves health and quality of crop
Encourages fruit production

TOO LITTLE - plants less healthy and poor fruit production
TOO MUCH - Few harmful effects
VERY GOOD for potash-responsive crops like potatoes, tomatoes, tree fruits & legumes

- **Nitrogen** (available as nitrate) is the most important nutrient involved in vegetative plant growth and leaf building – it also helps to increases the final yield of crops. It is required in relatively large amounts. Plants deficient in nitrogen have pale leaves and look weak and the lower leaves gradually turn yellow, as the plant transfers the vital nutrients to where they are most needed in the formation of new leaves. However nitrogen cannot do its work unless phosphorus, potassium and other elements are also present in the soil in sufficient quantities. An excess of nitrogen can also reduce the uptake of other important nutrients like potassium which is important for the general health, fruit formation and disease resistance of plants. Most soils in Zimbabwe and surrounding countries are very deficient in nitrogen. Nitrogen is quickly washed out of the soil after heavy rain or watering, and needs to be replaced fairly often.

- **Phosphorus** is important because it gives a good start in life for plants by assisting strong root growth and shoot formation. It is also a good fruit builder and encourages early maturing and ripening. It hardens stems and vegetative growth and increases resistance to disease. Unlike nitrogen, which is easily flushed out, it is held by the soil and does not need to be replaced so often. Also unlike nitrogen and potassium, it does not burn plants. Generally phosphorus is deficient in most top soils in this part of Africa. A deficiency in phosphorus results in poor root growth which is revealed later by slow plant growth in general. One indication of deficiency is the purpling of leaves. There is seldom an excess of phosphorus in any soil. It is a very precious mineral in short supply unlike nitrogen which is available in abundance and potash which if needs be can be taken from wood ash. Most soils in Zimbabwe and surrounding countries are very deficient in phosphorus.

- **Potassium** (potash) builds fibre & skeletal growth in the plant and also helps to promote good fruit development. It promotes the general vigour and health of plants. A balance must be maintained between potassium and nitrogen as they interact with each other. Many important plants are "potash hungry" like tomato, potato, onion, runner bean – so potassium is important in our story. Potassium is not washed out of the soil as easily as nitrogen but is not held as strongly as phosphorus. Most soils in Zimbabwe and surrounding countries are very deficient in potassium.

Most garden fertilisers have a balance of nitrogen, phosphorus and potassium for use on vegetables. The ratio of the "NPK" in fertilisers, with phosphorus predominating, indicates that on the phosphorus deficient soils in Zimbabwe, most require more phosphorus than nitrogen overall. As the plants mature, more nitrogen may be required. Most leafy vegetables respond very well to the application of nitrogen after they have become established and this is available in large quantities in urine. Fruiting vegetables and root crops require far more potassium as they mature, and an excess of nitrogen may retard fruit growth, favouring lush leafy development. But each vegetable or crop has its own specific requirements. Also different soils vary greatly in what nutrients they can naturally provide for the plants. So the application of ***Fossa*** humus and urine to plants may result in a variable reaction, depending on the soil used and the type of plant grown. The ***Fossa*** humus improves soil texture and a good balanced supply of additional nutrients to the soil and most plants respond very favourably to its application.

Fruit and trees.

All plants have the same basic requirements, whether they are vegetables or trees. Thus in the early stages of a tree's growth, phosphorus will be required for good root and early shoot growth. Nitrogen once again will be required for vegetative growth. But fruit bearing trees do require plenty of potassium to produce of their best. Perhaps this is why young tree grow well on composted human excreta – it does contain generous supplies of phosphorus.

All fruit trees need adequate fertilisation to produce their best yields. Feeding of some sort is required every year, with manure, compost, diluted urine or other fertilisers. The amount of plant food required increases as the tree grows larger. In the case of citrus trees about 10 kg of manure or compost is required per tree per year for the first two years. This increases to 15 kg in the 3rd year, 20 kg in the fourth year, 25 kg in the 5th year, 30 kg in the 6th year, 35 kg in the 7th year, 40 kg in the 8th year and 50 kg between the 9th and 14th years. 10 kg is a wheelbarrow full or 150 gms ammonium nitrate, 200 gms single super-phosphate and 200 gms potassium chloride. For guava about 15kg manure or compost is required in the first year, 20 kg in the second and 45 kg from then on. Similar amounts are required by mulberry and avocado. Mango requires 10 kg manure or compost spread out through the year during the first year, 16kgs from the 3rd to 4th years, 18kgs for the 5th and 6th year and after 11 years about 60 kg. For Bananas about 15 kg manure or compost are required every year for each banana clump.

In ecological sanitation, the ***Arborloo*** is the closest link between the toilet and the tree. The nutrients present in the composted excreta, will be enough to start the tree off and a good quantity of phosphorus will be present and sufficient nitrogen and potassium to feed the tree for a year or two. The analysis of compost from a few ***Arborloo*** pits and from those ***Fossa alterna*** pits analysed (see below) show that even after a year of composting the nutrient level is high. Once the tree is planted, the nutrients held within the pit compost will start to be used up. So after two years, annual feeding of the fruit trees will be required to gain the best fruit yields. Urine can supply plenty of nitrogen, but less potassium. So the best way of applying urine is to dilute the urine (5:1) and add wood ash. The exact amounts required are still being worked out. As the tree grows larger, more will be required. A single charge in a watering can will be a mix of 2 litres urine to 10 litres water with a mug full of ash added and stirred in. Once the young tree is 2 years old, a mix of 2 litres, urine diluted with 10 litres water with a mug full of ash mixed in can be applied twice a month during the rains and with additional watering at other times. As the tree grows much larger quantities are required. It is important to keep the level of potash high in relation to nitrogen for best fruiting. The annual application of manure or compost will also help to sustain fruit output from trees.

Soil pH

For most crops the pH of the soil is best at a value of around 6.0 to 6.5. That is just slightly acid. At such a pH bacteria of the helpful kind will enjoy good conditions. The various soil nutrients will be kept in an optimum state of availability, various fungi that cause disease will find unfavourable conditions and the soil will tend to granulate to a more favourable size. If the pH drops too much below 6.5 or 6.0 then phosphoric acid ceases to be available. If the pH goes up to high, that is towards alkalinity, then certain trace nutrients will become entirely unavailable eg manganese, iron, copper, zinc, boron, and such a condition would be very hard to correct. There is therefore a serious danger in the over use of lime.

Special requirements

We have already mentioned that some plants require increased amounts of certain nutrients to give their best yields. All young plants require generous phosphorus and perhaps that is why the amount of phosphorus available in most general fertilisers contains more phosphorus than the other main nutrients. ***Fossa alterna*** humus does contain quite a generous supply of phosphorus. Most green vegetables and maize respond to a good supply of nitrogen, and diluted urine has much nitrogen. Indeed most plants respond positively to diluted urine if applied carefully during their main phase of vegetative growth. Several important plants like tomato, onion, potato and some types of bean need more potassium to give their best yields and this can be supplied by applying wood ash. Wood ash can also be applied in a liquid feed with diluted urine, or with water. Alternatively a liquid feed made from composted leaves in which comfrey leaves are included provides a good mix of nutrients including potassium. Most plants respond positively to soil to which compost has been added. As the plants use up nutrients for their growth, the soil requires replenishment, from whatever suitable source is available.

Nutrient levels in pit compost

It is interesting to record that the balance of available nutrients in humus derived from the pit compost (***Fossa alterna)*** is well spread between nitrogen, phosphorus and potassium, as they would be in commercially available general compound vegetable fertilisers. By comparison, urine has a very high level of nitrogen in relation to both phosphorus and potassium. Thus the effect of applying urine is much like applying a rich nitrogen fertiliser. Urine is particularly useful for promoting the growth of leafy vegetables like rape, covo and spinach, once they are established. Maize also responds very positively to the application of urine.

Soil analysis of ***Fossa alterna*** humus shows it contains much higher levels of the main plant nutrients than topsoil collected from a number of sites around Harare. These analyses are described in more detail in the next chapter.

Summation of levels of nutrients in *Fossa alterna* soil compared to local top soils

Soil source	pH	N	P	K	Ca	Mg
Mean value (local soils)	**5.5**	**38**	**44**	**0.49**	**8.05**	**3.58**
Mean value (*Fossa alterna*)	**6.86**	**273**	**278**	**4.22**	**11.11**	**5.61**

Conclusions

These various results show that the ***Fossa alterna,*** when well managed, offers the family a valuable asset, which is not only an effective toilet system, controlling both flies and odours, but also provides an excellent source of humus for the vegetable garden. Soil analysis reveals why the addition of humus derived from the ***Fossa alterna*** pit every year helps to enhance the fertility and nutrient levels of an existing vegetable bed. This can greatly enhance back yard vegetable production (see plant trials later). By combining these advantages with its low cost and relative ease of use and management, the ***Fossa alterna*** may hold much potential for future use in many parts of Africa. Since the same ingredients are also added to the ***Arborloo*** pit, it is logical to suppose that young trees will also gain much benefit, in their early life. Many generations of experience in countries from all over the world can vouch for the improvement of tree growth in old toilet pits. Even the Pilgrim Fathers used the idea when they arrived in the New World. The same method is practised in many countries in Africa today. The ***Arborloo*** concept is an extension of a well established and widely used traditional method. The formation of humus by mixing soil, leaves and excreta was invented by Nature itself.

Abundant growth of green vegetables in backyard garden enriched with contents of *Fossa alterna* pit compost.

10. The value of Fossa alterna compost

The unique challenge of the ***Fossa alterna*** is to achieve the conversion of human excreta held in a shallow pit into a relatively safe and valuable compost within 12 months. The ***Fossa alterna*** pits have been designed so they take 12 months or more to fill when used by an average family of about 6 persons. So a balance is struck between the rate of filling and the rate of conversion. The rate of conversion must take place in a shorter time than the rate of filling. If this can be achieved then a true alternate use of the twin pits can take place indefinitely. Most families of about six persons will fill a 1.2 meter deep pit (cross section 1m X 0.7m – total vol. approx 0.84sq.m.) in 12 months or more with a combination of faeces, urine and paper (anal cleansing material) together with soil, wood ash and leaves. Thus in the family unit, it is essential that the conversion of raw excreta into a pleasant humus must take place within a 12 month period. Against this challenge, one must not forget that in a normal deep latrine pit, the conversion of excreta into humus may take several years. In a fully lined pit latrine observed by the writer in Maputaland, South Africa, very offensive material remained 8 years after the pit had been abandoned. However in Malawi, the contents of pit latrines have been excavated 5 years after the pit had been abandoned and used to fertilise trees and crop. In the latter case the excreta was in close contact to the soil in both the side walls as well as the base of the pit, since, unlike the South African example, the pit was unlined. This would have helped the conversion a great deal, even in the absence of extra soils and compostable materials like leaves being added to the pit.

The conversion of excreta into humus in such a relatively short space of time becomes possible simply because extra ingredients are added to the pit contents which promote the formation of humus. Also simplicity is of the essence - hence the use of the drop and store method as in the pit latrine. A complicating factor is that urine is added into the pit and this must either be allowed to drain away or better still combine with the dry soil and leaves added and hence improve the nutrient level of the material formed within the pit. In practice some urine will drain away from the pit, but some will be retained in the forming pit humus. For this reason the volume of soil and ash added to the pit must be about equal to the volume of solid excreta added - a small mug full after every deposit of solids. To improve the texture, speed of conversion, as well as the nutrient level of the final product - it greatly helps to add leaves to the pit from bottom to top. Leaves should be added in plenty to the base of the new pit, during filling and also at the closing off stage.

The ideal combination of pit contents in the ***Fossa alterna*** is faeces, urine, paper, fertile soil, wood ash and leaves. This combination was first used in the prototype built and tested in Woodhall Road, Marlborough, Harare in 1999 (see *Ecological Sanitation in Zimbabwe*. Vol.1). The excreta occupied about half the volume of the experimental pit (the remaining half being soil and leaves) which had a total occupied capacity of about 212 litres (the pit was quite shallow). A pleasant humus-like material was formed within 4 months and excavated by the writer and used in various ways in the garden. Since that time large numbers of ***Fossa alterna*** pits have been excavated and their contents recycled.

Factors which will assist the conversion of excreta into humus within shallow pits include:

Adding plenty of soil and wood ash to the shallow pit after defecation
Adding dried leaves to the pit base before use, during use and at closure
Adding fertile top soil if possible
Trying to ensure good pit drainage
Observing the pit filling rate & spreading out pit contents as the pit fills
Using at the family level (ie not overusing)

The use of the ***Fossa alterna*** demonstrates how effective the soil can be as a converter of human excreta into "humus," using the myriad of naturally occurring beneficial bacteria present in the soil itself. The addition of wood ash to the mixture also assists by acting as an absorbent of moisture, increasing the potash component and also making the reaction slightly more alkaline, which may help the biological process. Wood ashes also reduce odour and helps to control flies. The addition of leaves to the mix helps the composting process considerably by improving amount of air in the mix and adding the fungae and bacteria which help to break down leaves. The addition of leaves, not only improves the physical characteristics of the resulting humus, making it darker and more crumbly but also adds extra plant nutrients. An analysis of leaf mould, formed from composted leaves is also provided in this chapter, and reveals how valuable composted leaves can be a source of plant nutrients. Thus it makes sense to add them to the pit, as well as soil and ash, thereby improving the overall nutrient level and the final crumbly, water retaining properties of the humus. Plants grow best in soils which are fertile, crumbly, hold water and where there is a living, biological content.

Nutrient levels in *Fossa alterna* "humus" - an analysis of soil

After one year of composting in a shallow pit a mix of human excreta, soil, ash and leaves will completely change into a pleasant smelling humus. However this ideal mix may rarely be achieved in practice – at least at first. It is most likely that any poor surrounding soil will be added rather than a mix of soil, ash and leaves. Even in the ***Fossa alterna*** toilets observed and tested by the writer, it was rare indeed that the ideal mix was added, the norm being soil alone with very few nutrients. Thus the data given below for soil nutrients in ***Fossa alterna*** humus are a result of the combination, not of the ideal mix, but of the mix which has resulted in practice - just soil and excreta. The results reveal however, that even when only poor soil and excreta are added and allowed to compost, the nutrient level in the resulting humus is high, and infinitely higher than either the soil that went into the pit or the surrounding soil.

The figures below show the pH and levels of nitrogen (ppm - after incubation), phosphorus, (ppm) and also potassium, calcium and magnesium (ME/100gms.) in twelve samples of the ***Fossa alterna*** taken from the Friend Foundation (10 samples), Epworth (one sample) and Woodhall Road (one sample), all in the Harare area. Later these figures are compared to various naturally occurring soils in Zimbabwe (in the Harare area) and also to samples of humus excavated from jars used to process faeces derived from the urine diverting ***Skyloo*** (see later chapter).

The soil analyses were performed at the Chemistry and Soil Research Institute of the Ministry of Agriculture, Harare. The nitrogen is analysed by the Kjeldahl method for Min N. ppm (initial) and Min N ppm (after incubation). Min N ppm (initial) refers to nitrogen immediately available to plants such as nitrate (N03) and ammonium (NH4). The soil is then incubated for 2 weeks, turning the organic nitrogen in the soil (living and non living) to inorganic nitrogen. This is tested again. The pre-incubation nitrogen is available to plants immediately and the nitrogen, after incubation, is available to plants throughout the growing season. It is the latter which is used to base recommendations for fertilisation and this has been used in presenting the data here. Phosphorus is analysed with the resin extraction method in which the soil is shaken with an Anion Exchange Resin that progressively absorbs the P as it comes into solution. Results, in ppm show available P not total P. The exchangeable bases (Ca, Mg, K) are extracted with ammonium acetate in a reaction where the NH4 ions replace these bases on the exchange sites of the soil. The concentrations are derived from analysis by the atomic spectrophotometer (Farai Mapanda pers.comm).

Examples of *Fossa alterna* soils

Most of the ***Fossa alterna*** soil samples analysed for major plant nutrients are a mix of human excreta and soil only (samples 1 – 10). In these early experiments the ideal mix of soil wood ash and leaves was never attained. Also poor soils were added rather than richer more crumbly soils. Thus the humus formed was of a very basic type of a lower quality, in the absence of ash or leaves.

The final quality of the eco-humus is much related to the type of soil added to the pit contents, and also whether leaves are added. Sandy soils will produce an "eco-soil" which has a sandy texture, grey soils turn into darker grey soils. Clay soils will result in a soil which is more clay like. Crumbly soils with good texture make the best eco-humus. The best eco-soils are made by adding a fertile top soil in combination wood ash and leaves. The leaves convert into leaf compost - and this is an excellent material for improving soil texture and also nutrient levels in the final product. What ever the soil added, the final resulting soil will be considerably improved in terms of nutrient levels.

Ideally fertile topsoil should be added to the pit, as this will have a higher content of both living organisms and nutrients, and lead to a more fertile humus being formed within the pit, compared to adding poor soil. However it is not always possible to find good topsoil near an eco-latrine, and the obvious procedure for the householder would be to add soil that is found nearby. This would normally be local topsoil with a low nutrient level. In the cases analysed below locally available topsoil was added to all the pits under study and never fertile topsoil. No leaves or ash were added to the Friend Foundation samples. Leaves and ash were added to the Epworth sample, as well as local topsoil. The Woodhall Road sample, which produced the darkest and most crumbly humus was a mix of excreta (urine and faeces), local topsoil and leaves (dried guava and avocado) only, without ash. It also converted into humus in the fastest time, no doubt due to the high air contents resulting from the addition of leaves throughout the depth of the pit. Leaves are valuable additions to the composting pits, like soil, and are best added prior to use, during use and in the final covering of the pit contents following closure.

NUTRIENT LEVELS IN *FOSSA ALTERNA* HUMUS

Soil source	pH	N	P	K	Ca	Mg

Sample 1. (Friend Foundation)	**6.5**	**269**	**317**	**1.59**	**20.77**	**11.28**
Sample 2. (Friend Foundation)	**6.1**	**246**	**330**	**4.64**	**5.53**	**5.41**
Sample 3. (Friend Foundation)	**6.6**	**174**	**374**	**3.74**	**8.59**	**5.74**
Sample 4. (Friend Foundation)	**6.2**	**222**	**422**	**2.22**	**3.60**	**3.57**
Sample 5. (Friend Foundation)	**6.5**	**319**	**196**	**3.26**	**13.70**	**7.26**
Sample 6. (Friend Foundation)	**7.7**	**316**	**242**	**3.84**	**9.96**	**3.42**
Sample 7. (Friend Foundation)	**7.6**	**355**	**258**	**7.14**	**8.97**	**6.26**
Sample 8. (Friend Foundation)	**6.9**	**305**	**230**	**6.65**	**12.00**	**10.32**
Sample 9. (Friend Foundation)	**7.7**	**354**	**257**	**9.18**	**9.26**	**3.46**
Sample 10 (Friend Foundation)	**6.3**	**197**	**299**	**2.94**	**26.64**	**4.77**
Sample 11 (Epworth)	**7.1**	**240**	**194**	**2.80**	**5.22**	**3.65**
Sample 12 (Woodhall Road)	**7.8**	**285**	**228**	**2.80**	**9.24**	**2.33**
Mean value (*Fossa alterna*)	**6.86**	**273**	**278**	**4.22**	**11.11**	**5.61**

Enhancement of deposited soil

The quality of the humus derived from ***Fossa alterna*** pits varies depending on what extra ingredients are added to the pit in addition to excreta (urine and faeces). The texture, nutrient levels and water holding capacity, for instance, are improved if fertile topsoil and leaves are added in addition to the excreta. The texture of the excavated humus is similar to the soil added to the pit. However even when poor soil is added alone, significant improvements can be achieved in nutrient levels as the results below show. In the cases cited below soil analyses were made on the soil added to the pit as well as the soil (humus removed).

Example 1.

	pH	N	P	K	Ca	Mg
Soil added to FA pit (cemetery topsoil)	**4.9**	**50**	**13**	**0.18**	**2.95**	**0.78**
Humus removed from *Fossa alterna*						
Sample 4	**6.2**	**222**	**422**	**2.22**	**3.60**	**3.57**
Sample 6.	**7.7**	**316**	**242**	**3.84**	**9.96**	**3.42**

Examples 2, 3 and 4

	pH	N	P	K	Ca	Mg
Soil added to FA pit (kennels site. pit soil)	**5.5**	**27**	**5**	**0.29**	**10.23**	**4.11**
Humus removed from *Fossa alterna*						
Sample 7.	**7.6**	**355**	**258**	**7.14**	**8.97**	**6.26**
Sample 8.	**6.9**	**305**	**230**	**6.65**	**12.00**	**10.32**
Sample 9.	**7.7**	**354**	**257**	**9.18**	**9.26**	**3.46**

Example 5 (Epworth sample 10)

	pH	N	P	K	Ca	Mg
Soil added to FA pit (Epworth topsoil)	**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**

Note local dried leaves and some wood ash were also added to the pit)

	pH	N	P	K	Ca	Mg
Humus removed from *Fossa alterna*						
Sample 11 (Epworth)	**7.1**	**240**	**194**	**2.80**	**5.22**	**3.65**

Example 6 (Woodhall Road sample 12)

	pH	N	P	K	Ca	Mg
Soil added to FA pit (Woodhall Rd soil).	**6.2**	**27**	**32**	**0.63**	**9.68**	**2.30**

Note dried guava and avocado leaves were also added to the pit)

	pH	N	P	K	Ca	Mg
Humus removed from *Fossa alterna*						
Sample 12 (Woodhall Road)	**7.8**	**285**	**228**	**2.80**	**9.24**	**2.33**

Urine inclusion and urine diverting

In one experiment a urine diverting slab was placed over the pit. The resulting soil formed was compared to soil formed in a pit where both urine and faeces were added.

	pH	N	P	K	Ca	Mg
Soil added to *Fossa alterna* pit	**5.5**	**27**	**5**	**0.29**	**10.23**	**4.11**
Humus removed from *Fossa alterna*						
Sample 1. (Urine inclusion)	**7.6**	**355**	**258**	**7.14**	**8.97**	**6.26**
Sample 2. (Urine diverting)	**6.9**	**305**	**230**	**6.65**	**12.00**	**10.32**

Note that levels of nitrogen, phosphorus and potassium are slightly elevated in the eco-humus in which urine and faeces are added compared to those in which urine is diverted elsewhere. However the difference was slight.

We can now compare the nutrient levels found in *Fossa alterna* humus and mixed soils with a series of samples taken of naturally occurring top soils taken in the Harare area.

Examples of naturally occurring top soils

Soil source		pH	N	P	K	Ca	Mg
Harare (Tynwald 1.)		**6.1**	**32**	**68**	**1.59**	**6.42**	**4.02**
Harare (Tynwald 2.)		**5.5**	**27**	**5**	**0.29**	**10.23**	**4.11**
Harare (Marlborough Vlei)		**5.1**	**72**	**30**	**0.99**	**22.88**	**18.06**
Harare (Epworth 1**)**		**4.0**	**18**	**9**	**0.08**	**1.46**	**0.32**
Harare (Woodhall Road**)**		**6.2**	**27**	**32**	**0.63**	**9.68**	**2.30**
Ruwa (Knuth Farm 1. veld**)**		**7.5**	**30**	**30**	**0.12**	**3.79**	**0.56**
Ruwa (Knuth farm 2. pit soil)	**5.1**	**14**	**23**	**0.01**	**1.12**	**0.48**	
Ruwa (Knuth farm 3 - garden soil)		**6.7**	**96**	**143**	**0.73**	**15.23**	**1.96**
Harare (Epworth 2)		**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**
Mean value (local soils)		**5.5**	**38**	**44**	**0.49**	**8.05**	**3.58**

According to the Chemistry and Soil Research Institute, many naturally occurring top soils found in Zimbabwe reveal very low levels of nutrients available for plants. This is due to weathering, lack of tree cover, and the effects of rain on badly eroded soils. A nitrogen level in soil of less than 20ppm is regarded as low, 20 – 30 as medium, 30 -40 adequate and 40 plus is regarded as "rich". So the soils produced from the ***Fossa alterna*** are rich indeed, with those in our range of naturally occurring soils being in the adequate range.

For phosphorus, less than 7 ppm is regarded as low, 7 – 15 marginal, 15 – 30 medium, 30 – 50 adequate and 50 plus "rich." Thus once again the natural soils tested were in the adequate range. Once again the ***Fossa alterna*** humus is rich in P, which is a valuable component. It can be mixed with local top soils to get an enhanced production of vegetables, which is what this story is all about. Critical ranges for Ca are 15 – 20ppm, and 0.3 – 0.4 meq/100g for Mg and 10 – 15ppm for K.

The top soils of many parts of Southern Africa are worn out and almost devoid of humus or nutrients. In Zimbabwe 70% of rural farmers work on a soil which is labelled as poor or very poor, holding less than 42ppm of phosphorus. Nitrogen, phosphorus and zinc, amongst other minerals were seen as limiting to meaningful agriculture in 70% of samples collected around Zimbabwe. Most soils are sandy and have a low pH. Few soils in the rural and even peri-urban and urban areas can sustain any form of healthy crop production without meaningful inputs of both humus and nutrients (Farai Mapanda (pers.comm). Thus any form of fertile soil which can be locally produced and mixed with the poor local topsoil can only be seen as advantageous.

Basic comparisons

Mean value (local soils)	**5.5**	**38**	**44**	**0.49**	**8.05**	**3.58**
Mean value (*Fossa alterna*)	**6.86**	**273**	**278**	**4.22**	**11.11**	**5.61**

Mixes of *Fossa alterna* humus and other soils

Enhancement of nutrients by combining with poor soils

Fossa alterna humus, resulting from a mix of faeces, urine, paper and soil (and preferably leaves) can be mixed with less fertile soils to make a planting medium in which vegetables grow well without additional "fertilisers" being required (see later).

The following figures show how the ***Fossa humus*** can elevate the nutrient levels of very poor soil when a 50/50 mix is made between barren soil and eco-humus.

Example 1.

Soil source	pH	N	P	K	Ca	Mg
1. Knuth soil	**6.1**	**32**	**68**	**1.59**	**6.42**	**4.02**
2. *Fossa alterna* (orchard site)	**6.6**	**174**	**374**	**3.74**	**8.59**	**5.74**
Result of 50/50 mix mix .	**6.2**	**91**	**337**	**1.45**	**4.58**	**2.29**

Example 2.

1. Knuth soil	**5.5**	**27**	**5**	**0.29**	**10.23**	**4.11**
2. *Fossa alterna* (1a site)	**6.5**	**319**	**196**	**3.26**	**13.70**	**7.26**
Result of mix .	**6.4**	**91**	**247**	**0.88**	**3.05**	**2.49**

Example 3. (33/33/33 mix)

1. Woodhall Rd soil	**6.2**	**27**	**32**	**0.63**	**9.68**	**2.30**
2. *Fossa alterna* soil (FA1a site)	**6.5**	**319**	**196**	**3.26**	**13.70**	**7.26**
3. Leaf mould	**7.4**	**540**	**266**	**9.00**	**291**	**12.90**
Result of mix	**6.8**	**331**	**294**	**2.10**	**12.14**	**5.85**

Example 4. (50/50)

1. Epworth soil	**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**	
2. Fossa alterna (FA long site)		**6.3**	**197**	**299**	**2.94**	**26.64**	**4.77**
Result of mix		**6.4**	**78**	**356**	**1.01**	**15.75**	**1.78**

These figures reveal now the nutrient levels in poor soils can be enhanced considerably by mixing them with equal volumes of ***Fossa alterna*** soil, as would be expected, although the unusually high levels of phosphorus in the mixes of examples 2, 3 and 4, which exceed both poor topsoil and ***Fossa alterna*** soil, cannot be explained but appear to be consistent.
These figures show clearly how human excreta when mixed with topsoil can produce a “new soil” with significantly more nutrients than most naturally occurring top soils. Enough nutrients in fact to mix in equal proportions with existing topsoil or even at a rate of 2 parts local soil with none part ***Fossa*** humus to make viable vegetable production possible without further fertilisation (see later chapters). The results also show a good mix of nutrients with meaningful quantities of phosphorus and potassium as well as nitrogen. Thus the nutrients available in the humus are balanced more as they would be in commercially available compound vegetable fertilisers. However, the actual nutrient level in soil is not the only factor which helps plants grow well – and the physical condition of the soil, and its living content are also very important. The ***Fossa*** humus appears to provide both a physical improvement by providing humus together with a significant increase in all major nutrient as well.

What all these results show clearly is the significant level of nutrients held in human excreta. It is sufficient to change a worthless soil into one on which vegetables can be grown, if needs be, without further application of nutrients. Later chapters in this book describe how the eco-humus is best used in agriculture and also how urine can be used to enhance the effect even further particularly for leafy vegetables.

What these experiments also reveal is the very considerable value of nutrients which are daily taken to waste, both in standard sewered sanitation and also pit sanitation. In Zimbabwe alone, half a million Blair VIP Latrines accumulate approximately 250 000 cubic metres of human waste per year which remains unused. Had the use of eco-latrines of the type described in this book been introduced and adopted years ago, backyard vegetable gardens would surely have been more fertile.

The value of leaves as an additive of *Fossa alterna* pits.

Constant reference is made to the considerable benefit which can be derived by adding leaves to ***Fossa alterna*** pits. Leaves help the composting process considerably, by adding more air into the mix, and by adding a composting process undertaken largely by fungi to the already existing bacteriological process undertaken by soil micro-organisms.

During the first year of operation, the second pit of the ***Fossa alterna***, which must be built at the same time as the first pit, can be left empty and covered with a wooden lid. This will be the standard procedure. However it is possible to take advantage of the second pit during the first year of operation. One of the best methods is to make leaf compost within this pit for the first year of operation.

At one site in Epworth close to Harare, leaves were gathered and emptied into the pit interspersed with thin layers of the local topsoil. Water was added from time to time. After 12 months the leaf compost was excavated and proved to be much richer in nutrients than the original soil. In fact plants grew in this leaf mould far better than in the original soil. The second pit acted like a pit composter and was well worth the simple effort involved of adding leaves, soil and water. The following table shows the increase of nutrient levels in the leaf compost made in the second pit compared to the local topsoil. The figures below show the pH and levels of nitrogen (after incubation), phosphorus, (ppm) and also potassium, calcium and magnesium (ME/100gms.) in the leaf compost formed in the second pit of a ***Fossa alterna*** compared to the surrounding topsoil which was added together with local leaves.

Soil source	pH	N	P	K	Ca	Mg
Local topsoil (Epworth)	**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**
Leaf compost from second pit	**7.7**	**81**	**130**	**1.86**	**9.31**	**1.88**

Composted leaves clearly have a considerable nutrient value of their own and no doubt greatly enhance the final quality of ***Fossa*** humus, if added. The results of four soil analyses of leaf mould formed in wire baskets and a variety of containers is given below. A description of these leaf mould makers is given later in this book.

Analysis of leaf compost

Soil source	pH	N	P	K
Leaf compost in wire basket	**8.2**	**256**	**344**	**3.92**
Leaf compost formed in plastic bag	**7.8**	**267**	**294**	**8.50**

Leaf compost formed in steel drum	**7.6**	**239**	**255**	**0.60**
Leaf compost formed in brick moulder	**7.4**	**540**	**266**	**9.00**

Overall comparisons of soils and composts

Soil source	pH	N	P	K
Mean value (local top soils)	**5.5**	**38**	**44**	**0.49**
Mean value leaf mould	**7.75**	**325**	**290**	**8.00**
Mean value (*Fossa alterna*)	**6.86**	**273**	**278**	**4.22**

Physical properties of excreta, soil, leaf mixes.

One interesting property of excreta or mixes of excreta and soil, both in jars and pits is that the volume is considerably reduced over time. Even with abandoned full latrine pits the volume may decrease considerably over time. In urine diverting toilets the urine is channelled away and the faeces dehydrate or compost and loose their initial volume due to loss of moisture. In shallow pits the combination of urine and faeces also loose volume over time with the urine being absorbed into the soil added to the pit and also into the soil surrounding the pit. The bulk and volume of the faeces is also reduced over time with the liquid fraction of the faeces being absorbed into the soil added to the pit. It is known that the water content of the faeces is variable but always high. It is this larger water fraction of the faeces which can be absorbed into other ingredients added to the pit (soil, ash, leaves),whilst the remaining smaller solid fraction of the faeces is converted into humus, which forms part of the final total volume of the humus formed in the pit or jar.

But what are the fractions?

The following experiment was carried out to calculate the percentage water content of faeces by combining a known weight and volume of faeces with a known weight and volume of dry soil. Since the dry soil would loose neither weight of volume, any change in the final volume and weight of the mix would be caused by changes in the properties of the faeces.

A sample of faeces was collected in the ***Skyloo***. This sample weighed 357gms, had a volume of 340mls and a density 1.05 gm/ml. This was mixed with a near equal volume of dry soil with a weight of 352gms, a volume of 310mls and a density of 1.135 gm/ml. Therefore the total weight of the mix was 709gms having a volume of 650mls and an overall density of 1.084 gm/ml.

On the left, raw faeces and soil being mixed prior to composting. On the right a mix of leaves, soil and raw faeces prior to mixing and composting

This was allowed to slowly compost over a period of 24 days. Fly larvae developed in the mix, which also attacked by ants. Slowly the mix changed into soil. Another mix was made with an approximately equal mix of faeces, dry soil and crushed dry leaves. This mix was also allowed to compost for the same period. After the period of composting both samples were laid out in the sun to substantially dry out, but not to full desiccation status. The final weight of the dried soil/faeces mix was 420gms, with a volume of 405mls and a density of 1.037gm/ml.

Thus the weight of the "new soil" formed had increased from 352 to 420g (about 19%), compared to the original soil in the mix and the volume of the "new soil" had increased from 310mls to 405mls (about 30%) compared to the original soil in the mix. Since the volume and weight of the dried original soil cannot change, the faeces weight had therefore been reduced from 357g to 68g (420 - 352g) - 19% of original. So water content was 81%. The faeces volume had therefore been reduced from 340mls to 95ml (405 - 310ml) - 28% of original). So the final density of the mix was less than the original soil. The mix was also darker in colour. The overall initial combined wt of the combo was reduced from 709g to 420g) (59.23% of original). The overall initial volume of the combination was reduced from 650 ml to 405ml. (62.3% of original). The processed combination of "NEW SOIL" was very similar in appearance to original soil since 76.5% of its new volume and 83.8 % of its new weight consists of the original soil.

Samples of original soil (left), and "new soil" made from faeces and soil (centre) and from faeces, soil and leaves (right)

In the case of the faeces/soil/leaf mix a final weight of 270gms was measured with a volume of 405mls. This gives a density of the combination of 0.66gms/ml. This is a much lower density compared to the faece/ soil mix. **Clearly the addition of leaves lowers the density**, a result no doubt of the less compaction and more air in the mix due to the presence of leaves. These properties would encourage far more efficient composting. **Composting is far more effective as the air content increases.** This is a very important finding.

Density trials on *Fossa alterna* humus

The results shown above would explain why a mix of excreta, soil and leaves appears to compost much faster than a mix of soil and excreta only. To test this theory the humus taken from a ***Fossa alterna*** which had a mix of excreta, soil and leaves was compared to the humus taken from another ***Fossa alterna*** which had a mix of excreta and soil only. The initial comparisons (for volume, weight and density) were made in crumbly (not dried) ***Fossa alterna*** humus. These samples were then dried out in the sun to obtain new parameters.

***Fossa alterna* soil (crumbly, not dried)**

Soil /humus type	**Vol. ml**	**Wt.gm**	**density**
FA kia (excreta,soil,leaves)	410 (jam jar)	370g	0.90g/ml
FA FF (xcreta,soil only)	410	402g	0.98g/ml
Garden soil	400	443g	1/10g/ml

***Fossa alterna* soil (sun dried)**

Soil/humus type	vol. ml	Wt.gm	density
FA kia	325	278	0.85g/ml
Fa FF	370	338	0.91g/ml
Soil	368	392	1.06g/ml

These results reveal that where leaves are added to the ***Fossa alterna*** pit the resulting density of the humus is lower. The density of the humus is related to both the moisture content and the air content. The more air (with some moisture) the better the conditions for composting. Thus a mix of excreta, soil and leaf in the Fossa alterna pit is more effective and leads to a faster and more efficient composting process than the mix of excreta and soil alone. Interestingly it was this mix of excreta, soil and leaves which was tested in the initial ***Fossa alterna*** trial in 1999.

Leaves are an important ingredient in this process because the leaves provide extra nutrients to the mix, they provide extra air and improve soil texture. They add a process of fungal decay in the mix as well as composting based on bacteria. They also provide a larger surface area for the composting process to take place and allow for better pit drainage. All these combined beneficial effects of leaves enhance the composting process considerably.

Consequently the addition of leaves to the shallow pit composting process in both the ***Arborloo*** and ***Fossa alterna*** has been greatly encouraged. Similarly leaves are now added to the buckets holding faeces, ash and soil in the ***Skyloo*** and subsequent jar composters.

Adding leaves to shallow pits

Adding leaves to *Fossa alterna* pits. On left at Woodhall road, on right at Epworth. Adding dried leaves to shallow pits used in the *Arborloo* and *Fossa alterna* helps the composting process considerably.

Adding semi composted palm leaves to the base of a *Fossa alterna* pit in Mombasa, Kenya (left). Two sacks full of leaves at the base of a concrete lined pit in Maputaland, South Africa.

Conclusions

These various results show that the ***Fossa alterna,*** when well managed, offers the family a valuable asset, and well worth the initial investment. It is not only an effective toilet system, controlling both flies and odours, but also offers the family a simple and effective unit for making nutrient rich compost.

The annual production of humus, when mixed with poor local topsoil can enhance back yard vegetable production considerably (see plant trials later). By combining these advantages with its low cost and relative ease of use and management, the ***Fossa alterna*** may hold much potential for future use in many parts of Africa.

It must be remembered however that the annual output of compost from the family owned ***Fossa alterna*** is not large, possibly about 500 litres per family per year. So its value lies in enhancing food production on a small scale on the family vegetable garden and not on extensive fields. However such improved fertility will improve year by year and thus the back yard vegetable crop can be sustained.

Early experiments with the *Fossa alterna* Revealing the miracle of conversion of excreta into compost. Ephraim Chimbunde at work. An early photo of a *Fossa alterna* in Epworth.

11. Methods of using "Fossa alterna" compost in the garden

This chapter deals with methods of utilising humus formed in the ***Fossa alterna.*** This humus is ideally formed as a result of composting of a combination of faeces, urine, good topsoil, wood ash and other vegetable matter like leaves. In practice however, until the best state of the art is reached, the ***Fossa alterna*** "humus" may only be a combination of faeces, urine and soil and the soil component may be poor. This results in a pit soil which has rather a poorer texture compared to a humus formed with good topsoil and/or leaves added. If this so called "humus" is a mixture of excreta and poor soil alone - is may not be really humus like at all. In texture it more closely resembles the soil that was placed in the pit. If sandy soil was added, the "humus" is sandy like. If clay like soil is added, the "humus" tends to be more clay like. Grey soils lead to a darker grey coloured "humus" and red or yellowish soils form into a darker red or yellow coloured "humus." Only when the added soil is crumbly and humus like or when vegetable matter like leaves are added in quantity does the final product really look or feel like crumbly humus. And that is what should be aimed for. However, whatever the soil looks like, the nutrient levels are considerably enhanced, as we have seen in the previous chapter.

The same applies to the humus formed from combining faeces alone with other ingredients, as is the case with humus formation in urine diverting systems like the "***Skyloo***" – see later chapter. If it is just a straight mix of faeces and poor soil, the soil will be greatly improved in terms of nutrient levels, but the texture will be improved to a much lesser extent. But this will depend on what ingredients have been added to the excreta. Thus if poor sandy soil is added to the bucket together with faeces and this combination is transferred together with paper into the jar composter, with more poor sandy soil added, the end result will be a material which is sandy in texture, but which has greatly improved nutrients levels. Its texture will be marginally improved. But a far better humus, both in terms of texture and nutrient levels, will be formed if the faeces are combined with a good topsoil, wood ash and vegetable matter as well - leaves are ideal. So what is formed in the pit or compost jar is much dependent on the ingredients – much like making a cake!

What ever the case, the overall aim of ecological sanitation is to utilise the nutrients available in processed human excreta and put it to the best possible use and thus enhance the production of food, especially vegetables, without the use of any external commercial fertiliser. Thus it pays in the end to add the best possible ingredients to the pit, if they are available. Humus like soil assists root growth and the overall growth of plants as well as improving the water retaining properties of the soil. It should be remembered that the growth of plants is not reliant solely on the presence of nutrients in the soil alone, but also on other factors which include the physical properties of the soil itself. A good soil texture is very important and this means plenty of humus. Plants grow better where the soil is fertile, crumbly and has a high content of living organisms - from bacteria and fungi to the small soil animals like worms and insects. Plants also require regular watering and sunlight. Adding a protective layer over the soil, like a mulch, also helps especially in areas of hot sun to retain water in the soil which would otherwise be lost in evaporation from the soils surface. The products formed from ecological toilets should be introduced into agriculture with these requirements in mind.

Excavating the *Fossa alterna* compost

This compost is best excavated from the ***Fossa alterna*** with a pick and shovel. It is best placed in bags at this stage and stored for later use. The mixing and aeration associated with "bagging" helps further the composting process. Leaves and extra soil can also be added. Alternatively it can be dug directly into beds or mixed with topsoil and then introduced into beds or containers. If there is any doubt about its safety it should be bagged and later combined with topsoil. If the mix in the pit has not been ideal, in other words if too little soil has been added to the pit, the pit soil may be tainted with an odour, and in this case it should be bagged and left for another six months. However if the right mix of ingredients has been added to the pit, the compost will be safe and pleasant to handle and should have a pleasant aroma. The excavated pit soil can also be laid in the sun, allowed to partly dry out, sieved or broken up, and then mixed with topsoil before application to vegetable gardens. The sieving is useful as it removes unwanted items such as plastic, rags and stones which may have fallen into the pit. After one year of composting the original characteristics of the excreta like odour, colour and texture will have changed completely. The compost smells good and is pleasant to handle. If the second pit of the ***Fossa alterna*** has been used for composting, or for making leaf mould, as is recommended in the first year, this material will also be very valuable in the garden. The main use will be for vegetable growing.

Compost being excavated from a *Fossa alterna* pit at the Friend Foundation, Harare (left) and in Niassa Province, Mozambique (right), a project of WaterAid. It is best placed in bags for storage first, and then mixed with topsoil and applied to vegetable gardens or containers. It can also be mixed with topsoil.

Volumes of compost formed

It must be accepted that the total volume of compost formed every year in a family owned eco-latrine, like a ***Fossa alterna***, is relatively small - around 500 - 600 litres. Thus compost derived from these toilet systems is not sufficient to apply generally to the fields to obtain any noticeable widespread effect. However the effect can be pronounced if the compost is applied to the small backyard vegetable garden and various means must be sought to make the most effective use of this precious product.

Vegetables can be planted directly into the ***Fossa alterna*** compost, but this is an uneconomical method of using the material. The richness of the compost allows for mixing with poor unfertile soils. Thus the mixing of ***Fossa compost*** with topsoil is the recommended method. The most practical method is to apply and mix the ***Fossa alterna*** soil with soil already present on a vegetable bed or to prepare a new bed using the ***Fossa alterna*** soil mixed with local topsoil. Importing leave

compost and normal compost obviously will also help a great deal in the formation of a new vegetable bed if it is available.
In fact a poor infertile soil in which plants can hardly grow can be transformed into a valuable planting soil, simply by mixing in ***Fossa*** compost with the local topsoil. The volume may be almost trebled if one part of eco-humus to two parts topsoil or mixed with one part natural soil and one part of leaf mould. Thus a 1.5 cu.m. soil/pit compost mix may result from a year of use of the eco-latrine if a 1:2 mix is used. It is good to mix a variety of composts from different sources into the topsoil to enhance its value as a fertile environment for plants.

Thus the various possible soil combinations are as follows:
1. Neat humus (eco-humus) from ***Fossa alterna.*** **(500 litres)**
2. Mix of eco-humus and natural topsoil (ratio 50/50%). **(1000 litres)**
3. Mix of eco-humus/natural topsoil (ratio 33% and 66%). **(1500 litres)**
4. Mix of eco-humus/natural topsoil and leaf compost (33/33/33%). **(1500 litres)**
5. Mix of eco-humus/natural topsoil, leaf mould and compost. (25/25/25/25%). **(2000 litres)**

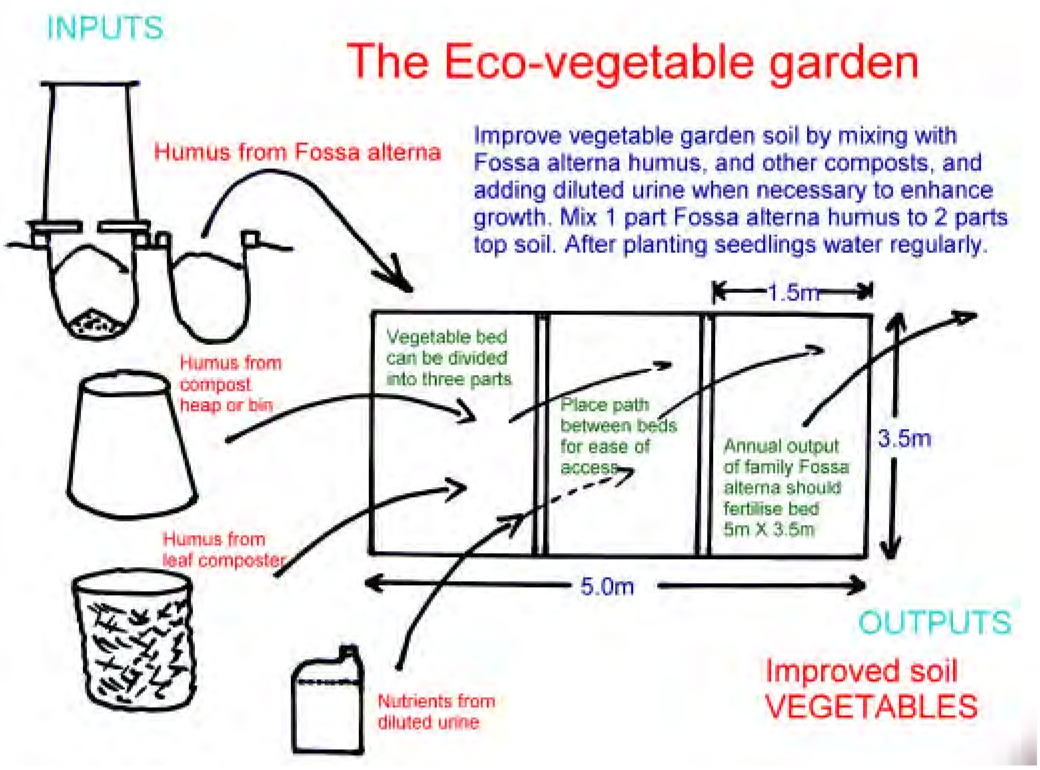
Handling the compost and safety
The compost derived from ***Fossa alterna*** pits should be relatively safe to handle (as discussed in the previous chapter and also the chapter on Health) if processed correctly with adequate amounts of additional materials being added to the pit and 12 month period of composting being allowed. There will be variations in the quality of the compost depending on the ingredients in the pit. The more soil and leaves are added, the more effective will be the composting process, and the better the final product will be. The ratio of excreta to additional materials should be about 50:50. As with all gardening practice, hands should be washed after handling compost and always before eating food. If simple hygiene principles are followed there should be little danger involved with handling compost. Every effort should be made to teach children not to eat soil, But children will be children! Children all over the world have a habit of eating nasty things. If there is any doubt about the compost from a health point of view it is best to transfer it into sacks for further storage for a further period of 6 months. Alternatively transfer to another pit, cover with soil and plant a tree. When this extra composting or transfer takes place it is possible also to add leaves, which helps make the final product darker and more crumbly. Its water retaining properties can then be enhanced.

HAND WASHING IS ESSENTIAL

The various methods of using toilet compost in the garden

We now combine the use of the eco-toilet and the vegetable garden so they can operate with one common aim – to provide more food for the family.

We now describe practical ways of using the toilet compost and other valuable composts and urine to provide more food for the family. To get the most effective production from a small vegetable garden it is wise to take advantage of all these various products if they are available. The small vegetable garden is built to use the materials derived from the toilet with toilet compost being added every year to restore what nutrients the plants have withdrawn. The vegetable garden is linked not only to the toilet, but also to the compost heap, the leaf composting basket and to any source of urine the family can produce. The aim is to bring all these parts of organic gardening together – compost, eco-humus, urine, for the best production of vegetables. Growing vegetables in small containers is also a practical method, especially where space is limited. Buckets or cement basins are ideal.



Application of pit compost.

Pit compost can be mixed with the existing topsoil soil at the rate of 2 parts topsoil to 1 part pit compost. Using the size of one bed illustrated above (3.5m X 1.5m) the toilet compost is applied to each of the three beds by distributing 12 piles, each of 15 litres over the bed with 0.5m between each pile. Thus 12 piles of 15 litres each can be made over each 3.5 X 1.5m bed. That is a total of 12 X 15 litres = 180 litres. This is about 35 litres humus per square metre of bed. The total annual production of humus from a family (0.5-0.6cu.m.) should be sufficient to distribute over 3 such beds totalling about 15sq.m. Once deposited in a measured way from the buckets, the humus is spread out over the surface with a hoe (badza) and then dug in and thoroughly mixed with the local soil to a depth of about 10cm.

1. Preparing and managing an eco-garden linked to the *Fossa alterna*

In this case a special small vegetable garden was prepared near to the toilet to use the yearly supply of ***Fossa alterna*** compost. The photos and captions describe the process.

Preparing the bed of the eco-vegetable garden. In this case an old vegetable bed is being prepared by weeding, digging down and mixing the soil over an area of approximately 15 sq.m. The vegetable garden was divided into three beds, each of about 5 sq.m. each. In the background on the left photo the humus from the *Fossa alterna* is being dug out. On the right two heaps of *Fossa alterna* humus have been excavated. The 360 litres of humus was divided into two piles of 180 litres each. This volume of humus was sufficient to enrich two of the three beds in this vegetable garden.

Three beds were prepared each 1.5m X 3.5m in area (5.25 sq.m.). The eco-humus was mixed with the existing soil in two of the beds and the same amount of local red topsoil was mixed in the central bed (for comparisons). The humus was applied to each bed by distributing 12 piles, each of 15 litres over the bed with 0.5m between each pile. Thus 12 piles were made over each bed (12 X 15 litres = 180 litres). The humus was spread out over the surface with a hoe (badza) and then dug in and mixed with the local soil to a depth of about 10cm.

This was then spread out over the surface as evenly as possible with a rake. This application rate is thus 180 litres humus to 5.25 sq.m. of bed (35 litres per square metre. If we calculate that the depth of the improved soil is 10cm, the total volume of the mix is 100 litres per sq. m. To make up with 100 litres about 35 litres humus has been mixed with 65 litres topsoil. That is a ratio 2 topsoil (65 litres) to 1 humus (35

litres). A ratio of 2:1. After watering, the seedlings are planted. In this case spinach and rape. 50 plants were sown in each of three beds making a total of 150 plants.

An example of the eco-vegetable garden just planted with seedlings with the *Fossa alterna* toilet behind. A family should provide enough excreta, when combined and composted with soil, leaves and wood ash to make 0.5 – 0.6 cu.m. eco-humus per year. This is enough to apply to an eco-garden 3.5m X 5m.

After 4 weeks a good harvest of green vegetables has grown ready for the first cropping. In the bed mixed with extra *Fossa alterna* soil, the spinach harvest was increased by 1.7 times, and rape 1.4 times, despite the existing bed being already quite adequate in terms of soil nutrients. After 6 weeks and two croppings the increase had been reduced slightly to1.6 times (spinach) and 1.3 times (rape). After 8 weeks and three croppings the total weight of spinach cropped on Bed A was 4754 gms, compared to 3027 gms on Bed B. After 8 weeks and three croppings the total weight of rape cropped on Bed A was 3233 gms, compared to 2736 gms on Bed B . Thus overall the application of the humus increased the spinach crop by 1.57 times and the rape crop by 1.18 times. Additional output of green vegetables can be achieved by the regular application of diluted urine. This is described later in this book.

The first crop of spinach and rape being harvested at 4 weeks. The vegetables in this case were prepared for sale in neat bundles. Further crops can be harvested. When the crops are finished, the old plants are removed and the soil dug down and aerated. Additional compost can be added if required. New seedlings are then planted. The vegetable garden is maintained in the same way as any other vegetable garden. Regular weeding and watering is essential to obtain maximum crop output.

2. Digging *Fossa alterna* compost into existing vegetable gardens and planting maize seed in plugs of *Fossa alterna* compost in the maize field.

The most obvious and simplest method is just to dig in the humus into existing vegetable beds, turning and mixing the new humus into the layer of topsoil already present. If this is done carefully the new topsoil may be enhanced over an area of about 10 square metres of bed with0.5 cu.m. humus. With less care the humus may be distributed unevenly. When a very poor soil is mixed with a good soil or eco-humus, the resulting mixture will be patchy unless the mixing has been done well. Some plants may appear to grow well and others not. So thorough mixing is very important.

The *Fossa alterna* of Mr and Mrs Nyirenda of Yazoza Village, Embangweni, Malawi. The soil is hard and there was no need for a pit lining. The humus had recently been dug out of the pit (right).

Mrs Nyirenda applies the humus from the Fossa alterna pit to the soil in her vegetable garden. The material is first applied with a shovel over the surface. It is then spread out and dug in and mixed with the soil with a hoe. Planting begins with the advent of the rains.

Planting maize seed

In poor soil the germination of maize seed may be helped by planting in plugs of richer soil like *Fossa alterna* compost. This technique may give the young plants a better start. Treatment with urine and water greatly assists the further growth of maize as described later in this book.

3. Growing tomatoes in compost derived from the urine diverting toilet.

When the urine diverting toilet is used urine builds up in the urine chamber and compost builds up in the secondary composting unit. This compost is a mix of faeces, soil, ash and leaves. This final compost is rich in nutrients and also contains seeds which have passed through the alimentary canal. If this compost is placed in a container and watered young tomato plants will spontaneously grow. These may germinate in considerable numbers, but if most of the young plants are removed leaving the strongest two, the tomatoes will grow strongly using the nutrients contained in the bucket.

Compost from the urine diverting toilet is placed in a bucket and watered. Tomato seedlings grow spontaneously. All weaker plants are removed leaving the strongest one or two. These grow on the nutrients available in the bucket. Extra nutrients like dilute urine can be applied if necessary.

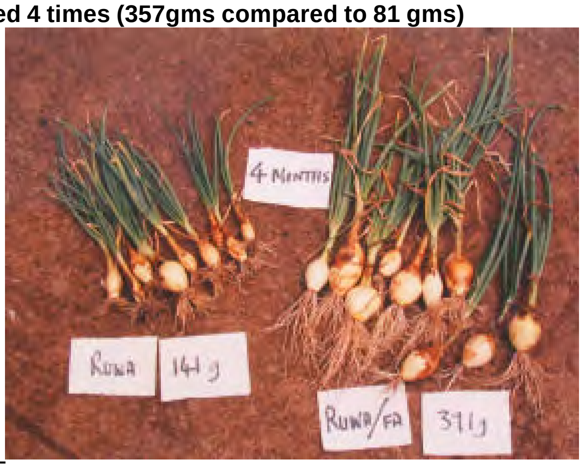
Growing tomatoes from compost derived from urine diverting toilets is a very good method of demonstrating the "closing the loop" concept. The nutrients and seeds coming out of the system are put back into the system and recycled.

4. Effect of enhancing poor topsoil with pit compost in containers

Most soils in this part of Africa are very deficient in nutrients and unless fertilised in some way, produce very poor yields. The fertility of poor soils can be increased significantly by adding compost and also cow manure, and these methods are often practiced and should be encouraged more. However, cow manure may not always be available, especially where people live in the peri-urban fringes. On this page you can see the effect of enhancing very poor soil (taken from Epworth) with pit compost (taken from ***Fossa alterna)***. In each case shown, the very poor topsoil was mixed with an equal volume of pit compost (5 litres + 5 litres). The increase in growth is very significant. Poor soils, such as those used in the trial are very common in Africa. By combining poor soil and eco-humus, vegetable production can be enhanced significantly. Output of onion and leafy vegetables can be increased further by applying diluted urine in addition to eco-humus.

Left Photo: The photo shows spinach grown on poor soil (from Epworth) in left bucket compared to spinach grown on the same poor soil mixed with an equal volume of *Fossa alterna* soil (right bucket) after 30 days of growth. The harvest was increased 7 times (546 gms compared to 72 gms).

Right Photo: The photo shows covo grown on poor soil (from Epworth) in the left bucket compared to covo grown on the same poor soil mixed with an equal volume of *Fossa alterna* soil (right bucket) after 30 days of growth. The harvest was increased 4 times (357gms compared to 81 gms)



Left Photo: The photo shows lettuce grown on poor soil (from Epworth) in left bucket compared to lettuce grown on the same poor soil mixed with an equal volume of *Fossa alterna* soil (right bucket) after 30 days of growth. The harvest was increased 7 times (912 gms compared to 122 gms).

Right Photo: The photo shows onion grown on poor soil (from Epworth) in the left bucket compared to onion grown on the same poor soil mixed with an equal volume of *Fossa alterna* soil (right bucket) after 4 months of growth. The harvest was increased nearly 3 times (391gms compared to 141gms). Whilst this a significant increase in onion production, the best crops are produced on very rich organic soil. Onions are hungry feeders. See next chapter on use of urine.

5. Further methods of growing vegetables in containers

Other methods of utilising the relatively small quantities of humus available annually from eco-latrines include growing vegetables in containers like plastic buckets, old car tyres, basins and jars and even plastic bags. Here smaller quantities of humus can be more efficiently mixed and used in a small garden or small vegetable plot where the soil is poor. Such containers can be filled with a mix of eco-humus and topsoil or with eco-humus, topsoil and leaf litter or compost. In the small back yard, this may be an ideal method of producing vegetables. The method of using car tyres and buckets has also been used in Mexico and elsewhere (Paco Arroyo, pers. comm).

Growing vegetables in plastic bags

Plastic bags are perhaps the cheapest method of containing the soil in which vegetables can grow. The life of the bag will generally be a single season, especially if the bags are exposed to the sun. Small holes are punched into the lower side of the bag for drainage.

Growing tomatoes in bags

Growing vegetables in plastic buckets

Plastic buckets are ideal for growing many vegetables and a variety of crops including tomato, onion, rape, spinach and even maize can successfully be grown in them. 10 litre, 15 litre and 20 litre plastic buckets can be used to grow vegetables. A series of about 5 X 8mm diameter holes are drilled in the base for drainage. Plastic buckets have the advantage that they are light and have handles and are portable, so can be taken into and out of the sun where necessary. They can be placed in any suitable parts of the garden or yard. Once the plants have been reaped the soil in the buckets can easily be tipped out and reconstituted with other compost or soils and placed back in the bucket for a new planting. Any roots that have congested the bucket can be removed by sieving. Also because of their shape they tend to conserve water quite well. Plastic buckets, when looked after can have several years of life. The same combinations of eco-humus and soil and leaf mould can be used in the buckets as has been described above. Applying mulch also helps.

Ten litre buckets can be used to grow a range of vegetables. They are light and durable. Here rape are being grown in the left and green pepper on the right. A series of drainage holes are drilled in the base.

Growing vegetables in concrete containers

The most economical method of making containers that will last year after year and be recharged many times is to use off-the-shelf plastic buckets or basins as a mould and caste replicates in concrete. The concrete containers are heavier than the plastic bucket or basin, and thus more cumbersome to move, but in the long term they are very durable. However they are not resistant to being dropped. Split cement jars can be made of 30 or 80 litre capacity and a good concrete basin of 10 litres capacity. The best shape for growing shallow rooted vegetables (onion, lettuce, rape, covo, spinach etc) is broader and not so deep, so the concrete basin of 10 litres capacity (38cm in diameter and 14cm deep) is possibly best and most economical. Deeper rooted vegetables like maize will prefer 10 - 20 litre buckets as soil containers, although, they too will grow in cement basins (see later). Up to 50 ten litre concrete basins can be moulded from a single 50 kg bag of cement and river sand. Each basin will contain up to 3 - 5 rape, covo, lettuce or spinach plants, two tomatoes or up to 10+ onion plants.

It means that by making 50 concrete basins from a single bag of cement there is the potential to grow about 250 - 500 onions, or 150 - 250 rape, covo or spinach plants. Even maize and tomato plants can be grown in these containers (see later). Thus this is quite an effective way of growing vegetables if space is limited. With a good soil up to 2 kg spinach, 1 kg rape, 0.5 kg green pepper and 1.4 kg of onion, can be grown in a 10 litre container. However the amount of the crop depends on the soil fertility, the amount of watering and sunlight and the amount of liquid feed added - there is much variation.

The basins when filled with soil have a larger surface area exposed to the atmosphere compared to the standard 10 litre plastic bucket. This means that a few more vegetables can be planted in the increased area. But the evaporative surface is increased. The basins will therefore require more frequent watering and a good mulch of leaves helps to retain water, reduces weeds and reduces sun damage on the soil surface. It is therefore wise to include more humus in the soil mix to improve the water retaining properties of the soil mix and also to add a mulch of leaves on the surface. The method of making these containers is described in the chapter on special construction techniques.

Since the volume of the soil, both in shallow vegetable gardens and containers, is not great, there is a tendency for the water contained in the soil to be reduced more readily by evaporation or transpiration. Thus more frequent watering is required. As plants become larger and their leaf area increases, they will transpire a lot of water, which will need replacing in the soil. Thus larger plants growing on containers will need frequent watering in hot dry weather. This can be partly compensated by the inclusion of humus in the soil mix and by mulching, but large leafy plants do use much water in transpiration which must be replaced in the soil to avoid wilting.

Fine crop of covo growing in 10 litre cement basins. With care 50 of these basins can be made from one 50 kg bag of cement and river sand. The covo are grown from seed. The soil mix in this case is half leaf mould and half composted kitchen and animal manure. The plants are also fed a liquid feed of water and urine mixed at a 3:1 ratio, 0.5 litres per basin, twice a week. The plants are watered at all other times with either borehole water or grey water from the house. Grey water derived from shower and basin.

2 kg spinach can be grown in a single 10 litre cement basin and up to 12 onions weighing 1.4 kg.

Also limited amounts of soil contain only finite quantities of nutrient. There will come a time when the nutrients available in the container or bucket will be used up (unless this is replaced by liquid feeds) and this will have an effect on plant growth and yield. However as we shall see in the next chapter, ***Fossa alterna*** soil mixed with poor soil in a container can produce an excellent crop of vegetables during the growing season and far more than the poor soil alone. But the nutrients available cannot last for ever. Normally a charge of humus and topsoil will provide enough nutrients for a single crop and then soil enhancement will be required again, either by remixing with further humus or by nutrient enhancement with liquid feeds or compost etc.

Also where poor natural soils are mixed with eco-humus there will normally be fewer weeds developing in the bed, which means that more of the nutrients released from the soil combination will go into vegetable growth. Where garden compost is used to grow vegetables it is normally linked to the rapid growth of weeds which must be removed if the nutrients in the soil are to be fully utilised by the food product. Mulch can help to reduce weeds and therefore increase the proportion of nutrients taken by the productive vegetables compared to the unproductive weeds.

Where eco-humus is mixed with very poor soil, particularly sandy soil the value of the eco-humus comes under the maximum test, as shown in the trials described in the next chapter. The resulting combination will have much reduced nutrient levels compared to the levels found in the eco-humus itself. If the eco-humus itself is derived from a combination of excreta and poor soil alone, the nutrient levels may only reach marginal levels for some vegetables. Mineral deficiencies can be detected in certain plants like rape. A purple colouration of the leaves may result when the phosphorus levels are low and a yellowing of the leaf fringes denotes reduced levels of magnesium. Pale green leaves denote low levels of nitrogen.

Additional requirement for nutrients

The final output of crops grown on a mix of ***Fossa alterna*** humus and topsoil can be enhanced further by applying an organic liquid plant food or a mix of urine and water to the soil. Most soils used in gardening are enhanced by the addition of additional nutrients in the form of manure, compost, organic liquid plant foods or inorganic fertilisers. In fact it would be normal practice to add liquid feed or manure or compost to a vegetable garden to produce optimal growth of vegetables. The nutrients used up by the plants in their growth must be restored to the soil. Inorganic fertilisers are widely used in agriculture, but these will be little used in the organic farming concepts promoted by eco-san, although a careful mix of inorganic and organic methods is acceptable. Thus if the mix of eco-humus and local topsoil shows signs of becoming depleted, as indicated by signs on the plants, like paling leaf colour, then it is perfectly acceptable, and even desirable to add a liquid feed - and the liquid feed most suitable in eco-san is urine diluted with water. Young plants need plenty of phosphorus to help establish their root system and to establish early shoot development. This is where the well balanced distribution of nutrients in ***Fossa alterna*** humus helps a great deal. With its high content of nitrogen and much lower content of phosphorus, the urine/water mix is best applied when the plants are established to gain extra crop yield. Too much nitrogen at an early stage, as applied with urine, may not help the early formation of the plant. Urine application must come later.

A variety of vegetables growing in buckets - from the front: covo, then lettuce and spinach further back. The two rows on the left hand side are growing in poor local top soils and on the right hand side are growing in a 50/50 mix of poor local top soils and *Fossa alterna* compost. A significant increase in growth can be seen in those vegetables where the poor top soil (taken from Epworth and Ruwa) is enhanced with *Fossa alterna* compost.

6. Growing trees in toilet compost

When an *Arborloo* is used the tree is planted directly in the toilet pit. But it is also possible to plant trees in toilet compost which has been excavated from a compost toilet pit and transferred to a hole dug specifically for a tree. The following photos were taken when pit compost was excavated from a *Fossa alterna* pit after only 6 months of processing, when it was not fully composted (12 months is recommended). The material was sufficiently composted however to be easily transferred from the toilet pit to the tree pit.


A tree pit is dug 60cmX60cmX60cm deep. Toilet compost is dug out.


The tree pit is filled with the toilet compost to ground level. A circle of bricks is laid around the tree pit and filled again with good topsoil.


A hole is dug in the middle of the bed and topsoil added to the base of the hole. A young tree is planted in the hole (Mulberry), and the soil levelled. Leaf mulch is then added and the tree watered. The final picture in the series shows the mulberry tree 4 months after planting. Vigorous new growth of leaves and even fruit can be seen, the signs of a healthy young plant. All work undertaken by writer!

7. Using pit compost in the flower bed

Pit compost can also be used to enhance all soils including those used for ornamental purposes in flower beds. This may be the preferred methods if there is some resistance at first to applying the humus on to vegetable beds. The same technique is used as on the vegetable beds. Humus from the toilet, once well composted can be applied with a bucket to the soil, at the rate of about 35 litres humus per square metre soil. Humus can be held in sacks before application, and this tends to improve the quality and safety of the product, since it involves aeration, turning and greater storage. The new humus is spread out and then mixed in with the existing topsoil, making a new soil which is more organic and fertile. Seedling flowers can then be sown and the resulting colour will be a great pleasure for the householder. Once established, urine can also be applied to the beds by mixing with water (10:1) and apply weekly in a watering can. Nutrients derived from human excreta can assist in the growth of all plants – and that includes flowers and other decorative ornamentals.

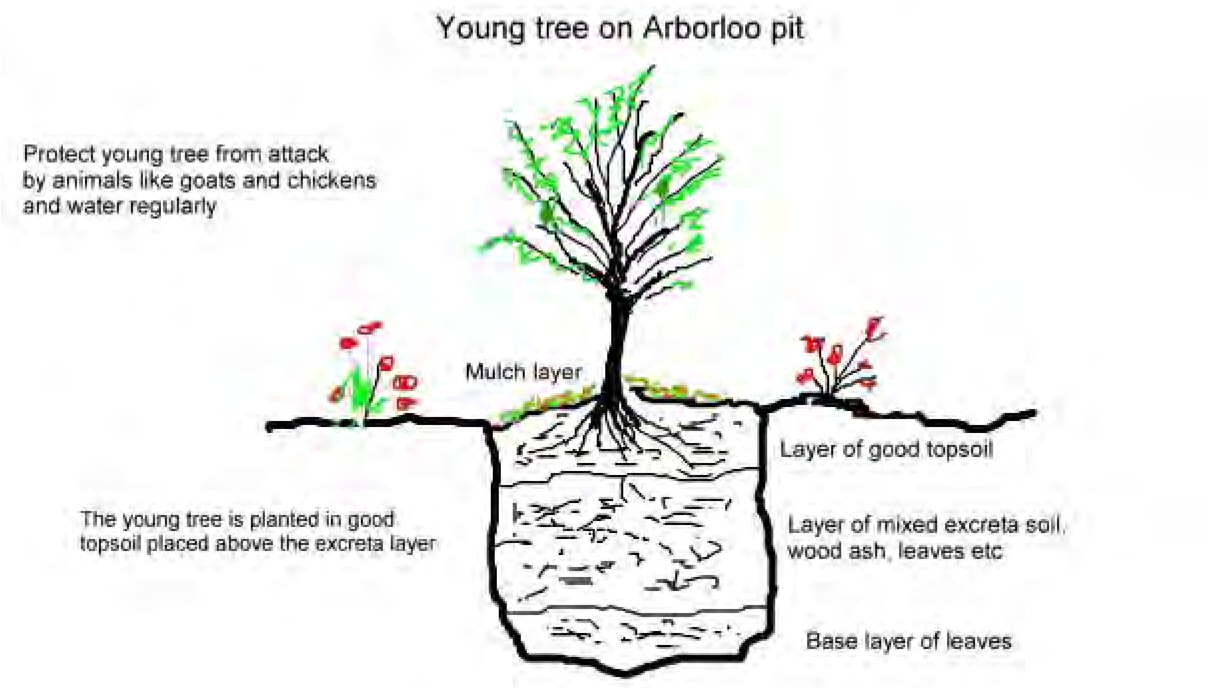

The *Fossa alterna* humus is carried to the bed in buckets and spaced so that about 3 to 4 ten litre buckets of humus covers a square metre of bed area. The piles are then spread out and mixed with the existing topsoil with a hoe.


The Dutch hoe is a fine gardening tool and valuable for many jobs of the vegetable or flower bed. Here it is used to mix the new humus with topsoil.

The new bed with enhanced growth of flowers

12. Growing trees on composted toilet pits

After a period which can vary from a few months to a few years, depending on the pit size and extent of use, the compost pit will be filled with a composting mix of ingredients. In the case of the ***Arborloo***, it is time to move the structure, including the concrete slab and any ring beam to a new site. The toilet itself moves on a "never ending" journey, through the "lands." A new site will have been chosen and possibly a pit dug, but it is always wise to place the ring beam first and then dig the pit within the ring beam. This makes a much more stable unit.



Preparations for tree planting

The contents of the used pit (filled with excreta, soil/ash/leaves etc) are now levelled off and topped up with a generous layer of leaves followed by fertile soil, at least 150mm deep. This soil can come from old compost heaps, fertile soil/leaf litter found under trees or any other place where the soil looks good. The aim is to plant the young tree in topsoil so the roots are placed well above the composting excreta layer below.

What is important with the ***Arborloo*** is that a generous layer of soil (15cm) is laid over the excreta/soil layer in which the young tree is planted. If a good layer of leaves followed by top-soil is added to the excreta in the pit, the young tree can be added the same day as topping up with soil. But there is no reason to delay the movement of the latrine if no trees are available for planting. The latrine can be moved and the pit topped up with soil awaiting the arrival of a new young tree. In fact some may prefer this method, as it gives time for the excreta in the pit to partly convert into humus before the tree is planted. More topsoil can then be added before planting. If water is scarce, it is actually advisable to delay tree planting until the rains begin. Then the chances of the young tree dying as a result of a lack of water will be much less. Young trees need a lot of care, protection and water.


Left: Women from the Sanitation club in Epwengeni Village, Embangweni, Malawi, perform a play showing how trees are planted in *Arborloo pits.* The Village has large numbers of *Arborloos* in operation. Right: Young fruit tree being planted by children in Embangweni, Malawi. Right photo: Jim McGill.

Planting young trees

Young trees can be obtained from a nursery, or in some cases can be taken from cuttings from existing trees (mulberry, banana) or can be grown from seeds (guava, paw paw, mango, avocado etc). This is described in the chapter on gardening techniques. Mulberry, banana, gum, mango, guava, paw paw & avocado do well. In fact most trees will thrive if given the right opportunity. Citrus trees can also be grown, but need more care. Experiments in Harare have shown that when planted in a good layer of topsoil covering very organic pits, most trees will thrive, including a wide range of fruit trees, indigenous trees, ornamental trees and trees used for construction or fuel. At least three things are important for young trees.

1. Keep the young tree roots well away from the excreta layer.
2. Protect the young tree from goats, chickens etc with a protective basket
3. Water regularly. A mulch of leaves or grass helps to retain water in the soil.


Left: Right: In a programme in Kusa Village on the shores of Lake Victoria, Kenya, many young trees have been planted on *Arborloo* pits. This young citrus tree is being planted in the soil placed above the pit contents. Thanks to RELMA. Right: This *Arborloo* at the Eco-Ed Trust has just been moved onto a new site (rear right). The old pit has been topped up with soil, a tree planted and mulch added. Note substantial protection against animals. Thanks to Jim and Jill Latham, Eco-Ed Trust.

The growing roots of the young tree first invade the topsoil layer, whilst the excreta below is turning into humus. So the young tree does not immediately gain benefit from the formation of humus derived from human excreta. This benefit will be realised later on. Because of the highly rich nature of the pit contents, there may be invasions of the pit by roots already present in the soil. If the young tree for any reason begins to struggle, a new tree can be planted later. Also if the trees are very young it may better to allow them to establish themselves in buckets, pots or larger containers first, so the root system can grow more extensively and become more resilient before transplanting into the pit. Experimentation will be required. There will be a variation in local conditions - soils, climate, season etc. The most suitable tree type will vary with the area and altitude. Also the owner will choose some trees in preference to others. Some may choose trees for fruit, others for fuel, others for shade etc. The banana is perhaps the most widely grown fruit tree on traditional latrine pits. But the orange and tangerine are the most popular in more recent ***Arborloo*** programmes.

In some cases the tree may not grow fast at first, a condition known as “hesitancy.” Obviously a pit full of richly organic material may not be the most ideal environment in which young trees can grow. But with time, the conditions of the pit become favourable. Some trees are more tolerant of the richly organic conditions than others. Mulberry is a very good tree species to start. It makes tasty fruit and is very tolerant of the rich pit environment. It can also be grown from cuttings.

Looking after young trees

There are some trees which may fail to grow on the first attempt for various reasons. Sometimes these will have been attacked by goats or chickens or dug out or trodden on by children, or simply not watered. Sometimes a poor soil will have been chosen to cover the excreta layer or the soil layer may have been too thin (trees will die if placed in or very close to raw excreta!). And some trees are hardier than others. So some tree deaths can be expected. Try again with a new tree - replanting is the order of the day!

Common gardening practice must be applied to the planting of young trees. The soil should be fertile (that is the layer of soil placed on top of the excreta). The young tree should be healthy, protected against animals, children, possibly excess sun and it must be watered regularly. The soil should ideally be covered with a layer of mulch. Mulch is a very valuable addition to the topsoil. It is a layer of material, preferably organic material that is placed on the soil surface around the tree. It is a protector of the topsoil. The layer of mulch helps to conserve moisture in the soil and thus reduces the amount of water required. It holds down weeds and also protects the soil from the effects of sun and wind. The layer of mulch improves the soil structure and fertility. It can be made of leaves, leaf compost, grass cuttings, compost or other decomposing vegetable matter. Some animal manure, compost, etc or other suitable fertiliser might even be dug into the topsoil to assist the young plant once established. Here the local forestry or nursery people will know what to do. The aim is to help the tree to get established and stabilised in the layer of topsoil, in preparation for its penetration into the decomposing layer.

Hesitancy

For various reasons a young tree may hesitate to grow with maximum vigour at first. It may be stressed for a number of reasons and that is why every effort must be made to encourage the young tree in its first months after transplanting. If all other factors in the topsoil are ideal, the tree should have a good start. But if the organic layer is too close to the roots the plant may hesitate or even die. The tree roots are actually quite sensitive to the soil beneath and the plant as a whole may wait until it senses the best time to start growing more rapidly. That is when the excreta is fully converted into a humus which can be tolerated by the roots. There is a balance between the rate of conversion from excreta to humus and the rate of growth of the roots into the deeper layers. One thing is certain, when the time is right, the young tree will certainly begin to grow vigorously.

Replanting

If for any one of a number of reasons the young tree does not grow, it should be replaced. If the plant struggles for a period of 3 - 4 months then it is best to take the tree out and replant with a new tree. It may be wise to take out the composted soil from the pit, loosen and mix up and reapply to the pit and replant the same tree or preferably a new tree and water etc. Some trees are stronger and more tolerant than others, even when they come from a nursery. Some people who dig out the tree pit prefer to use the humus on their vegetables. That choice is of course optional. Many people may decide the humus is more important on vegetables. But opinions vary greatly.

Feeding the trees

All trees require a good supply of nutrients if they are to grow well. This is particularly true for fruit trees which are planted to produce fruit. The amount of fruit produced will eventually depend on how much nutrient the tree can gain from the soil. The early growth of trees can certainly be sustained from the nutrients held in the composted pit soil. But during heavy rain, part of the nitrogen will be lost from the topsoil, although phosphorus is normally held in place far better by the soil. Also trees use up much of the nutrients held in the soil and their root systems search wider and wider for a supply of food. So for the best results, particularly with fruit trees, extra feeding will be required.

Each type of tree has its own very specific requirements for feeding. Avocado pears, for instance, require more phosphate and potash and very little nitrogen. Banana trees require large amounts of nitrogen and potash. Citrus trees require more of a balanced diet. When fed with compound fertilisers, fruit trees require between 250 – 500gms of fertiliser per year for each year of life if they are to produce good yields. This is normally given in 2 or 3 doses over the year. However, all trees require the most phosphorus at an early stage of root growth and shoot formation. Then they require more nitrogen for vegetative growth. But the final stage is critical. The trees require generous amounts of potassium to produce fruit in abundance.

It is wise to dig in compost or manure around the tree from time to time. For most trees, about 10 kg manure or compost (a wheel barrow full) will be required each year for the first two years. The amount required increases by about 5kg for every successive year, so apply about 15kg in year 3, 20 kg in year 4, 25 kg in year 6 and so on. In eco-san, one option for feeding will be diluted urine. Since urine contains a lot of nitrogen and much less potassium, it is wise to dilute the urine first, and then add a source of potassium. The source of potassium most commonly available is wood ash. As a rule of thumb, most trees, once they have been growing for two years, respond well to a monthly application of a mix of 2 litres urine to 10 litres water (5:1) to which has been added a mug full of dry wood ash and well stirred. This can be applied with a watering can. Several charges of this mix can be added to more mature trees, especially during the rainy season. It helps if the soil around the tree is well mulched.

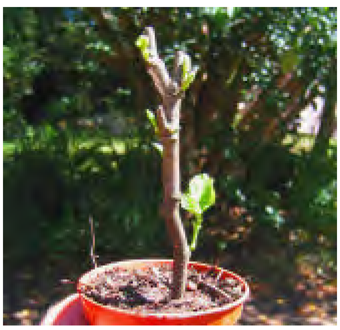
Some examples of growing young trees from cuttings and seed

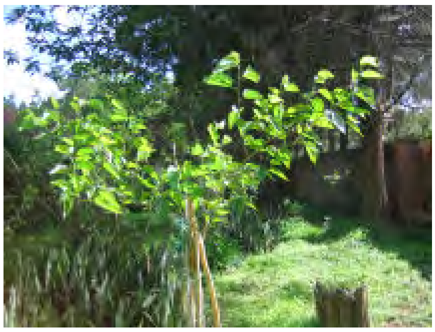
Many of the most successful fruit trees for planting on ***Arborloo*** pits can be grown easily from seed or cuttings. These include banana, mulberry, guava, paw paw, avocado pear, mango and many others. If a nursery is not available for a supply of young trees it is best to use trees which are easy to propagate from cuttings or seed in the home garden. Citrus trees are more difficult to grow from seed and will normally be purchased as grafted trees from a nursery. Innovative programmes which promote the ***Arborloo*** method may also provide not only small material subsidies like divided packets of cement to make a concrete slab, but also tree seeds and/or seedlings. Instructions for toilet construction and use and the planting and caring of trees can also be included in such packages, sometimes called “start up kits.” The young tree or tree seeds can be planted in a suitable container, in preparation for later transplanting, at the same time as the concrete slab is made and the ***Arborloo*** is built and put to use. This period may extend between 6 and 12 months. By that time the young tree will have become well established in the container and will be ready for transfer to the ***Arborloo*** pit. It is a good way of starting off the process of uniting sanitation with food production.

Mulberry – a good example.

Perhaps the most successful tree to grow from cuttings is the mulberry. This is an excellent tree to start because it rarely fails and grows particularly well on organic pits. It also provides delicious fruit, rich in iron and vitamins A, B and C. There are two types of mulberry, black (*Morus nigra*) and white (*Morus alba*). The black type is the best known and the most tasty.

The method involves cutting a piece of **mulberry** tree branch about the size and width of a pencil. Each cutting should have 4 or 5 good buds on it. Cut at an angle with a shark knife or cutter. Remove any leaves and plant in potting soil or humus in a pot. Plant so the part nearest to main stem of the cutting is placed in the soil. Keep well watered. After a few weeks new shoots will appear on the cuttings. The young tree can be transferred into a bigger container to allow the roots to extend prior to planting on the ***Arborloo*** pit. This tree is usefully used in Compost toilet starter kits, as it is easy to propagate in large numbers.





Young mulberry sprouting new leaves 3 weeks after planting the cutting. Once well established, the young tree can be transplanted into a larger container or bag prior to the final transplant into the *Arborloo* pit. (Photo: April 2004). Middle photo - the tree is growing fast in a 10 litre bucket. Right the tree has been planted and after less than a year the mulberry is growing fast. The tree on the right is also being fed with a urine-water mix once a week (2 litres urine + 10 litres water). Trees grow particularly well during the rainy period, when the temperature is also high in Southern Africa. The start of the rains (November/December) is a good time to plant trees in organic or *Arborloo* pits.

Guava

Guava (*Psidium guajava*) is a tasty, nutritious and prolific fruit bearer and is very hardy. It grows almost like a weed in most parts of Southern Africa once established. Very often young trees will germinate and grow in areas where guava has been eaten and the pith thrown to one side or has just fallen off the tree. Guava can also be grown from seed and this is a good way of distributing the trees in ***Arborloo*** programmes. But guava seeds do take a long time to germinate

Guava like mulberry and most of the other trees grown on ***Arborloo*** pits grow into very large trees eventually. The pit should be spaced about 4 - 6 metres apart. The young trees pick up the nutrients left in the mix of composted excreta, soil, ash and leaves. The presence of a good supply of phosphorus is particularly valuable when the tree is young. Also the presence of potassium is particularly valuable for later fruiting. As the tree matures, extra supplies of nutrients will be required and this can be provided by adding diluted urine mixed with wood ash (see ***Arborloo*** chapter). .

A pink fleshed cultivar which has been cut to reveal the seeds. In the region guava fruit ripens between February and April. The seeds should be taken from fresh fruit and soaked in water to remove the fruit pulp. The seeds are dried in the shade (right) and stored in a cool dry place for later planting. It is wise to plant 3 or 4 seeds in a suitable container or potting bag and later thin out the best young tree.

Once established the young guava tree can be transplanted into the *Arborloo* pit. On the right a young Guava growing in a potting bag. On the left a wild sown guava growing in a garden. Where guavas are common in the garden, large numbers of guava seeds become dispersed and grow like weeds. The guava is a tough resilient tree, with delicious fruit and like the mulberry a good choice for the *Arborloo* pit.

Avocado

Avocado (*Persea americana*) trees grow very large and provide huge amounts of fruit over the years. After eating the fruit take the large seed and plant in a clean deep container with the point of the fruit facing upwards and just beneath the surface of the potting soil. Keep well watered. Some people place the fruits in water and wait for them to germinate. Some seeds may be attacked by fungus which causes root rot and this can be dealt with by placing the seed in water at 50 degrees C for 30 minutes before placing in the soil. Root rot kills trees slowly and can spread to healthy trees. Once well established the young tree can be placed on the filled ***Arborloo*** pit. Since the trees can grow very large, the pits are best spaced between 8 and 10 metres apart.


Bucket of avocado seeds. On right a seed has germinated in a small container.


Avocadoes growing in bags from seed originally soaked in water and once germinated transferred to the soil in the bag. On the right more mature avocado growing on an organic pit at the Friend Foundation in Harare.

Other Trees

Many other trees can be grown from seed including paw paw and mango. The tree of choice is chosen by the family itself, bearing in mind that some trees are easier to grow than others. It is best to consult the local tree nursery or Forestry Department for all details of tree cultivation and care.

Photo gallery of trees growing on *Arborloo* or organic pits

Mr and Mrs Phiri and Mr Twitty Mukundia of CCAP in Embangweni inspect a paw paw planted on an *Arborloo* pit and well protected against animals. Several fruit trees are growing on a series of Arborloo pits in Chiputa Village, Embangweni. Thanks to WaterAid and CCAP.

Citrus trees (orange) growing on *Arborloo* pit in Kusa Village near Kisumu, Kenya (left photo). Note the banana in the background. Bananas flourish on old latrine pits and also *Arborloo* pits.

Trees are amongst Natures greatest wonders.

Trees grown on *Arborloo* pits at the Porta farm, Zimbabwe Project of Mvuramanzi Trust.

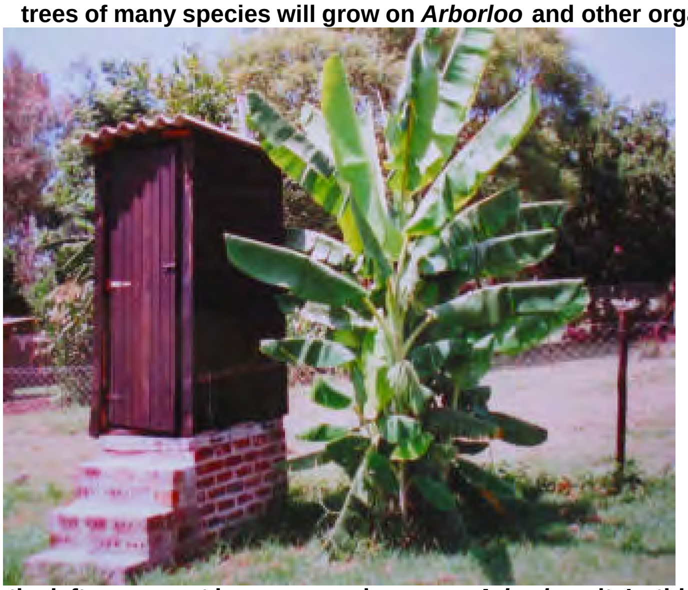

A fine paw paw grows on an *Arborloo* pit, now 4 years old. On the right bananas have been planted on a series of old *Arborloo* pits in this garden. These are also 4 years old.


An avocado tree, about 3 years old. On the right an orange tree between 2 and 3 years old. Peach and guava trees have also grown well on *Arborloo* pits at Porta Farm.

Further photos of trees growing on "organic" pits

A guava tree at Eco-Ed Trust on ***Arborloo*** pit, Mutorashanga, Zimbabwe.

Variety of trees growing in a sanitary orchard at the Friend Foundation in Harare, Zimbabwe. Indigenous trees of many species will grow on *Arborloo* and other organic pits like this *Swartzia sp* (right)



On the left a rampant banana growing on an *Arborloo* pit. In this case the timber structure alternates as an *Arborloo* and a *Fossa alterna*. Earlier in its life the structure was placed at ground level over a shallow pit protected with a ring beam. A banana was planted on the used pit which filled. Later, after a period of flooding, the structure was elevated onto an above-the-ground vault. The vault contents later turned into humus. Banana is planted on old latrine pits in several African countries like Malawi, Mozambique, Kenya and Rwanda. On the right a huge banana plant grows on an old latrine pit in Epworth, close to Harare.


On the left a healthy gum tree grows on an organic pit at the Friend Foundation in Harare. On the right a healthy paw paw tree is growing. In both cases the trees are growing on a mix of dog manure and soil. As with the *Arborloo,* the pit is filled first with a mix of "manure" and soil, and when nearly full is topped up with a good layer of topsoil. The young tree is planted in the topsoil layer. Mulch is added and the tree is protected from animals. It is then watered thoroughly.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Mulberry growing on an *Arborloo* pit at Kufunda Village, Ruwa, Zimbabwe. On the left at the time of planting during an eco-san course for students. On the right about a year later. Mulberry is a versatile fruit tree to grow on Arborloo pits. It rarely fails to do well. The fruit is both nutritious and tasty. Young trees can be grown from cuttings, making them easy to multiply.


Banana and Passion fruit growing in Malawi

Trees in all their splendour

The green backcloth to a splendid scene of Nature

A mature plantation of gum trees near Rhodes Nyanga Hotel, Zimbabwe.

13. Plant trials using Fossa alterna compost

Poor top soils are so common in Africa, that soil enrichment is essential if any viable growth is to be achieved. Very often cattle manure is used to enhance the soil where it is poor, and this is a very successful method. But cattle are not owned by a considerable proportion of the population, and those living in the peri-urban areas may have no easy access to it. The alternative is to buy and import the manure, make compost or to use inorganic fertilisers. Compost making and application to gardens is a very practical method of solving the problem and must be encouraged (see chapter on gardening techniques). However the inorganic fertilisers are becoming scarce and expensive in Zimbabwe, at least, and they are certainly expensive over much of Africa, and beyond the means of most poor people. So other possibilities must be explored. The possibility of using humus derived from human excreta thus becomes a meaningful and practical option, because it costs almost nothing to produce and its supply is almost guaranteed year by year. As we have seen this can change a barren soil into one which has potential for growing vegetables.

The ultimate proof of the usefulness of eco-humus and urine in agriculture is to demonstrate its effect on plant growth and yield directly. This chapter describes a series of trials in which the growth and yield of vegetables planted in humus derived from the ***Fossa alterna*** were studied**.** In some cases the trials involved comparing the growth of vegetables planted directly in ***Fossa*** humus with plants grown on other soils. However this is an uneconomical way of using the humus. The best method is to mix the humus with less fertile soils.

Comparative growth trial in containers

One of the most rewarding ways of using the humus derived from ***Fossa alterna*** pits is to mix the humus with other soils and grow the vegetables in the mix. This can be done in varying proportions with soil/humus mixes of 1:1 and 2:1 being most practical. For containers, where the soils are contained, the most suitable mixture is a 50/50 mix of topsoil and ***Fossa*** humus. This simple procedure effectively doubles the volume of valuable soil produced and enhances the texture and nutrient level of the original topsoil considerably. Thus it is possible to record the growth of plants in the poor topsoil and compare this with the growth of plants in the ***Fossa*** enhanced topsoil. The use of containers is very convenient for plant trials. When mixing **Fossa** humus with soil in vegetable beds a 2 (soil):1 (humus) mix may be the most suitable.

The primary aim of these trials was to show that by taking humus derived from the family toilet, and by mixing it in equal proportions with poor top soil, a meaningful vegetable production could be achieved where little growth would have been possible before on poor topsoil alone. The addition of ***Fossa*** humus to a poor soil might be regarded as the first stage of soil enhancement. To improve the plant yield further, a second stage of soil enhancement would be required by using manure, compost or liquid plant foods, such as water/urine mix. These trials are revealing - they clearly show that the addition of ***Fossa alterna*** humus to poor topsoil, in equal proportions, can considerably enhance the properties of the topsoil, turning it from a soil in which plants do not grow well into a soil in which viable vegetable production can be achieved.

PLANT GROWTH TRIALS

A simple series of preliminary trials were undertaken to study the effect of the ***Fossa alterna*** humus on plant growth. The trials were undertaken in containers like 10 litre plastic buckets and cement basins. The aim was two fold.

First, to demonstrate the value of the eco-humus as an enhancer of the nutrient level in poor top soils, which are so common in Africa. Soil analyses reveal this improvement.

Second by measuring and comparing the yield of vegetables produced in poor soil and poor soil enhanced by the addition of ***Fossa alterna*** humus, after a fixed number of days of growth. Trials were undertaken with the following vegetables: spinach, covo, rape, lettuce, green pepper, tomato, onion and maize. Only small numbers of plants were used in these preliminary trials, and they must be seen as precursors for more elaborate trials using larger numbers of plants. The trials are described under type of plant.

Nutrient levels of trial soil.

Two types of poor soil were used in the trials, the first from Ruwa, the second from Epworth. The ***Fossa alterna*** humus used in these trials was taken from a single toilet. Final nutrient levels of the 50/50 mix of poor soil and ***Fossa alterna*** soil show an intermediate position between the samples as shown in the table. All samples were analyses using the method described in the earlier chapter.

Soil analysis	**pH**	**N**	**P**	**K**	**Ca**	**Mg**
1. Ruwa soil	5.5	27	5	0.29	:10.23	4.11
2. Fossa humus	6.5	319	196	3.26	:13.70	7.26
Result of 50/50 mix.	**6.4**	**91**	**247**	**0.88**	**3.05**	**2.49**

Soil analysis	**pH**	**N**	**P**	**K**	**Ca**	**Mg**
1. Epworth soil	**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**
2. Fossa humus	**6.3**	**197**	**299**	**2.94**	**26.64**	**4.77**
Result of 50/50 mix.	**6.4**	**78**	**356**	**1.01**	**15.75**	**1.78**

Note in both examples there is a considerable increase in nitrogen, phosphorus and potassium in the poor soil after it has been mixed with ***Fossa alterna*** soil. This is to be expected. However the exceptionally high levels of phosphorus in the resulting soils, which are consistent and have been found in other analyses cannot be explained.

The plant trials with *Fossa alterna* humus applied to poor soils

SPINACH – Trial 1.

Spinach is an adaptable plant and grows well on many soils. The initial trials with spinach were conducted in ten litre cement basins in which vegetable seedlings were planted in either poor (Ruwa) topsoil or the same topsoil mixed with an equal proportion of ***Fossa*** humus. The following figures show the weight of spinach grown over a 3 month period (July-Oct. 2002).

The photo shows 18 gms of spinach grown on poor Epworth soil (right) compared to 180gms of spinach grown on Epworth soil enhanced with *Fossa* soil (left), after a 3 month growth period.

SPINACH – Trial 2.

In a further series of trials, spinach seedlings were planted in 10 litre buckets containing Epworth soil and a mix of Epworth soil and ***Fossa*** humus. The soil from Epworth (a peri-urban settlement of some 100,000 persons close to Harare) is notoriously poor, and most residents are unable to grow crops in their gardens. Those that do must import manure or use commercial fertiliser. Significant improvements in growth were measured for spinach, covo and lettuce by enhancing the poor Epworth soil with ***Fossa alterna*** humus.

Growth/weight/yield of spinach produced in 10 litre buckets (gms)
(mean of 3 plants in each of 2 buckets)

	Fossa soil and poor mixed 50/50	Poor soil only (Epworth)
Leaf wt after 30 days (buckets 1&2)	243gms	32gms
Leaf wt after 30 days (buckets 3&4)	303gms	40gms
Total	**546gms**	**72 gms**

Note below weights of individual spinach (on 30 day trial)
On Epworth (poor soil) : 11, 10. 11, 20, 10, 10, Total (T) 72gms, Sample no (N) =6, Mean (M) = 12gms, Standard deviation (SD) = 3.95,

On 50/50 Epworth/Fossa alterna soil : 85, 80, 78, 118, 110, 75, Total, 546 gms, Sample no = 6, Mean = 91 gms, Standard deviation (SD) = 18.29.

The two samples are significantly different at the 95% level of confidence.

Thus the yield of spinach on Epworth soil was increased over 7 times as a result of enhancing it with ***Fossa alterna*** soil, without further enhancement. An analysis of the Epworth soil, the ***Fossa*** humus and the resulting mix is shown earlier. In a settlement like Epworth, such an enhancement would be regarded as very significant. In effect the *Fossa* humus turned a meaningless yield on poor soil to a meaningful yield on enhanced soil. In the case of spinach, this first crop was reaped and the plant continued to yield more leaves for further cropping.

The photo shows spinach grown on poor Epworth soil (left) compared to spinach grown on Epworth soil enhanced with *Fossa* soil (right), after 30 day growth period. The increase is seven fold.

COVO - Trial 1.

Covo is a popular vegetable in Zimbabwe and also in the sub region (e.g. Mozambique). Its leaves are tasty, and can be cropped from the main stem for a two year period. It is resistant to drought and copes quite well in poor soils. It can also be planted from cuttings. In this trial three covo seedlings were planted in neat ***Fossa alterna*** soil in a 10 litre cement basin and the growth was compared to identical seedlings planted in the poor soil from Epworth.

The photo shows 20 gms of covo grown on poor Epworth soil (right) compared to 161gms of covo grown on neat *Fossa* soil (left), after a 30 days growth period. This is an eight fold increase in yield.

Note below weights of individual covo (trial 30 days)
On Epworth (poor soil) : 10, 2, 8. Total 20 gms. Sample no =.3, Mean = 6.66gms, SD =4.16
On 50/50 Epworth/Fossa alterna soil : 62, 49, 50. Total 161gms, Sample no =.3, Mean = 53.66, SD = 7.23

The two samples are significantly different at the 95% level of confidence.

COVO - Trial 2.

In a further series of trials, covo seedlings were planted in four 10 litre buckets, 2 containing the poor Epworth soil and 2 containing a 50/50 mix of Epworth soil and ***Fossa*** humus. Once again significant improvements in growth were measured by enhancing the poor Epworth soil with ***Fossa alterna*** humus. In this case the yield of covo on Epworth soil was increased over 4 times as a result of enhancing it with ***Fossa alterna*** soil. Note this is a first cropping. Covo can be repeatedly cropped depending on soil fertility.

Growth/weight/yield of covo produced in 10 litre buckets (gms)
(mean of 3 plants in each of 2 buckets)

	Fossa soil and poor mixed 50/50	Poor soil only (Epworth)
Leaf wt after 30 days (buckets 1&2)	180 gms	41 gms
Leaf wt after 30 days (buckets 3&4)	177 gms	40 gms
Total weight	**357 gms**	**81 gms**

Note below weights of individual covo (trial 2 - 30 days)

On Epworth (poor soil) : 11, 10, 20, 20, 10, 10. T = 81 gms, N = 6, M = 13.5 gms, SD = 5.05.
On 50/50 Epworth/Fossa alterna soil : 50, 70, 60, 72, 20, 85. T = 357 gms, N = 6, M = 59.5 gms, SD = 22.66.

The two samples are significantly different at the 95% level of confidence

The photo shows covo grown on poor Epworth soil (left) compared to covo grown on Epworth soil

enhanced with *Fossa* soil (right), after 30 day growth period. The increase is four fold.

RAPE - Trial 1.

1. Growing Rape in a shallow above ground vegetable garden with *Fossa* humus

This trial was undertaken in a one square metre brick enclosure built above ground on a plastic sheet. The soil mixture was made by combining 40 litres ***Fossa*** humus with 40 litres of poor sandy soil from the Ruwa, making a soil depth of only 75- 80 mm. A more suitable volume would have been 50 litres of eco-humus + 50 litres topsoil for this area, making a soil depth of 100mm, which is just adequate for shallow rooted vegetables. The soil was watered and then planted with about 50 rape seedlings. The bed was watered generally twice a day with borehole water only (ie no plant food of any type added). The bed was also covered with shade cloth. Rape seedlings were produced from seed in a seed tray. The growth of rape was good. The same technique could be used over a wider area.

During the growing period of 4 months (June to October 2002) 3.1 kg of rape were reaped from the first and second harvest. Almost the entire nutrient supply for this small garden was derived from the 40 litres of ***Fossa*** eco-humus (the sandy Ruwa soil had almost no nutrients in it). Thus once again we see a very real use for the eco-humus. Almost no growth of the rape took place on Ruwa soil alone on a control basin. If all the ***Fossa alterna*** humus had been used to grow rape about 40 kg would have been produced. In this case, the production could have been enhanced by additional feeding with a 3:1 water/urine mix applied twice a week. However that was not the point of the trial.

In the case cited above, the ***Fossa alterna*** humus was itself a mix of poor soil and excreta only, with no inclusion of leaves or vegetable matter. The nutrients were further diluted by combining with another poor soil. The table below records this sequence. The vegetable output is thus even the more remarkable.

Nutrient levels in soils

Soil source		pH	N	P	K	Ca	Mg
Natural soil added to ***Fossa*** pit	**4.9**	**50**	**13**	**0.18**	**2.95**	**0.78**	
Resulting eco humus from ***Fossa***		**6.5**	**319**	**196**	**3.26**	**13.70**	**7.26**
Natural soil (Ruwa) added to ***Fossa*** humus		**5.1**	**14**	**23**	**0.10**	**1.12**	**0.48**
Final soil mix	**6.4**	**91**	**247**	**0.88**	**3.05**	**2.49***	

One sees the considerable enhancement of nutrient levels in the soil removed from the ***Fossa*** pit compared to the soil placed into the ***Fossa*** pit. And for the second time, one sees considerable enhancement of nutrient levels in the soil resulting from the combination of this ***Fossa*** humus with a very poor naturally occurring soil (Ruwa). And yet despite being mixed with poor soil twice, the end result was still a positive result for vegetable growth. It is remarkable that with such dilution with poor soils, the nutrients available in the humus excreta can still result in meaningful yields of vegetables without the addition of any further plant food.

Harvest of rape growing in an above the ground vegetable garden.
Almost 100% of nutrients derived from *Fossa alterna* humus

LETTUCE

Three lettuce seedlings were planted in each of 2 X 10 litre buckets containing poor Epworth soil and also 2 X 10 litre buckets containing a mix of Epworth soil and ***Fossa*** humus (50/50 mix). The total weight of lettuce grown after 30 days on the buckets of Epworth soil alone was **122 gms** compared to **912 gms** grown on Epworth soil enhanced with ***Fossa alterna*** humus. This is a 7 fold increase in production of the poor soil as a result of enhancing it with ***Fossa alterna*** humus.

Growth/weight/yield of lettuce produced in 10 litre buckets (gms)
(mean of 3 plants in each of 2 buckets)

	Fossa soil and poor mixed 50/50	Poor soil only (Epworth)

Total wt. after 30 days (buckets 1&2)	447 gms	56 gms
Total wt after 30 days (buckets 3&4)	465 gms	66 gms
TOTAL	**912 gms**	**122 gms**

Note below weights of individual lettuce (30 day trial)

On Epworth (poor soil) : 15, 20, 21, 25, 19, 22: T = 122 gms, N = 6, M= 20.33 gms, SD = 3.33
On 50/50 Epworth/Fossa alterna soil : 130, 160, 157, 150, 155, 160,. T= 912 gms, N = 6, M = 152 gms, SD = 11.40
The two samples are significantly different at the 95% level of confidence.

The photo shows lettuce grown on poor Epworth soil (left) compared to lettuce grown on Epworth soil enhanced with *Fossa* soil (right), after 30 day growth period. The increase is seven fold.

GREEN PEPPER

Most plants thrive on the undiluted eco-humus. The green pepper shown in the photo below has shown exceptional growth when planted in undiluted eco-humus after a 4 months of growth period. In this case the green peppers were grown in ***Fossa*** humus without mixing and comparisons made with identical seedlings grown on a 50/50 mix of ***Fossa*** humus and Ruwa soil and also in the basic Ruwa soil. The photos reveal the huge difference in growth. The weight of green peppers produced after 4 months on neat ***Fossa*** soil was **415 gms** (first crop). This compared to **89 gms** produced on the 50/50 mix of Fossa and Ruwa soil and only **19 gms** on the Ruwa soil only. The minuscule production on the Ruwa soil, reveals now poor it is as a growing medium for plants.

Weight of Green pepper produced after 4 months

Soil type	Weight produced
Ruwa soil	**19gms**
50/50 mix of Ruwa and ***Fossa*** soil	**89 gms**
Fossa soil without dilution	**415 gms**

These figures reveal that some hardy plants like green pepper can grow well in undiluted ***Fossa*** compost. However the compost is rich and best diluted with an equal or larger volume of top soil. It is not only the nutrients in the soil which are important to ensure good growth. Soil texture is also an important factor which determines how well a plant will grow. Experience has shown that by mixing ***Fossa alterna*** humus with most top soils including sandy soils and red soils improves the texture considerably enabling roots to penetrate the media more. Thus by mixing the eco-humus with other soils, the texture of the parent soil may be improved as well as nutrient level.

Green pepper growing on buckets of undiluted *Fossa* soil (left), poor Ruwa soil (right) and a 50/50 mix of the two (centre). A 20 fold increase in yield from poor to rich soil

TOMATO

Initial trials were conducted in ten litre cement basins in which vegetable seedlings were planted either in poor topsoil (Ruwa) or the same topsoil mixed with an equal proportion of ***Fossa*** humus (5 litres + 5 litres). The following figures show the weight of tomato grown over a 3 month period (July - October 2002) in each ten litre basin.

	Fossa soil and poor mixed 50/50	Poor soil only (Ruwa)
Tomato	**735** gms	**73 gms**

Note below weights of individual tomato (harvested after 3 months)

On Ruwa soil (poor soil) : 33, 10, 30. T= 73gms, N = 3, M = 24.33, SD= 12.62
On 50/50 Ruwa soil/Fossa alterna soil: 20, 40, 50, 60, 50, 50, 40, 50, 40, 50, 40, 50, 40, 45, 50, 30, 30. T = 735 gms, N = 17, M = 43.23, SD = 9.83

The two samples are significantly different at the 95% level of confidence.

A ten times yield in tomatoes was obtained by mixing eco-humus with the poor topsoil which was itself unable to produce any meaningful growth of tomato at all. However the nutrients held in 5 litres of ***Fossa*** humus led to the reaping of 735 gms tomatoes. The full 500 litres of annual output of humus might have let to a crop yield of 73.5 kg tomatoes. However in this particular trial, the total yield of tomatoes, even in the mixed soil was well below which could be expected from well manured or fertilised soil. Special techniques are required to get the best crop of tomatoes. They require a rich soil, with plenty of potassium in the later stages of growth to promote full fruit development.

MAIZE

Maize is certainly the most important crop grown in Southern and Eastern Africa and a study of its reaction to eco-humus is important. In this trial, comparisons were made with maize grown in poor Epworth soil and Epworth soil enhanced with ***Fossa alterna*** humus (50/50 mix).

Maize seedlings were planted in four 10 litre buckets, 2 containing poor Epworth soil and 2 a mix of Epworth soil and ***Fossa*** humus (for soil analysis - see early in chapter). The maize seedlings were planted on 28th September Significant growth was initially observed in the Epworth soil enhanced with ***Fossa alterna*** humus. The growth of maize on the plain Epworth soil was very poor by comparison. However by 5th November, nutrient deficiency was beginning to reveal itself, even in maize plants growing on ***Fossa*** enhanced Epworth soil - with the oldest leaves on the maize showing some signs of yellowing (an indication of reduced nutrient availability), as the nutrients in the basin were used up. When a plant like maize starts to struggle for nutrients, the available nutrients are directed to the youngest leaves, and withdrawn from the oldest - which shows up as yellowing in the basal leaves, lightening in colour of all leaves and subsequently as a reduced yield of maize cobs. The full potential of growth was never reached in any of the 12 maize plants grown in this trial. After about 3 months of growth the cobs were removed from the plants, stripped of their covering and weighed. The following data was recorded.

Growth/weight/yield of Maize produced in 10 litre buckets (gms)
(mean weight of 6 plants in 2 buckets)

	Fossa soil and poor mixed 50/50	Poor soil only (Epworth)
Mean cob wt after 3 month	**18.33 gms**	**0.41 gms**

The cobs produced in all plants in this trial were very low weight. Cob weights for maize grown on ***Fossa alterna*** /Epworth soil combinations were **30, 10, 20, 30, 14,** and **6** gms respectively (one per plant). Cob weights for maize grown on Epworth soil were **2 gms** and **0.5gms only**. This reveals the exceptional poor nutrient value of the soil in Epworth (near Harare) where at least 100,000 people live. ***Fossa alterna*** humus did enhance the output, but not nearly sufficiently to produce a meaningful yield.

Although adding *Fossa* humus to Epworth soil enhanced the growth of maize, this was not sufficient to produce a meaningful crop. Urine treatment is required to gain good maize harvests from poor soil.

Maize is the most important food crop grown in Southern and Eastern Africa and requires a considerable nutrient input for grow to its full potential. The relatively small volumes of eco-humus produced in the ***Fossa alterna*** annually (about 500 litres), particularly, when they are combined with an equal volume of naturally occurring top soils (to make 1000 litres), are sufficient to sustain a good annual production of vegetables in the backyard. But this eco-humus by itself is quite insufficient to have an influence on crops like maize plants, which are grown in large numbers and are hungry feeders. The conclusion to be drawn is that ***Fossa*** humus is more productively used in growing vegetables in the backyard, rather than enhancing maize growth. Maize responds very well to the application of urine

The best way of enhancing maize growth is in two stages. Improving the nutrient and humus content in the top soil first (by adding eco- humus or manure) and then elevating and sustaining the nutrient level further by the further application of a liquid feed like urine and water. The use of urine as an enhancer of plant growth, including maize is described later in this book.

ONION

Early trials were conducted in ten litre cement basins in which onion seedlings were planted either in very poor topsoil from Ruwa or the same topsoil mixed with an equal proportion of ***Fossa*** humus. The following figures show the weight of plants grown over a 4 month period (July - November 2002 - trial 1 and August - December - trial 2).

Weight of onion produced in 10 litre basin (gms)

	Fossa soil and poor (Ruwa) mixed 50/50	Poor soil only (Ruwa)
Onion (trial 1)	**391 gms** (10 plants)	**141 gms** (9 plants)
Onion (trial 2)	**558 gms** (10 plants)	**271 gms** (10 plants)

Note below weights of individual Onions (harvested after 4 months)

Trial 1.

On Ruwa soil (poor soil) : 38, 15, 18, 10, 8, 18, 10, 8, 16. T = 141 gms, N = 9, M = 15.66, SD = 9.30

On 50/50 Ruwa soil/ Fossa alterna soil: 47, 20, 55, 41, 58, 26, 29, 40, 45, 30. T = 391, N = 10, M = 39.10,

The two samples are significantly different at the 95% level of confidence.

Trial 2.

On Ruwa soil (poor soil) : 42, 40, 5, 40, 22, 30, 5, 40, 30, 29. T = 271, N = 10, M = 27.1. SD = 14.65

On 50/50 Ruwa soil/ Fossa alterna soil: 92, 80, 60, 40, 20, 80, 70, 50, 40, 20. T = 558, N = 10, M = 55.8, SD 25.82.

The two samples are significantly different at the 95% level of confidence.

Normally onion should be left to mature for 6 months, at least, to gain maximum weight. In these trials onions were weighed early to give a comparison between the growth potential on onion of poor soil and also soil enhanced with ***Fossa alterna*** humus. In both cases the onion yield was at least doubled by the addition of ***Fossa*** eco-humus to the poor Epworth soil. In fact the best mix for onion is to plant in rich soil mixed with leaf mould and to feed regularly with a water-urine mix. In much richer soils fed with a water-urine (3:1) feed, twice or three times a week, 1.4 kg of onion can be produced in a 10 litre basin in a 4 month period (see urine trails). The ***Fossa alterna*** soil, when mixed with poor soil does not provide the ideal medium for impressive yields of onion or maize by themselves. However, supplemented with urine, they can produce excellent crops.

The reaped onions reveal the enhancing effect of *Fossa alterna* humus on very poor top soils. The yield on poor Ruwa soil (141 gms) has been increased to 391 gms in *Fossa* enhanced Ruwa soil, an increase of nearly 3 times. This is a significant increase in onion production. However the best onion crops are produced on very rich organic soil. They are hungry feeders.

Plant trials with *Fossa alterna* soil on an existing vegetable bed

This trial was carried out at Woodhall Road between November 2003 and January 2004 to test the influence of ***Fossa alterna*** soil (with and without urine application) upon an existing vegetable bed. The addition of ***Fossa alterna*** soil to an existing bed is perhaps one of the most likely methods of using the humus. The influence of both eco-humus and urine will vary greatly depending on the existing state of the soil and the plant. Where nutrient levels are depleted, the influence may be considerable. Where nutrient levels are adequate, the effect will be less noticeable. In this case existing nutrient levels were quite high in the soil.

In this case, the influence of the humus and urine was tested on two green vegetables, rape and spinach, which are both popular in Zimbabwe. The existing bed was re-dug and soil mixed as best as possible and divided into three equal sections, A, B and C. Each bed measured 1.5m X 3.5m (5.25 sq.m.). ***Fossa alterna*** soil was applied to two of the beds (A and C) at the rate of 12 X 15 litres spread over the bed and mixed into the topsoil (see chapter). Local topsoil was applied to the centre bed (B), also at the rate of 12 X 15 litres spread over the whole bed and mixed in. 25

spinach and 25 rape plants were planted in each bed (on 22nd November). These were watered regularly to keep in good health. After 11 days urine treatment started on bed C with a 3:1 mix being applied to the bed, three times per week (2 X 8 litres per application). At all other times all beds were watered in the same way. Soil samples of the ***Fossa alterna*** humus were analysed on several occasions, with two samples being analysed from each bed before planting and after initial watering. Further samples were taken after urine application (see later chapter).

During the trial there was no evidence of nutrient deficiency in any of the beds, even in the centre bed (B). This shows that the bed already had sufficient nutrients to sustain vegetable production, as would be expected in an existing bed. The aim was to demonstrate any additional benefit from the addition of humus and urine.

Results

All the vegetables were harvested on a single day 28 days after the initial application of urine to bed C. Each plant was harvested and weighed. Since both spinach and rape can be harvested several times a single small leaf was retained by the plant after cutting to allow the plant to continue to grow. The results of the first harvest are shown below. In a few cases plants were taken by rats and a low plastic wall was built around the vegetable garden.

Bed A (topsoil+ecohumus)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	4153 gms	25	166.12 gms
Rape	2478 gms	23	107.73 gms

Bed B (topsoil)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	2349 gms	24	97.87 gms
Rape	1928 gms	25	77.12 gms

Bed C(topsoil+ecohumus+urine)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	3918 gms	24	163.25 gms
Rape	2488 gms	23	108.17 gms

The vegetable garden associated with the *Fossa alterna* at Woodhall Road. On the left, the day of planting vegetables 22nd November 2003. 25 spinach and 25 rape seedlings were planted on each of the 3 beds. The bed on the extreme left and right have been enhanced with *Fossa alterna* soil. The bed in the centre has existing topsoil. The right photo shows the state of the beds on 10th December.

The beds the day before harvesting on 30th December 2003. Vigorous growth is seen throughout. The bed improved with *Fossa alterna* soil showed an increase of 70% for spinach production and 40% for rape production over the unimproved bed, which was already clearly good. On the right harvesting and measuring each plant (see results below).

1. Plant growth

In the bed mixed with extra ***Fossa alterna*** soil, spinach harvest was increased by 1.7 times (after 4 weeks) and rape 1.4 times (after 4 weeks), despite the existing bed being already quite adequate in terms of soil nutrients. After 6 weeks and two croppings the increase had been reduced slightly to1.6 times (spinach) and 1.3 times (rape). After 8 weeks and three croppings the total weight of spinach cropped on Bed A was 4754 gms, compared to 3027 gms on Bed B and 4425 gms on Bed C. After 8 weeks and three croppings the total weight of rape cropped on Bed A was 3233 gms, compared to 2736 gms on Bed B and 2698 gms on Bed C. Thus overall the application of the humus increased the spinach crop by 1.57 times and the rape crop by 1.18 times.

However the application of urine in this particular case does not seem to have had much beneficial effects on the overall growth of either rape or spinach. This negligible effect may have been the result of either an over application of urine, or an application which was in excess of what the plants required. In this case both appear applicable, as existing levels of NPK were quite adequate without any further urine application being necessary. Towards the end of the trial vegetables planted in the urine fed bed were beginning to die out, no doubt due to over feeding with nitrogen derived from urine. 3 weeks after the second cropping all the rape plants had died out. This will be discussed in more detail in the section on plant trials with urine.

The results of this trial also reveal that the extra nutrients provided by the ***Fossa alterna*** humus do not sustain increased plant growth for much over 2 months, and the main effect is during the month following application of the humus. The figures show a depletion of both spinach and rape output after successive croppings. This would be expected to be generally the case for plants that are cropped repeatedly. But in urine fed basins, crop output of spinach was maintained at a high level during the second month of cropping spinach when the current trial was running. This indicates a depletion of nutrients in the soil or adverse conditions for growth in the chosen bed. Clearly the best option for beds is combine the use of both ***Fossa alterna*** humus and diluted urine to the beds to sustain maximum output throughout the year. As indicated earlier, the application of other organic materials like leaf or garden compost to the bed also helps production greatly. Note that the addition of humus, not only adds nutrients but provides a better soil environment for the application of urine.

The bed used in this case was surrounded by trees so full sunlight came later in the morning and was not identical for each of the beds with the centre bed being the most sunned. The growth potential for all plants including vegetables depends on a variety of factors of which soil fertility is an important one. Regular watering, either by natural rainfall or by artificial watering is essential for a good crop. Also the best crops are produced where there is plenty of sunshine. In the present case, the sun did not arrive on the bed until mid to late morning, and this would have had an overall reducing effect on the final production.

Individual weights

BED A. Spinach gms.
90,65,110,120,188,174,188,103,173,263,170,160,260,175,169,218,150,258,160,240,228,138,90,213,50. T=4153. N= 25. M=166.72.

BED A. Rape gms.
149,28,58,52,23,198,185,220,140,55,128,42,111,130,22,104,78,70,131,156,118,242,38. T=2478. N=23. M=107.73.
BED B. Spinach gms
100, 90, 102, 124, 80, 83, 130, 98, 58, 102, 138, 184, 40, 70, 192, 91, 58, 132, 70, 90, 110, 60, 42, 105. T=2349. N = 24. M= 9787.
BED B. Rape gms
60, 130, 42, 128, 47, 70, 38, 60, 46, 60, 170, 142, 58, 90, 62, 100, 72, 118, 35, 48, 86, 37, 87, 40, 102. T=1928. N= 25. M=77.12.
BED C. Spinach gms
82, 34, 110, 40, 179, 100, 268, 202, 368, 211, 115, 178, 198, 423, 153, 183, 177, 118, 249, 128, 50, 99, 42, 211. T=3918. N=24. M=163.25.
BED C. Rape gms
162, 222, 100, 142, 122, 130, 49, 82, 163, 39, 135, 60, 50, 47, 60, 34, 90, 189, 61, 37, 207, 140, 167. T=2488. N=23. M=108.17.

Second harvest

Both spinach and rape can be harvested several times from a single plant if the conditions are suitable. In this case the initial crop was cut and weighed from beds A, B and C four weeks after urine application (on bed C). A second crop was cut and weighed 2 weeks later (after 6 weeks of urine application on bed C) and about 7-8 weeks after planting. The second crop cut 2 weeks after the first crop was much less than the initial crop as shown below.

Bed A (topsoil+ecohumus)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	429 gms	19	22.57 gms
Rape	576 gms	18	32.00 gms

Bed B (topsoil)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	508 gms	20	25.40 gms
Rape	622 gms	22	28.27 gms

Bed C(topsoil+ecohumus+urine)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	405 gms	17	23.82 gms
Rape	210 gms	10	21.00 gms

Third harvest

A third small crop was cut and weighed 4 weeks after the first harvest, 2 weeks after the second harvest and 8 weeks after initial urine application on bed C). The second crop cut 2 weeks after the first crop was much less than the initial crop and the second crop as shown below.

Bed A (topsoil+ecohumus)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	172 gms	12	14.3 gms
Rape	179 gms	14	12.78 gms

Bed B (topsoil)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	170 gms	18	9.44 gms
Rape	186 gms	14	13.28 gms

Bed C(topsoil+ecohumus+urine)	**Total harvest**	**No. plants**	**Mean wt per plant.**
Spinach	302 gms	12	25.16 gms
Rape	0 gms	0	0 gms

2. Nutrient levels

The humus derived from the ***Fossa alterna*** was high in all major nutrients as the 2 initial samples show (mean N: 655, mean P: 296, mean K: 5.26). This was mixed with the existing vegetable bed soil at a rate of 2 parts garden soil to one part ***Fossa*** humus. The resulting mixed soil contained NPK as follows. Bed A (mean N: 207, mean P: 325, mean K: 4.16). Bed C (mean N: 367, mean P: 328, mean K: 1.42). By comparison the existing vegetable garden soil contained NPK as follows. Bed B (mean N: 304, mean P: 316, mean K: 1.37).

All 3 beds were then thoroughly watered and planted with seedlings and then re-watered again. After a few days the soil was sampled again. This time the results were as follows: Bed A (mean N: 253, mean P: 308, mean K: 2.02). Bed C (mean N: 367, mean P: 305, mean K: 2.89). By comparison the existing vegetable garden soil contained NPK as follows. Bed B (mean N: 116, mean P: 156, mean K: 1.04). Thus as the plants were growing the application of the eco-humus had increased the NPK levels significantly, but even existing levels were quite adequate for normal plant growth. After a further 4 weeks, and the day before cropping, further samples were taken. The results were as follows: Bed A (mean N: 151.5, mean P: 323, mean K: 1.73). Bed B: (mean N: 97.5, mean P: 259, mean K: 0.79). By comparison, bed C after 4 weeks of urine showed: mean N: 199.5, mean P: 302, mean K: 1.65). No sample showed any sign of a lack of nutrients. All samples were quite adequate for plant growth.

Soil analysis (N, and P as ppm and K, Mg and Ca as ME/100gms)

Fossa alterna soil	pH	N	P	K	Ca	Mg
Sample 1.	6.8	720	307	3.32	27.04	13.08
Sample 2.	6.8	590	286	7.20	27.56	12.80

Bed samples before watering

Bed A	ph	N	P	K	Mg	Ca
Sample 1.	7.1	214	331	6.75	34.78	5.13
Sample 2.	7.4	200	320	1.58	32.64	4.98

Bed B	pH	N	P	K	Mg	Ca
Sample 1.	7.1	275	329	1.40	31.10	4.77
Sample 2.	7.1	333	304	1.34	33.74	4.93

Bed C	pH	N	P	K	Mg	Ca
Sample 1	6.8	294	358	1.26	24.58	4.70
Sample 2.	7.1	174	298	1.58	32.46	4.61

Bed samples after watering

Bed A	pH	N	P	K	Mg	Ca
Sample 1.	6.9	295	289	1.32	26.66	8.00
Sample 2.	7.0	211	327	2.72	30.32	6.88

Bed B	pH	N	P	K	Mg	Ca
Sample 1.	7.0	118	176	0.99	17.74	3.44
Sample 2.	7.0	115	137	1.10	12.45	2.91

Bed C	ph	N	P	K	Mg	Ca
Sample 1	7.0	400	296	3.44	30.42	7.90
Sample 2.	6.7	334	315	2.34	33.02	8.00

Bed samples – 4 weeks after urine treatment to Bed C.

Bed A	pH	N	P	K	Mg	Ca
Sample 1.	6.9	160	312	1.65	24.96	7.26
Sample 2.	7.0	143	334	1.82	29.62	6.20

Bed B	pH	N	P	K	Mg	Ca
Sample 1.	7.2	119	341	0.82	31.08	4.46
Sample 2.	6.9	76	177	0.77	13.45	3.25

Bed C	pH	N	P	K	Mg	Ca
Sample 1	6.4	217	290	1.50	19.49	5.06
Sample 2.	6.7	182	314	1.80	27.60	5.76

Overall conclusions

These simple plant trials reveal the considerable value of humus derived from the ***Fossa alterna*** when applied to very poor sandy soils in equal proportions in containers (see table below). The effect is also positive even when applied to existing vegetable beds, at a ratio of one part ***Fossa alterna*** soil to two parts top soil, although the increased yield is less. Every year a single family ***Fossa alterna*** will provide at least 0.5 cubic metres of humus which can be mixed with an equal volume of very poor topsoil to make one cubic metre of suitable planting medium for vegetables. This one cubic metre mix of rich soil will provide enough material to fill 100 ten litre buckets or basins, or 7 shallow trenches (each 3 m long, 0.3m wide and 0.15m deep), or about 10 square metres of shallow vegetable garden, about 10cm deep. At the slightly lower rate of application of 2 parts topsoil to l part humus about 16 sq.m. of vegetable bed can be invigorated.

The production of vegetables from such a back yard vegetable garden might be considerable. Using figures revealed in from the trials in containers, one can estimate that **27 kg of spinach** (first crop only at least two crops can be reaped) or **17 kgs of covo** (first crop only - covo can be cropped for an extensive period) or **37 kg rape** or **45 kg lettuce** or **41 kg green pepper** or **73 kg**

tomatoes or **40- 50 kg onion** could be grown on the annual output of ***Fossa*** humus mixed with local topsoil. Obviously there would be a mix of these crops produced in practice. As can be seen from the equivalent weight of vegetables grown on poor soils alone, this is a remarkable enhancement in vegetable production compared to what have been possible without the eco-humus. Crop yields are consistently increased by adding eco-humus to poor soils from doubling to over a ten fold increase. However the actual increase in yield would depend on the existing nutrient status of the treated vegetable bed. For an already fertilised bed, one could expect an increase in yield of about 50%.

Summary of plant trials in containers described in this chapter.

Plant. Top soil type. Growth period.	Weight at cropping Top soil only	Weight at cropping 50/50 mix topsoil/FA*soil
Spinach on Epworth 30 days.	72 grams	546 grams (7 fold increase)
Covo on Epworth 30 days.	20 grams	161 grams (8 fold increase)
Covo 2. on Epworth 30 days.	81 grams	357 grams (4 fold increase)
Lettuce on Epworth. 30 days	122 grams	912 grams (7 fold increase)
Onion on Ruwa 4 months	141 grams	391 grams (2.7 fold increase)
Green pepper on Ruwa 4 months	19 grams	89 grams (4.6 fold increase)
Tomato on Ruwa 3 months	73 grams	735 grams (10 fold increase)

Whilst such an output would not sustain the family throughout the year, it is a meaningful contribution to vegetable crop yield, and in areas which are deprived would be seen as valuable addition to the family's food supply. Since the value of the humus must be seen in addition to the value of the improved and long lasting nature of the sanitary facility itself, the overall benefit is considerable.

As with all methods which take advantage of fertile soil for vegetable production, the soil nutrients do become depleted as they are used for plant growth. Therefore the fertility of the soil itself must be restored by re-mixing with more recently made eco-humus or with other compost. In this way the fertility of the soil is maintained - what is taken up by the plants is put back. This is the best way of maintaining a healthy annual crop of vegetables.

Another important point to mention is that the results shown in this chapter apply mostly to ***Fossa alterna*** soils mixed with naturally occurring soils of exceptionally poor quality. Sadly such soils are common where people live in many parts of Africa. Epworth, one source of the poor soil used in these trials, comes from an area close to Harare where over 100 000 people live. Ruwa is typical of so many other sandy areas in Zimbabwe where huge numbers of people live where the soil has been depleted of nutrients, as a result of erosion, leaching and constant use of land without re-fertilisation. In Zimbabwe 70% of rural farmers work on a soil which is labelled as poor or very poor in terms of the nutrient and humus content. Most soils are sandy and have a low pH. Few soils in the rural and even peri-urban and urban areas can sustain any form of healthy crop production without meaningful inputs of both humus and nutrients (Farai Mapanda (pers.comm). Thus any form of fertile soil which can be locally produced and mixed with the poor local topsoil can only be seen as advantageous.

In all these cases, there is an urgent need to replenished the fertility of the soil. This can be achieved by cattle manuring or composting where alternative means are too expensive. It is in such places that the value of the humus derived from the ***Fossa alterna***, maybe most eagerly sought. Obviously where ***Fossa alterna*** humus is used on garden soils which already hold higher level of nutrients, then the effects will be less dramatic than those described in this chapter (see later chapter). The important point is that ***Fossa*** humus does contain meaningful amounts of valuable nutrients which are important to plant growth and by applying them to any soil, the nutrient levels are restored or increased. In addition the physical condition of the natural soil is improved where ***Fossa alterna*** humus is added. Thus what ever soil is considered the overall effect is one of enhancement and improvement.

Yet another important point to stress is that the annual production of eco-humus from the family latrine (***Fossa alterna***) is only sufficient to enhance the family backyard vegetable garden and no more. But this backyard production of vegetable matter can be increased significantly in areas where the soil is poor. The results also reveal that the eco-humus may have limited application with crops like maize, which are grown in very large numbers. But there is nothing to stop the gardener enhancing the effects of the eco-humus further by applying urine. This can be applied in diluted form to vegetable gardens or neat to maize in the fields. This can produce excellent results with maize as well as green leafy vegetables, as we shall see later. Also garden compost, manure, leaf compost and other liquid feeds should also be used to enhance the soil and subsequent vegetable production. Extra nutrients can be provided by inorganic fertilisers, but these will not be used to any extent in the organic farming promoted by eco-san. In fact it would be normal practice to add liquid feeds or manure or compost in the vegetable garden to produce optimal growth of vegetables.

In addition, the process operating in the ***Fossa alterna*** is entirely natural, and the humus which is withdrawn is nothing less than a marvel of Nature. A strong link is made between the sanitation and agriculture. The latrine becomes a humus factory. The second pit of the ***Fossa alterna*** can be used as a pit composter during the first year or it can be used as a site to make leaf mould. This leaf mould alone can make considerable improvements to poor soils.

The potential for this system is enormous. The ***Fossa alterna*** is cheap to build and easy to maintain and there is a valuable end product. But the routine upkeep of the ***Fossa alterna*** does require more effort and attention than the standard pit latrine. The excavation and mixing and reuse of the eco-materials in agriculture requires time and determination. It is hoped that the return of improved yields of food will make all the effort worthwhile. In a world where the soils are poor and there is always a need for more food, such an effort is surely worthwhile.

The 10 litre cement basin proved to be a useful container to conduct plant trials. Here the poor growth of rape on poor Epworth soils (left) is compared with the much improved growth of rape on the same poor soil enhanced with *Fossa alterna* humus. In almost every case the difference is striking. The influence of the humus is particularly noticeable on very poor sandy soils, which are very common in Africa. The humus applied to sandy soils also helps the process which enables the nutrients in urine to enhance vegetable growth. *Photo by Brian Mathew.*

14. The usefulness of urine

Urine has been used as a valuable plant food for centuries in many parts of the world, particularly in the Far East. It is surprising therefore that nearly all the urine produced in the West and in Africa goes to waste and is lost to agriculture. Each of us passes about 1.5 litres of urine every day - and almost to the last drop, it is either flushed down a toilet or enters a deep pit latrine. The fact is that urine is a very valuable product - in several ways. It contains a lot of nitrogen and also phosphorus and potassium in smaller quantities, nutrients which are very valuable to plant growth. Simply put, urine is too valuable to waste.

The nitrogen found in abundance in urine is good for plant growth because it helps to build protoplasm, protein and other components of plant growth. It certainly promotes leafy growth. Leaves become more numerous, go greener and larger and more fleshy with urine application. Phosphorus is important in the root formation, ripening of fruits and germination of seeds, although the percentage of phosphorus compared to nitrogen in urine is low. Potassium is also essential for promoting good fruit (and flower) development. Plants differ in their requirements, but overall plants fed with some urine grow better than plants which never come into contact with urine. Urine is particularly valuable for grasses like maize and leafy green vegetables, and onions, which respond to the high nitrogen content of urine.

Methods of collecting urine

By far the simplest method of collecting and storing urine is for men to urinate in bottles when they visit the toilet. There are several other methods which can be used - the "desert lily" concept is one - where a funnel is mounted over a plastic drum in some position which allows the passing male to urinate in privacy. The simplest are funnels mounted over 20 litre plastic containers. Piping, fittings and containers should be made of plastic - the urine is very corrosive – metal will corrode badly. Various types of urinal can be fitted within toilets built outside.

The urine diverting pedestal is also another suitable method for collecting urine. These pedestals are commonly used in ecological sanitation projects all over the world. There are variants which allow for squatting as well as sitting. The urine diverting pedestal has a pipe which can be used to convey urine into a storage vessel like a 20 litre plastic drum. Care must be taken to ensure that faecal matter does not enter the urine section. Pedestals mounted over removable buckets can also be used to collect urine - they are useful for women. "Potties" filled at night in the bedroom can also collect urine – a well established method. Urine collectors can also be made which fit into conventional flush toilets, the urine being decanted into plastic bottles. Once the urine is collected - it is stored in plastic containers which are capped before use or processing.


Collecting and storing urine in bottles is the easiest way for men. On the left urine stored in discarded two litre milk bottles. A funnel placed over a 20 litre plastic container is also effective if well placed in some private location. It is a type of "desert lily."


On the left a 10 litre bucket is placed beneath a pedestal which helps women to collect urine. On the right a urine collector shaped from a plastic bucket is used to collect urine from a standard flush toilet.

Storage

Urine can be stored in bottles (2 litre plastic milk bottles for instance) or plastic containers (e.g. 20 litres) for long periods provided they are well capped and the ammonia is not allow to escape. Deposits of the phosphorus and magnesium salts will be deposited however on the base and side walls of the container. Once stored, urine usually turns darker. The exact constituents of urine vary from one person to another.

Uses of urine in agriculture

There are at least five ways of using urine for the benefit of agriculture. These are:

1. **Urine applied to soil without dilution before planting**
2. **Urine applied to soil without dilution near the young plant, followed by watering**
3. **Urine applied to soil - diluted with water – to the growing plant**
4. **Urine as an "activator" for compost.**
5. **Urine as a medium for fermentation of plant residues**

Examples of using urine to enhance vegetable production in containers.

Vegetables like covo, rape, spinach and several other green leafy vegetables can adapt to a wide range of urine applications when applied to containers provided that water is also applied liberally. In fact in the case of vegetables and other plants grown on containers, which hold a relatively small volume of soil, it will always be necessary to apply water regularly to sustain plant health, since the volume of water held in the soil is small. On a hot day, the plants will wilt easily, and require frequent watering. With such a constant throughput of water, diluted urine can be applied as frequently as 3 times per week. For use on containers, urine can be diluted with water at the rates of 3:1 or 5:1 and applied once, twice or three times a week. Where there is a large throughput of water in containers it is best to apply in small doses more often then bigger doses less often. Experience has shown that provided fresh water is added to the basin frequently, green vegetables can withstand the 3:1 and 5:1 applications without harm. Generally the rate of growth of green vegetables is in proportion to the amount of urine applied. However in the longer term, a build up of salt occurs, and there may be an excess of nitrogen which will inhibit the uptake of potassium.

For these reasons it is wise to empty the containers of soil treated with urine and remove them to a compost site where the soil can be mixed with other composts and soils and watered without urine application. Thus the soil can be restored and invigorated.

A good standard procedure for green vegetables like rape and spinach growing in 10 litre containers is to apply a 3:1 mix twice a week for the first month, with intermediate watering. Reduce this to a 5:1 mix twice a week for the second month with intermediate watering. From then on apply a 5:1 mix once per week with intermediate watering.

For tomatoes grown in buckets only apply diluted urine after the first small fruits appear. Then apply 0.5 litres of 5:1, once per week with wood ash (add a tablespoon per week to the bucket soil and watering in).

Also for longer term onion (6 months to harvesting) in basins, apply a 3:1 mix twice a week for the first month, with intermediate watering. Reduce this to a 5:1 mix twice a week for the second month with intermediate watering. From then on apply a 5:1 mix once per week with intermediate watering.

Green vegetables respond well to diluted urine treatment

Preparing the urine/water mix

General equipment required for applying urine. Various buckets, watering can, rubber gloves and 0.5 litre jug for dispensing the mix. Supply of urine (in 2 litre plastic bottles). A 5:1 mix can be made with 2 litres of urine and 10 litres water. A 3:1 mix can be made with 2 litres of urine and 6 litres of water.

Add the 2 litres urine first to a larger (20 litre) bucket, then add 10 litres water from the 10 litre bucket.

Apply to the containers from a 0.5 litre jug or similar container. Once or twice a week depending on duration of application. For shorter term (1 – 3 months) on green vegetables, twice a week with plenty of watering in between. For longer term (3 – 6 months) the mix should be applied once a week with plenty of watering in between (tomatoes and onion).

In some applications additional sources of nutrient are mixed in with the urine/water. Like extra phosphate or wood ash applied at the rate of 5gms per 0.5 litre charge of urine and water (5:1). The wood ash supplies extra potassium, particularly suitable for tomatoes.

Mixing in extra wood ash to the jug. 5 gms (level tablespoon) ash per 0.5 litres of 5:1 application. The ash helps to make plants more healthy and is good for fruiting. In this case it is being applied to spinach in an experiment. This type of application is particularly good for tomatoes.

RAPE

Rape is one of the most popular vegetables grown in Zimbabwe. It is used a great deal in relish eaten with maize meal in combination with onion, tomato and meat. It responds well to being grown in containers which are fed urine diluted with water. In this trial, rape was fed diluted urine (3:1) twice a week. The urine application led to a 5 fold increase in harvest after 28days. This is an excellent response to urine.

Plant	Liquid plant food	frequency of application	weight harvested
Rape	water only	normal watering	160 gms (9 plants)
Rape	3:1 water/urine	0.5 litres 2 X per week	822 gms (9 plants)

Left: Photo shows 3 basins (on left) which were water fed and on right 3 basins fed with a 3:1 water/urine mix, twice a week. The effect only became noticeable after 10 days treatment. After 28 days water/urine application the effect is very noticeable (photo on right with water treatment below and urine treatment above. Some of the basins are obscured. Rape yield was increased about 5 times.

Left: The relative yields of water fed and water/urine fed rape grown on 10 litre basins after 28 days application. The plants have just been harvested for the first time. Right: the same plants almost a month later just before the second crop was harvested. Yellowing and mauve colour on some leaves begin to show after 2 months of urine application at this rate, indicating that the plants are beginning to weaken. This is probably due to over application of nitrogen from the urine. Longer trials like this provide the best indications of the most suitable water/urine treatment under these conditions. A weaker 5:1 application given to the plants once a week may be better in the longer term

Spinach

Spinach is another popular vegetable in Zimbabwe. Like rape, several harvests can be taken from the same plant over a period of several months. It is ideally suited for growing in containers which are fed diluted urine as shown below. During the first month, the urine application (3:1, twice per week) led to a 3.4 fold increase in harvest after 28days, compared to water fed plants. This is an excellent response to urine. During the second month the urine dose should be reduced to 5:1, twice a week and during the third month and after, the urine dose should be reduced further to 5:1, once per week. 0.5 litres of the diluted urine is applied to each basin per treatment. The plants are watered at all other times.

Plant	Liquid plant food	frequency of application	weight harvested
Spinach (22plants)	Water only	normal watering	741gms
Spinach (22plants)	3:1 water/urine	0.5litres 2 X per week	2522gms

Photos taken of the 16 basin spinach trial. Basins to the left of the green band are urine fed, those to the right water fed only. Photo on left taken on 3rd December 2003 on the first day of urine treatment. Photo on right taken on 31st December 2003, 28 days after first urine treatment. The effective of the urine treatment is very positive and very clear to see. Urine fed 3.4 times water fed.

Left: The total collected harvest of urine treated spinach on the left and water treated spinach on the right after 28 days of urine treatment (3:1, twice per week). Right: plants fed water/urine during their second month are beginning to lag behind plants fed the 3:1 water/urine mix for the first time. The best yield however is being produced by plants shown on the four basins to the right, which have been fed only two applications of the urine water mix and then leaf compost liquor under a mulch of leaves. These signs show that if urine is to be used as a liquid plant food over a prolonged period, the dose should become weaker as the time is extended. For spinach – first month 3:1, twice a week; second month 5:1, twice a week; third month and thereafter 5:1, once per week. Extended trials show that the lower dose can maintain spinach output, once the soil has been well fertilised by prolonged and correctly applied urine treatment. 0.5 litres of the diluted urine is applied to each basin per treatment. The plants are watered at all other times. Spinach responds very well to this type of treatment.

Onion

Onions are well suited to growing in containers and also respond positively to the application of diluted urine. Onions do take a long time to grow, between 6 to 8 months being required between planting seedlings and harvesting. Seeds are best planted during January or February (for Southern Africa) and allowed to grow in seeds trays. They are transplanted into cement basins when about 4 – 6 weeks old. During this period they can be fed with leaf compost liquor. After transplanting, a weekly application of a urine/water mix (1:5) will help the onion considerably and can begin a week or two after transplanting. Onions need good supplies of nitrogen as well as phosphorus (in the early stages) and plenty of potassium later on. The application of wood ash will help. Planting on a mix of ***Fossa alterna*** humus will help, even better if mixed with compost. A good leaf mulch will help the supply of phosphorus and potassium. The application of leaf compost liquor will also help.

Up to ten onion can grow in a single 10 litre cement basin. Onion are first grown in seed trays, then transplanted to basins. These onion were fed a 3:1 water/urine mix, once a week. They were planted as seedling on 17th May and reaped about 6.5 months later on 27th October 2003. An average of 1 kg of onion was reaped from each of ten jars planted. The number of plants varied between 5 -9 plants at harvest with weights per basin varying from 0.7kg to 1.3 kg. The growth was improved by the application of a mulch made of leaves. This reduced weeds and also provided some nutrients as well as reducing water loss from the soil. The basin and urine method appears to suit onion.

Some very good looking onion can be grown in cement basins with the help of a water/urine feed. Here two prize specimens! Onion seeds are best planted early in the year, late January or February being good times, so they can be transplanted into containers towards the end of the rains in April. The healthy onion on the right was harvested in early September after 6 months of water/urine treatment in a 10 litre cement basin. 0.5 litres of a 5:1 mix of water had been applied once a week for all that period together with intermediate watering. Such a result reveals the usefulness of urine as a plant food.

TOMATO

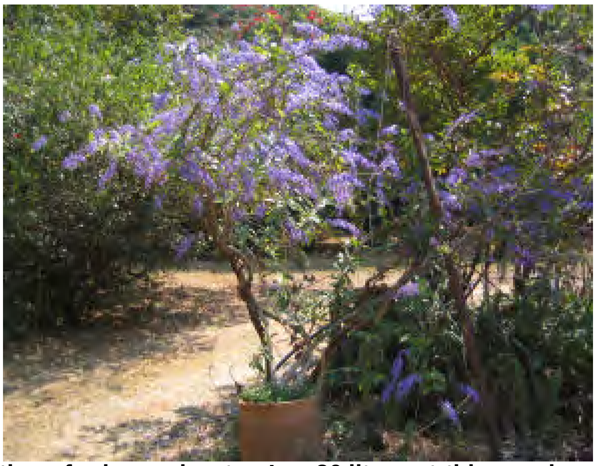
Tomato seedlings will grow in unmixed neat ***Fossa alterna*** humus, but grow better in a 50/50 mix of the humus and garden/leaf compost. The addition of the leaf compost makes the final mix more crumbly and well drained. The soil should be rich in phosphorus to start to help the plants grow sturdy roots and early shoots. When growing in containers most hungry feeders (like tomato, onion and other vegetables) will require additional feeding and in organic farming this is often supplied in liquid form. Diluted urine can be useful, if applied with care with the addition of wood ash (to enhance potassium) and also liquid feed from composting leaves. However diluted urine should not be applied until the flowers have formed and the early small fruit is starting to grow. If too much nitrogen is given (such as with too much urine application), the leaves will grow abundantly with less fruit production. After fruiting has begun more nitrogen (from urine) and particularly potassium (from wood ash) can be applied for the best yields. Tomatoes do require a lot of attention and special treatment to do their best. For more information on growing tomatoes using recycled human excreta, look at the chapter on gardening techniques.

Growing tomatoes in bags and buckets

More examples of plants grown with the help of urine


Young mulberry cuttings once established respond well to a dose of 5:1 water and urine weekly (0.5 litres per plant). The same applies to the mint plant on the right growing in a 10 litre bucket.

Passion fruit also responds very well to the application of urine and water. In a 30 litre pot this passion fruit is fed with 1 litre of a 5:1 mix of water and urine weekly. The petrea tree is also fed a 5:1 mix of urine and water (10 litres every month).


Celery also responds well to a 5:1 mix of urine and water (0.5 litres per container weekly). This large radish was fed in the same way.

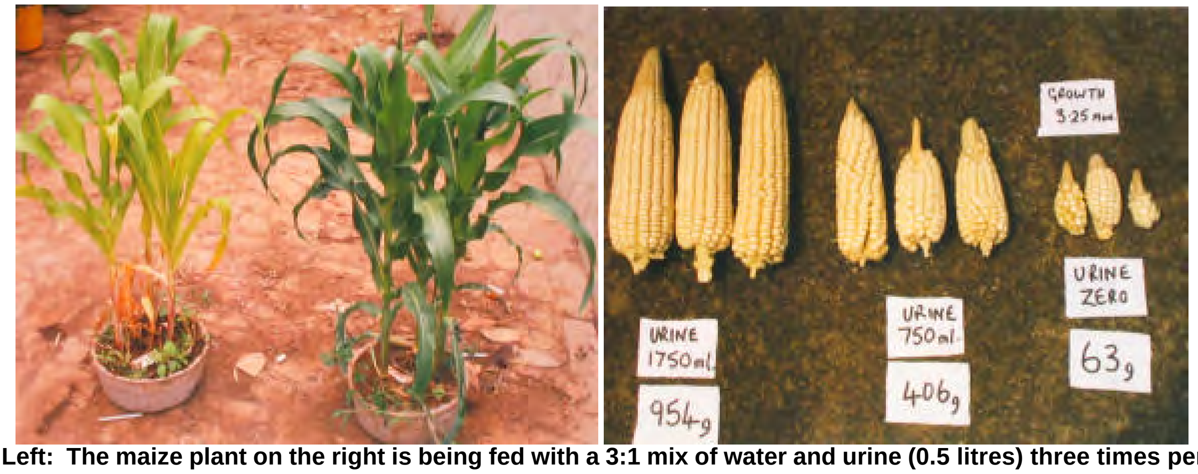
MAIZE

Urine can have a significant effect on maize growth. In the fields urine can be applied neat to soil before planting in beds. It can also be applied neat in hollows made near the growing plant. Neat urine applied to maize fields at the rate of 100mls per plant per week and then diluted with rain water, led to increases of cob weight between 28 and 39% compared to watered fed plants only in trials on the Marlborough vlei in Harare (See bibliography Ecological Sanitation in Zimbabwe vol. IV)

Maize trials on the fields using urine.

Growing maize in containers

Maize is rarely if ever grown in containers, but the effect of the growth of maize in containers when fed urine is stunning. Maize plants are hungry feeders and like a lot of nitrogen The application of a 3:1 mix of water and urine, once or twice or even three times a week on maize grown in 10 litre containers is particularly effective. For small scale maize or sweet corn production, this method may have application. It is also an effect way of demonstrating the effect of converting the nutrients held in urine into vegetative growth of valuable plants.



Left: The maize plant on the right is being fed with a 3:1 mix of water and urine (0.5 litres) three times per week. The maize on the left is irrigated with water only. The difference is striking. Right: Urine treatment also improves maize cob yield significantly. The total yield of cobs from maize planted in three 10 litre basins is shown. On the left the maize was fed 1750mls urine per plant over the 3.5 month growing period, resulting in a crop of 954 gms. A reduced crop resulted from reduced input of urine (middle). Maize plants on the right were irrigated with water. This is a very high rate of urine application, but one happily accepted by the maize plants in the containers which were irrigated frequently with water to keep the maize plants healthy.

Growing maize with the help of toilet compost and urine on poor sandy soils

Maize is the single most important crop in Southern and Eastern Africa – being the staple diet for hundreds of millions of people in the sub- region. And large numbers of these people live on poor sandy soils, which cannot support a good crop of maize without fertiliser, or adequate quantities of cow manure. For those living in the urban areas and peri-urban fringes, cow manure may be scarce and commercial fertiliser too expensive to buy. Yet millions of people eek out a living in these settlements by growing their own crops of maize and vegetables every year in back yard plots and gardens close to the home. It is a means of self survival in conditions which are often harsh and where malnutrition abounds. The simple question is then asked - can the use of toilet compost and urine, in combination, significantly increase the production of these backyard gardens, and thus make the effort worthwhile.

The work reported earlier in this chapter shows clearly how maize production can be enhanced considerably by the application of urine. Maize is a "greedy feeder" and requires considerable amounts of nitrogen to grow at its best and provide generous harvests. It also requires adequate amounts of phosphate in its early stages to enhance the growth of the root system and the young stem above ground. Normally, if commercial fertilizer is used a single maize plant is given at least 10gms of a mix of nitrogen, phosphorus and potassium in the ratio 1:2:1 (in Zimbabwe this fertilizer is known as Compound D). The elevated phosphorus content helps early root formation and shoot growth. At 4 weeks (or when the plant is at knee height) a further application of 10gms or more of ammonium nitrate is given. This is normally sufficient to carry the plant through its full vegetative growth. These two applications of "granular slow release" commercial fertilizer offer each plant between 4 and 5 gms of nitrogen, about the same as is found in one litre of urine produced by people who have a low protein diet - sadly the great majority who live in Zimbabwe. Very often an extra dose of ammonium nitrate is given when the young maize cob or cobs start to grow. This is thought to be an important application where bumper crops are required. It is generally known that the more nitrogen is applied the better the harvest. What is important is that the nutrients supplied first help the root and early shoot system, with the bulk of the nitrogen being applied to assist vegetative growth and cob formation during the life of the plant. So it helps if this application of nitrogen can be extended into the period of "grain filling" when the cobs themselves are growing. Grain filling normally starts about 10 weeks after the seed is planted. The cobs continue to gain in weight from 4 to 6 weeks after their formation. Good rains or adequate water supply are very important during this phase.

These requirements are well served by first planting the maize seed in a "plug" of toilet compost made in the soil. This compost is well aerated and contains humus – a requirement particularly useful for sandy soils. It also provides a supply of phosphorus and some nitrogen, suitable for the germination and early growth of the plant. Toilet compost also makes an excellent potting soil and is an ideal medium for the germination of seeds of many kinds. This compost is particularly valuable where local topsoil, like fine sandy soil, may not provide the ideal medium for germination. About 500 gms of toilet compost are applied per planting station. This is about one pea tin full.

A field trial in Epworth near Harare

Epworth is a large peri-urban settlement of about 200,000 people close to Harare. It was chosen as an experimental site to demonstrate the effectiveness of urine as an alternative to commercial fertilizer for maize production because it is characteristic of the conditions under which millions of people live both in peri-urban and rural areas in Southern Africa. Natural Epworth topsoil is sandy, porous, almost without nutrients and applied nutrients can easily be lost by leaching during heavy storms. Without commercial fertilizer or manure, maize and vegetable crops are generally very poor on soils of this type. However despite this backyard soil in Epworth is characteristically patchy with variable nutrient level. This is because over the years sections of land have been fertilized with manure and compost, particularly in delineated vegetable gardens. Also there is some fertilization of maize crops for those who can afford to buy. So there is some carry over of nutrients from year to year.

In the experiment, the field was dug and levelled beforehand and on planting day hundreds of small holes were dug in lines and rows ready for planting. 125mls of urine (which had been collected in 20 litre plastic containers previously) was applied to each "planting station. " This was followed by a 500gm plug of toilet compost. Two seeds were planted in the compost and covered over.


The field is prepared by digging and holes are made 30cms apart in rows 90cm apart. The 20 litre drum of collected urine is shaken up (to mix the phosphorus) and added to a 20 litre bucket. Date 5.11.2004


Using a dispenser, 125mls of urine is added to every hole


This is followed by one pea tin full (500gms) of toilet compost taken from the *Fossa alterna* or other composting toilet. Two seeds are then planted in the compost and pressed down and then covered with the topsoil. If seeds are in short supply then a single seed can be planted. Over 90% of registered maize seed will germinate. Another seed can be planted if a single seed does not germinate.


The seeds are pressed into the compost and covered with topsoil awaiting the rains


On the left the field site at Epworth showing the *Fossa alterna* from where the humus was taken. Picture on right taken 2nd December 2004 when the maize had started to grow.

If two seeds had germinated, which was normally the case, one was removed and planted elsewhere. Adding the second 125mls application of urine to the young plant.

Photos taken on 3rd January 2005. On the left photo the plants on the lower left were not treated with urine. Plants in mid picture and right had been treated. The difference is obvious. On the right photo, the lush growth of plants following urine treatment is clear to see.

Digging small hole near to plant step prior to urine application. On the right, the urine has been stored in the 20 litre plastic container. It is poured into a bucket and then dispensed with the small pill bottle dispenser next to each plant.

Applying the 125mls of urine in a hollow next to the plant. Best to cover over after application. 125mls are added weekly to each plant, the last 2 applications are added fortnightly to make a total of 1000mls for each plant. This is equivalent to around 5gms nitrogen.

17th January 2005, first signs of tassel (left) and cob (right).

This photo was taken 31st January 2005 at the time when the last of the urine was applied. In the treated area (right) the growth of maize has been good and cobs are already forming. On the left the untreated area shows smaller and paler plants with little cob formation.

Healthy lines of maize with healthy cobs growing in treated zone on 31st January 2005. On the right two cobs are growing, revealing that the urine application as per the schedule is adequate. On this day the final 125mls of urine was added making the total application one litre per plant. The first application was made at planting, the second to 6th application a week apart. The last two applications were spread a fortnight apart. This regime carries the application of urine nitrogen into the grain filling stage.

Final observations and cob measurement

In the current trial a small existing backyard maize field was chosen which also housed an ecological toilet **(*Fossa alterna*).** 200 maize were planted in 500gms of toilet compost and treated with a total of one litre urine during the vegetative and grain filling stages (as indicate above). A further 40 plants were not treated with compost or urine. 40 additional plants were treated with standard fertilizer. At harvesting and for comparison a small sample of cobs was also taken from an adjacent field where no treatment of any type had taken place. Seed was planted in mid November and cobs harvested in mid March a period of 4 months.

Results

Section	No. Plants	Mean cob Wt. (gms)	Equivalent grain wt.(gms)
.			
Untreated (field 2)	15	82.4	41
Untreated (field 1)	36	138.11	75
Treated: commercial fertilizer (field 1)	34	166.97	97
Treated: urine (1 litre per plant – field 1)	196	243.11	148

There was much variation between individual plants in all sections (apart from field 2) of the trial, mainly due to the variable existing nature of the soil even within each section of the experimental field, and probably due to earlier applications of manure, compost or fertilizer. This variation is characteristic of such fields and gardens. This variation was less evident in the urine fed section, where the treatment had a significant effect on maize growth and cob size – with more consistently larger cobs. Overall mean cob weight was increased by 1.76 times (138gms to 242gms) by urine application when compared to the untreated section. When plotted against grain weight, this increase in cob weight (X 1.76) represents a doubling in the yield of grain. When plotted on a graph, a 138gm cob yields 75gms of freshly stripped grain compared to the larger 243gm cob which yields 148gms of grain. The relatively high mean for untreated maize (field 1) was probably due to a sub-surface bed of manure or compost in one patch of the control zone which promoting healthy growth of a few plants making up 27% of the total cob weight in this section. The mean cob weight of urine treated maize (243gms) was about three times the mean cob weight (82gms) of sample cobs taken from another untreated field nearby, more typical of the area, where cob weights were more consistently poor. In terms of grain weight this is an increase of four times. The urine was produced by the family itself and probably contained about 5gms/litre nitrogen, approximately the same as the nitrogen applied with commercial fertilizer. Residents in the area were impressed by the effect of urine treatment, which was plainly visible and cost nothing, but did require effort on the part of the householder.

Put in simple terms

The application of 1 litre of urine per plant, applied in small lots (125mls) over the growth period, doubled the grain yield of maize growing on poor sandy soil compared to unfed plants.

15. Further plant trials using urine as a liquid feed

Now is the time to provide further evidence of the effect of urine treatment on plant growth and crop yield - particularly leafy green vegetables and the important crop of maize. There is an infinite variety of ways of applying urine to the soil - the dilution, frequency of application and volume applied are all variable. In the backyard vegetable garden the urine is best diluted with water and then applied periodically to the soil in which the plants are growing. Even when a particular dilution and frequency of application have been worked out, the response of plants to urine application may vary considerably - being influenced by several factors such soil type and its existing nutrient level and also the type and age of the plant itself.

Trial design

Since most of the plant trials described in this book have been undertaken in cement basins and plastic buckets, it is wise to explain the possible advantages and disadvantages of the container as an environment for growing vegetables and other crops. Take one example, for instance, where plants, say hungry feeders like maize, onion or even tomato, are grown in containers which hold a limited amount of soil available (ten litres). The soil in one container is fed water only and in the other container a water-urine mix. At first the soil filling both containers will be able to supply all the nutrient requirements for the early growth of the plants. Plants in both containers will grow equally. But as the plants mature, their demand for nutrients increases. Those plants fed with water only will slowly use up the available soil nutrients held within the container, and their growth may be retarded, depending on the nutrient level in the soil itself. The plants fed with water and urine will continue to grow healthily, using nutrients derived from the urine. For this reason the increased growth recorded in urine fed plants in these trials are the direct response to the nutrients available in the urine alone. Such growth is the result of an increased supply of nutrients only – urine has no influence on the physical properties of the soil.

There are some positive aspects to growing plants in containers. Those nutrients derived from the urine are dispersed and converted only in the soil held within the container itself. Thus the reaction can take place in a well defined volume of soil and not be dispersed and perhaps lost to the plant, as would be the case in fields or even vegetable beds where the soil depths are greater and excess watering or rain can drive the nutrients (particularly nitrogen) deeper into the soil. In Sweden urine is not applied to the fields during the main autumn rains, partly because of the fear that the nutrients will be lost as the rain soaks into the soil and makes its way down to the standing water table (Håkan Jönsson pers.comm.). There is a net movement of water down to much deeper levels in the soil. Thus soluble nutrients like nitrate may be lost to the topsoil during heavy rain. In Southern and Eastern Africa, maize is planted during the main rains, when water drains down through the topsoil and the "overburden" to top up the aquifer beneath. It is during heavy rains that there is a loss of nutrients from the topsoil to deeper lays. Nitrogen in particular is very soluble and easily flushed away during the rains. Thus the effect of nitrogen may be reduced or lost. Slow release commercial fertilisers in granular form assist by releasing their products slowly over time, but even in this case, the type of rainfall may influence the effect of the fertiliser on nutrient retention and uptake by the plants. Where nitrogen is released from urine, much of it may be flushed down below the root layer during heavy rains and the effect on maize growth will be less pronounced. Conversely if there is reduced rainfall and no artificial watering, the effect of urine treatment on plant growth can also be poor (Björn Vinnerås pers.comm.). Thus the use of basins has at least one advantage, that the use and uptake of urine may be more effective and the resulting uptake of nutrients greater. Also because the urine is applied quite frequently, any loss of nitrogen after flooding can be made up on the following application. By comparison, phosphorus binds better with the soil and is less easily flushed away during heavy rain (about 10% may be lost due to leaching). The salts of phosphorus derived from urine, calcium phosphate and magnesium ammonium phosphate ("struvite") are both good slow release fertilisers (Håkan Jönsson pers.comm.). Potassium is also fairly stable in the soil with about 10% loss due to leaching (Hopkins 1945).

Another factor is "pot binding," where the roots of plants growing in containers, being confined, have a negative influence on plant growth. This may be the case for the use of 10 litre cement basins and plastic buckets, where the root volume increases to occupy much of the space of the container. The roots of maize plants grown for 3 months in a 10 litre container occupy a great percentage of the volume of the container. And yet they appear to thrive well enough. The writer has grown maize 1.2 metres high in soil 100mm deep and produced maize cobs weighing 365 gms. The advantage is that once the crop has been harvested, the soil in the containers can be recycling through the compost heap and the roots sieved out. There can be constant replenishment of the soil held in containers– it is very adaptable method not dependent on the nature of local topsoil – which is invariably poor. When containers are emptied and the soil recycled, a huge array of roots can be seen in the soil. So much in fact that the roots bind the soil to form a plug. Once the crop has been harvested the plug of soil is removed, sieved and recycled ready for use in the next series of containers.

So there are advantages and disadvantages of growing vegetables and other food crops in containers. For experimental purposes they are ideal, since their environment can be standardised. The aim is to interpret the results for use in other environments. The writer has had much success in growing a wide variety of food crops in 10 litre cement basins, where 50 units can be made from a single 50 kg bag of cement together with river sand.

High levels of Nitrogen

Whilst vegetables require a lot of nitrogen, particularly for leafy growth, they also require phosphorus at an early stage to assist in root growth and early shoot formation and later potassium to help fruits form and mature. If there is too much nitrogen in the system, some of the other elements may not be able to act (Hill, 1981). Too much nitrogen can stress a plant and slow down its growth. If there is too much nitrogen about, the potassium, for instance, can get "locked up" - the transpiration system which becomes filled with chemical salts and only a fraction of salts like potassium gets through (Hill, 1981). Thus an excess of nitrogen may prevent other plant foods from working at their best. This is clearly very undesirable, particularly for plants that require potassium for fruiting - tomato is a good example. When there is much nitrogen the plant may direct nutrients to make more vegetative growth and leaves and use less to make the fruits. Also unless plants have plenty of humus in the soil they cannot take up the minerals even if the minerals are available. So it pays to introduce humus into the soil - as this helps the plant assimilate nutrients and also helps convert urea into nitrate which the plants can also use.

High levels of sodium chloride

Urine has a very high content of common salt (sodium chloride – NaCl). The daily output of urine (about 1.25 litres) contains about 7 gms chlorine and 5 gms sodium, combined to make sodium chloride, nearly as much as the 13 gms of nitrogen (mostly present as urea) and far more than the potassium and the phosphate. Excessive amounts of salt are known to be detrimental to plants (Håkan Jönsson pers. comm.) and can adversely affect the growth of plants. However, excess salt can be washed out by leaching with water. This may happen in the plant trials in containers – where a great deal of plain water is applied as well as the water/urine application.

Nutrient balance

We have already discussed in the previous chapter, that the ratio of nutrients contained in urine is not ideally balanced for vegetable or even maize production, particularly on phosphorus deficient soils, having a very high content of nitrogen in relation to phosphorus and potassium. Thus urine application at an early stage in plant life may actually slow down the growth of plants. This has been revealed in experiments in which the growth of seedling tomato, rape and spinach, fed urine continuously (at 3:1 and 5:1 applications) without further water dilution, grew more slowly than seedlings which were given water only. Thus, the initial nutrient need of the plants is best catered for by eco-humus and leaf compost.

This photo shows how the continuous application of urine can slow down the growth of seedlings. 3 rape and 3 spinach seedlings have been planted in each of the three lower sets of basins. The basin on the right has been watered with plain water only – the one on the left with a mix of 3:1 water and urine continuously. The one in the middle with a 5:1 water/urine mix continuously. The constant application of urine has slowed down plant growth, the greater the strength of the urine the more stunting effect. Plants are more tolerate of urine when they are more mature, and respond well to diluted applications of urine applied with plenty of intermediate watering with plain water.

Thus care is required on the application of urine, especially when the plants are young and require more phosphorus for their root and early shoot development. Whilst urine may not be the best plant food in terms of its nutrient balance, it is a great provider of nitrogen and has the unique advantage that it costs nothing and is freely available at all times to the gardener. Thus every possible advantage should be taken for the use of urine as a plant food.

PLANT GROWTH TRIALS WITH URINE

The following trials carried out on seedlings of lettuce, spinach, tomato, covo, and maize were conducted by planting the seedlings in either 10 litre buckets or basins and watering with plain water until the young plants were stable. Then some of the seedlings were watered with a urine water mix (normally 3 parts water and 1 part urine), three times per week and other control seedlings were irrigated with plain water only. This regime was followed for a specified number of days. At the end of the growth period, the plants were weighed and comparisons made between those fed with the urine/water mix and those irrigated with plain water only.

Lettuce - trials 1 & 2.

This trial was undertaken during August/September 2002.Three lettuce seedlings were planted in each of 4 X 10 litre buckets. The soil in two of the buckets was irrigated with 0.5 litres of diluted urine (a 3:1 mix of water and urine), three times per week (U1 application) with all other irrigations with water only, over a 30 day period. The other two buckets were irrigated with water only. Since these trials were conducted in the winter with no rain, a lot of watering was necessary to keep the plants healthy. A second trial following the same procedure was also carried out over a 33 days period. The results are shown below.

Plant	Liquid plant food	frequency of application	weight harvested
Lettuce	3:1 water/urine	0.5 litres 3X per week	**500** gms (30 days)
Lettuce	water only	normal watering	**230** gms (30 days)
Lettuce	3:1 water/urine	0.5 litres 3X per week	**345** gms (33 days)
Lettuce	water only	normal watering	**120** gms (33 days)

Note 1: Lettuce 30 day trial. 3 plants were grown in each container, one being watered only the other being fed a 3.1 mix of water and urine 3 X per week (500mls per container). In this only the combined weight of 3 lettuce in each container was measured, not individual weights. 230 gms for water only fed lettuce and 500 gms for lettuce also fed the water/urine mix.

Note 2. Lettuce (33 day trial)

Plants irrigated with water only. Weights per plant :40, 40, 40. T = 120 gms, N = 3, M = 40, SD = 0.
Plants irrigated with water and a 3:1 water/urine mix. Volume of water/urine mix applied approx 160 mls per plant, 3 X per week. Weights per plant: 115, 100, 130. T = 345 gms, N = 3, M = 115gms, SD = 15.

The two samples are significantly different at the 95% level of confidence.

Thus between **two and three times** the yield of lettuce resulted from applying 0.5 litres of 3:1 water/urine mix, three times a week, interspersed with watering compared to lettuce which was irrigated with water only. This is a significant increase in yield, resulting from the application of about 0.5 litres of urine per plant over the growth period. This is just less than one third of the daily output of urine per person per day.

Photo of lettuce growing in soil irrigated with water and urine (3:1) on the right (500gms) compared to 230 gms on the left grown on soil irrigated with water only.

Rape

This trial was undertaken during December 2003.Three rape seedlings were planted in each of 6 X 10 litre cement basins. The soil in three of the basins was irrigated with 0.5 litres of diluted urine (a 3:1 mix of water and urine), twice a week (Saturdays and Wednesdays) with all other irrigations with water only, over a 28 day period. The other three basins were irrigated with water only. The first application of urine took place on 3rd December 2003 and the crop was harvested on 28th December 2003. The results shown below indicate a five fold increase due to urine treatment.

Plant	Liquid plant food	frequency of application	weight harvested
Rape	water only	normal watering	160 gms (9 plants)
Rape	3:1 water/urine	0.5 litres 2 X per week	822 gms (9 plants)

Individual plant weights. Plants irrigated with water only: 51, 4, 38, 12, 10, 6, 4, 5, 30. T = 160 gms, N = 9, M = 17.77gms. Plants irrigated with water and a 3:1 water/urine mix (approx 160 mls per plant), 2 X per week. Weights per plant: 160, 68, 79, 94, 119, 91, 81, 100, 30. T = 822 gms, N = 9, M = 91.33gms.

Photo on the left shows little effect of urine after 10 days (water application on left, urine application on right – 13th December.). After 28 days (31st December) the effect is noticeable (photo on right with water treatment below and urine treatment above - the basins are obscured).

Photo on left shows nutrient deficiency on water fed basin. The mauve colour is due to deficiency of phosphorus. On the left the total harvest of rape from water fed basins (left) and urine fed basins (right).

The experiment was continued for another 28 days during which all the basins were fed the same 3.1 mix of urine and water, twice a week. There was surprisingly little reaction in the hitherto untreated plants, whilst the previously urine fed plants continued to respond to the urine treatment. The results below show that the previously urine fed plants continued to yield more than the more recently urine fed plants also by a factor of about five times. Rape is a sensitive plant, and perhaps the lack of nutrients in the early stage of growth of water fed plants led to a poor development of the root system. Thus despite the later application of nutrients, the plants failed to respond.

Plant	Liquid plant food	frequency of application	weight harvested
Rape	3:1 water/urine	0.5 litres 2 X per week	108 gms (7 plants)
Rape	3:1 water/urine	0.5 litres 2 X per week	713 gms (8 plants)

Individual plant weights. Plants irrigated with water and a 3:1 water/urine mix for the first time: 6, 10, 8, 13, 12, 24, 35. T = 108 gms, N = 7, M = 15.4gms. Plants irrigated with water and a 3:1 water/urine mix (approx 160 mls per plant), 2 X per week for the second month. Weights per plant: 98, 38, 72, 30, 130, 125, 129, 91. T = 7138ms, N = 8, M = 89.12gms.

Rape plants after 8 weeks of urine treatment (upper row)

In being a sensitive plant, rape also reveals nutrient deficiencies more readily than the tougher spinach plant. Towards the end of the second month of urine treatment very obvious signs of deficiencies of both phosphorus and magnesium were revealed, despite the generous urine treatment, or perhaps because of it. Phosphorus deficiency shows up as a mauve colouring in the leaves, and magnesium deficiency as a yellowing of the leaves, whilst the leaf ribs remain green. They indicate that for rape at least, the urine treatment given (0.5li X 3:1 X 2 per week) was too high for long term application. This may have been caused by too much salt or potassium provided by the urine which adversely affects magnesium uptake. The lush growth caused by high nitrogen input may have later led to inadequate phosphorus being available for the plant from the urine provided. Phosphorus is the least available of the major plant nutrients in urine.


Closer view of nutrient deficiencies showing up in rape after 8 weeks of urine treatment. The mauve colouring ís due to phosphorus deficiency and the yellowing of the leaf with green leaf ribs is magnesium deficiency. Both may result from high applications of urine. The application of urine was subsequently reduced from 0.5li per basin of 3:1 twice per week to 0.5li per basin of 5:1 once per week

The conclusion to be drawn is that for rape the 3:1 treatment twice a week is too high for prolonged application, and this was subsequently reduced to a 5:1 treatment weekly for all plants.

Spinach (trial 1)

Spinach is a hardy, easily grown vegetable which is very popular in Africa and all over the world. It grows easily from seed, grows well in beds and basins and is very responsive to the use of urine. The plant, once established can be repeatedly reaped for several months. The main leaves are harvested leaving one or two of the youngest leaves on the plant to start a new regeneration. It is therefore a natural choice for plant trials using urine. This trial was undertaken during August/September 2002. Three spinach seedlings were planted in each of 2 X 10 litre buckets. The soil in one of the buckets was irrigated with 0.5 litres of diluted urine (a 3:1 mix of water and urine), three times per week with all other irrigations with water only. The other bucket was irrigated with water only. The spinach was reaped after a 30 day growth period. The results are shown below. The urine/water application increased the harvest of spinach by over **six times**.

Plant	Liquid plant food	frequency of application	weight harvested
Spinach	3:1 water/urine	0.5 litres 3X per week	**350** gms (30 days)
Spinach	water only	normal watering	**52** gms (30 days)

Note: Spinach 30 day trial. 3 plants were grown in each container, one being irrigated with watered only, the other being fed a 3.1 mix of water and urine 3 X per week (500mls per container). Only the combined weight of the 3 spinach grown in each container was measured and not individual weights. 52 gms of spinach were measured in the container irrigated with water only. 350 gms of spinach were measured in the container irrigated with a 3:1 mix of water and urine and also water at other times.

On the left 52 gms of spinach produced in a bucket after 30 days of water treatment compared to 350 gms of spinach on the right in a bucket after water/urine treatment.

Spinach (trial 2.)

This trial was undertaken during November/December 2003. Three spinach seedlings were planted in each of 16 X 10 litre cement basins (29th November). The soil in eight of the basins was irrigated with 0.5 litres of diluted urine (a 3:1 mix of water and urine), twice a week (Saturdays and Wednesdays) with all other irrigations with water only, over a 28 day period. The other eight basins were irrigated with water only. The first application of urine took place on 3rd December 2003 and the crop was harvested on 28th December 2003. The results shown below indicate a 3.4 fold increase due to urine treatment.

Plant	Liquid plant food	frequency of application	weight harvested
Spinach (22plants)	Water only	normal watering	741gms
Spinach (22plants)	3:1 water/urine	0.5li. 3:1 X 2 per week	2522gms (X 3.4)

Individual plant weights.
Plants irrigated with water only. Weights per plants: 4, 29, 69, 42, 21, 26, 31, 22, 40, 32, 15, 40, 24, 115, 2, 25, 42, 4, 51, 30, 40, 37. T = 741 gms, N = 22, M = 33.68gms.
Plants irrigated with water and a 3:1 water/urine mix (approx 160 mls per plant), 2 X per week. Weights per plants: 151 65, 80, 35, 28, 39, 138, 32, 236, 35, 69, 68, 42, 31, 110, 164, 195, 219, 106, 389, 250, 40. T = 2522gms, N = 22, M = 114.63gms.

Photos taken of the 16 basin spinach trial. Basins to the left of the green band are urine fed, those to the right water fed only. Photo on left taken on 3rd December 2003 on the first day of urine treatment. Photo on right taken on 31st December 2003, 28 days after first urine treatment. The effect of the urine treatment is very positive and very clear to see.

Plants were individually weighed on 31st December, 28 days after urine treatment began. On the right the total collected harvest of urine treated spinach on the left and water treated spinach on the right.

After cropping, the experiment was continued for another 28 days during which the original 8 urine fed basins continued to be fed urine at the same rate (0.5li of 3:1 X 2 per week). A further four basins which had so far not been treated urine were fed urine at the same rate of the others. The remaining 4 basins were initially fed two treatments of the water/urine mix and then covered with leaf mulch and fed with leaf compost liquor (0.5litres, twice a week). This was done to compare the influence of urine and leaf compost liquor application. All plants were watered to keep healthy at all other times. The results are shown below.

Plant	**Liquid plant food**	**Application rate**	**weight harvested**
Spinach (18plants)	3:1 water/urine (2nd month)	0.5li. 3:1 X 2 per wk	1917gms (18 plants)
Spinach (10 plants)	3:1 water/urine (1st month)	0.5li. 3:1 X 2 per wk	853gms (10 plants)
Spinach (22plants)	Water/urine X 2 + leaf liquor	0.5li. 2 X per wk	1312gms (11 plants)

Individual plant weights.

Plants irrigated with urine (2nd month). Weights per plants: 42, 227, 22, 67, 140, 148, 60, 35, 143, 41, 189, 118, 55, 163, 160, 140, 180, 41. T = 1917 gms, N = 18, M = 109.5gms.

Plants irrigated with urine (1st month). Weights per plants: 38, 63, 60, 40, 97, 153, 94, 95, 148, 65. T = 853gms, N = 10, M = 85.3gms.

Plants irrigated with urine (2 applications) + leaf compost liquor. Weights per plants: 163, 162, 63, 108, 123, 123, 39, 219, 130, 132, 50. T = 1312gms, N = 11, M = 119.27gms.

Discussion

Previously urine fed plants continued to produce a good harvest during the second 28 days period of urine treatment, with a slightly reduced mean weight per plant of 109.5gms compared to the original 114.63gms. The mean weight of plants fed urine over a 28 day period after 28 days of water treatment only was less at 85.3 gms per plant. Clearly with urine treatment, the best plant growth results when urine is applied as the plant is still maturing. However the best mean weight of plants resulted from a combination of urine treatment (2 applications) followed by a series of application of leaf compost liquor. Here the soil was covered with a thick layer of leaf mulch. The liquor fed plants were lighter green in colour and looked more succulent and healthy. By comparison the urine fed plants were darker and appeared more prone to insect attack. Perhaps the liquor fed plants received a better balance of nutrients and this led to an overall improvement in the general condition of the plant. Also the mulch may have contributed to plant growth, partly by supplying extra nutrients, partly by reducing weed growth (which was rampant in many of the urine fed basins) and partly by reducing water loss from the soil. Reduced leaf weight due to insect attack, which was more common in urine fed plants compared to liquor fed plants, would also have reduced the mean weight per plant.

However liquor fed plants showed some early signs of nitrogen deficiency, revealed by yellowing of basal leaves in some plants. Leaf liquor does not have the same nitrogen content as diluted urine. Clearly the application rate of the liquor was not adequate to keep up with the optimal growth of the spinach. An increased application of liquor would therefore serve the plants better.

Of interest here is the effect of combining. The combined application of diluted urine with leaf liquor appears to have been effective. It is possible that the liquor provides more of the minor nutrients and helps to increase phosphorus and potassium, whilst the urine provides nitrogen, the initial boost of only two applications being beneficial.

The conclusion to be drawn is that prolonged urine treatment, even for spinach, may be more effective with a lower dose (0.5li. of 5:1, once per week), since the reduced nitrogen in the overall urine/liquor application during the 28 days period appeared to increase the crop, not reduce it. The application of both leaf liquor (if available) and diluted urine appears to be the most favourable option, possibly with a single dose of diluted urine once per week with intermediate liquor applications. The other beneficial feature is the introduction of a leaf mulch to the basins in which plants are growing.

Left: heavily urine fed plants turn dark green but appear to be more susceptible to insect attack as shown. Right: in this trial the much lower dose of urine coupled with leaf liquor treatment produced lighter green and succulent leaves which were less attacked by insects.


The garden of 16 cement basins with spinach used in this trial on the day of the second harvesting. Compare to the days of first harvesting, above. The plants nearer the camera are larger in this case. The lower dose of urine combined with leaf compost liquor has been effective. On the right the three piles of spinach, on the left the liquor fed (11 plants), in the middle the plants fed initial 28 days of urine treatment (10 plants), on the right plants fed with urine during 56 days (18 plants)


On the left the pale yellow leaf of one of the liquor fed plants revealing slight lack of nitrogen. On the right the nitrogen deficiency on spinach (below) is compared to magnesium deficiency in rape (above).

Spinach trial 3. (adjusting the balance of nutrients in urine application)

Urine has a very high content of nitrogen in relation to the levels of both phosphorus and potassium. Phosphorus is valuable for root growth and the establishment of early shoots and potassium valuable for fruit formation and the overall health of the plant. So the less than ideal balanced nutrients available in urine may reduce the overall capacity of the plant to reach full growth and maximum health. This trial was undertaken by comparing the growth of plants on relatively poor soil irrigated with water with plants grown on the soil irrigated with a 3:1 mix of water and urine and also a special mix of 5:1 water and urine to which supplementary phosphorus (5 gms) was added. The volume of 3:1 mix and 5:1 + P mix was 0.5 litres per container, twice per week. All plants were placed in 10 litre cement basins. Thus the N/P ratio was changed in the second type of application with the proportion of nitrogen falling and phosphorus rising. The spinach were planted on 3rd December 2003, with urine application starting on 12th December. Applications of either 3:1 (water and urine) or 5:1 water and urine supplemented with 5gms single super-phosphate fertiliser were applied twice per week for 4 weeks with harvesting taking place on 9th Jan.2004, 4 weeks after the first urine application. All plants were irrigated with water to keep them healthy at all times.

Results (weight of individual plants in grams after 1st 28 day period)

Water fed plants (5 plants): (10, 10) (16, 9, 12). Total wt.= 57gms. **Mean wt =11.4gms**
Plants fed 3:1 water/urine 2 x per week. (9 plants): (40, 74, 32) (68, 43, 22) (62, 70, 47). Total weight = 458gms. **Mean wt = 50.88 gms**. **4.46 times water fed plants.**
Plants fed 5:1 water/urine with P. 2 X per week (9 plants): (103, 43, 88) (135, 58, 95) (145, 66, 59). Total wt. 792 gms. **Mean wt = 88.00 gms**. **7.71 times water fed plants.**

On the left a photo taken on 12th December just over a week after planting. The two basins on the extreme right are fed with water only. The 3 upper basins from the left were irrigated with a 5.1 mix of urine and water (250mls + 50 mls) with 5 gms phosphate added, twice per week. The whitish colour of the phosphate can be seen on the soil. The 3 lower basins from the left were irrigated with a 3:1 mix of urine and water (about 300mls) three times per week.

The same basins 4 weeks later. Note the considerable growth in all urine fed plants, compared to the water fed plants. The application of the 3:1 urine/water mix (twice per week) led to 4.4 fold increase in spinach yield. The application of a 5.1 urine/water mix with additional phosphorus led to a7.7 fold increase in spinach yield. This result reveals the importance of phosphorus at an early stage of plant growth and how it can influence the final yield. Even the greater quantity of nitrogen present in the 3:1 water/urine application did not lead to a greater crop yield even with this green vegetable. Unfortunately urine has a low proportion of phosphorus compared to nitrogen and the best effects of urine are felt when the levels of other nutrients are elevated in some way.

The cut spinach after 4 weeks of urine application. The plants fed water only are very small on this poor soil (lower left). The mean weight of the 9 plants fed a 3:1 water urine mix was about 50gms (lower right) compared to 88gms for plants fed a 5.1 water/urine mix with phosphorus added. The application of less nitrogen and more phosphorus had a very positive effect on crop yield

After cropping, the experiment was continued for a further 4 weeks in which the water fed and 3:1 urine fed plants were irrigated in the same way as the first 4 weeks. However the 5:1 application was modified with the 5g phosphorus being replaced with 5g wood ash to supply potassium. Thus 50mls urine was combined with 250mls water to which 5gms wood ash was added. This treatment, like the 3:1 treatment was carried out twice per week.

Once again, after a further 28 days of growth the 5:1 water/urine treatment with additions (ash) produced a higher yield than the 3:1 treatment. So once again, the greater quantity of nitrogen present in the 3:1 water/urine application did not lead to a larger crop yield even with this green vegetable. Urine has a low proportion of both phosphorus and potassium compared to nitrogen and the best effects of urine are felt when the levels of other nutrients are elevated in relation to nitrogen, as the experiment reveals. Diluting the nitrogen (urine) more, and adding supplementary nutrients like P and K with correspondingly higher yields resulting appears to reveal that urine is not a well balanced plant food and is best applied with additional nutrients being applied. However, even with no supplementary nutrients being added, the urine fed yield on green vegetables growing on containers is still considerably higher than vegetables fed water alone.

The results of the second crop harvested after a further 28 days of growth are shown below.

Results (weight of individual plants in grams after 2nd 28 day period)

Water fed plants (5 plants): (10, 8) (10, 10, 14). Total wt.= 52gms. **Mean wt =10.4gms**
Plants fed 3:1 water/urine 2 x per week. (7 plants): (80, 59) (57, 30) (61, 102, 92). Total weight = 481gms. **Mean wt = 68.71 gms**. **6.60 times water fed plants.**
Plants fed 5:1 water/urine with wood ash 2 X per week (9 plants): (39, 23, 80) (127, 65, 209) (150, 61). Total wt. 754 gms. **Mean wt = 94.25 gms**. **9.06 times water fed plants.**

The spinach plants just before cropping, 28 days after first cropping. The two basins on extreme right hand side have been water fed only. The upper three basins have been fed a 5:1 water/urine mix with wood ash added. The lower three basins have been fed a 3:1 water/urine mix only. Even although green vegetable growth like spinach relies heavily on nitrogen, the additional phosphorus and potassium from wood ash enhanced the growth.

The cut spinach after a further 4 weeks of urine application. The plants fed water only are very small on this poor soil (mean wt 10.4 gms). The mean weight of the 7 plants fed a 3:1 water urine mix was about 68 gms compared to 94 gms for plants fed a 5.1 water/urine mix with wood ash added. The application of less nitrogen and more phosphorus followed by more potassium (in wood ash) had a very positive effect on crop yield

Discussion

This is an interesting result since it reveals that the final weight of even green vegetables, which are nitrogen hungry, is not entirely due to the quantity of nitrogen supplied, but is also considerably influenced by the level of phosphorus and also potassium. Whilst the application of a 3:1 mix of water and urine led to a 4.4 fold increase of the weight of spinach, the additional measure of phosphorus with reduced nitrogen led to a 7.7 fold increase in the harvest compared to water fed plants. It is assumed this is a direct relation to the enhanced root growth that would have resulted from extra phosphorus application. All plants benefit from the early healthy development of the root system, and this seems to have been revealed here. If the soils are deficient in phosphorus, which most soils in this part of Africa are, then the additional application of phosphorus is very beneficial. Perhaps this is why nearly all compound fertilisers sold in Zimbabwe have a higher proportion of phosphorus compared to other major nutrients. When the ratio of nitrogen to phosphorus is too high, the increased needs of the growing vegetative plants above ground cannot be fully met by the less developed root system, which in itself leads to a reduced overall crop.

The second 28 day harvest in which potassium (supplied by wood ash) was elevated also increased the yield but not to the same extent as the first 28 day harvest when phosphorus was elevated. The increase of mean plant weight by applying less nitrogen and more phosphorus (5:1 + P) compared to the standard water urine mix (3.1) was 1.72. This compares to a 1.37 fold increase of mean plant weight by applying less nitrogen and more potassium (5:1 + K) compared to the standard water urine mix (3.1). It is not known whether the increased growth during the second 28 day period is due to the additional potassium added or to the larger root system that may have developed during the first 28 days. In any event, the combined use of both additional phosphorus and potassium (with wood ash) was very beneficial to plant growth as shown below. The overall increase in harvest by applying both P and K was 1.64 compared to the 3:1 application only.

Total 56 day crop (2 croppings)

	Water only	3:1	5:1 with P and K
1st 28 day harvest	57 gms	458 gms	792 gms (with P)
2nd 28 day harvest	52 gms	458 gms	754 gms (with K)
TOTAL	**109 gms**	**939 gms (X 8.6)**	**1546gms (X 14.18)**

Interestingly the second harvest for both types of urine application was little changed from the first harvest. However the increased harvest due to diluted urine alone was very significant well worth the effort. This trial was performed on very poor topsoil, when increased harvests are greater compared to plants grown on soil containing more nutrients. Also the die off of plants was less, 5/6 for water fed plants, 7/9 for 3:1 water/urine fed plants and 8/9 for 5:1 water/urine fed plants.

In ascertaining the best method of applying urine, it must be accepted that it does not have the ideal ratio of major plant nutrients. It is mainly a supplier of nitrogen with some potassium and phosphorus. Any method of raising the level of phosphorus in relation to nitrogen will improve the crop. Similarly with the uptake of potassium, if the nitrogen content is too high, potassium uptake by the plant will be reduced, leading to poorer yields of fruit and poorer health of the plant overall.

In this case the percentage of phosphorus was increased artificially by adding chemical fertiliser. Other methods involve sedimenting out the phosphorus and using the lower half of the mix which has a higher proportion of phosphorus in relation to nitrogen. Potassium levels can be increased (as in this case) by the addition of wood ash to the soil. Also comfrey has a high proportion of potassium and can be added as a mulch or a liquid fed to potassium hungry plants like tomato, onion, potato and beans. Alternatively the use of compost or humus from the ***Fossa alterna*** can be used to build up the phosphorus levels of soils which are deficient in this important mineral.

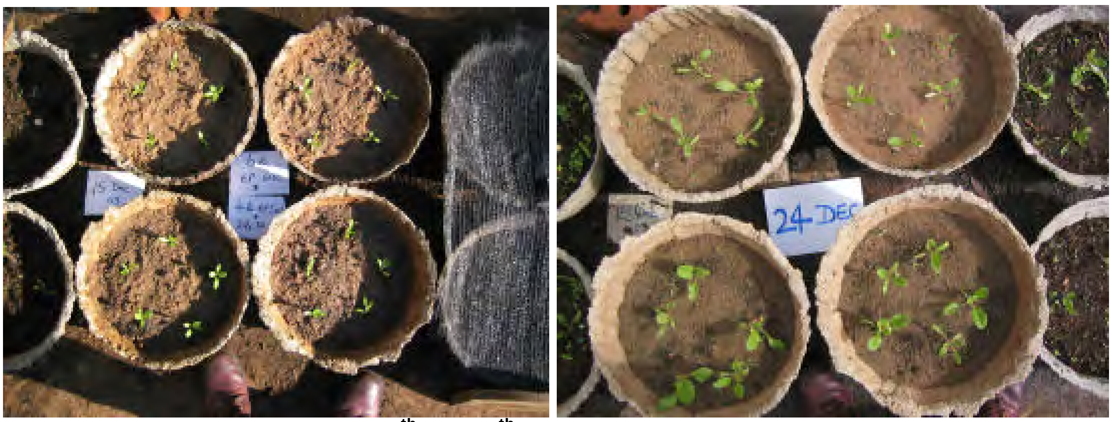
This experiment is also noteworthy in its implications for the growth of tomato, which responds very positively to the various primary plants nutrients. In particular a good supply of potassium is essential for a meaningful fruit crop, and too much nitrogen, whilst boosting leaf growth, will not induce a good harvest. As discussed later, the application of urine alone to tomatoes is not ideal.

Spinach trial 4. (effect on urine and *Fossa alterna* treatment on very poor soils).

This simple yet valuable experiment was conducted during the December 2003/January 2004 period. Four 10 litre basins were taken. Two were filled with a very poor sandy soil derived from the Epworth peri-urban settlement. The third and fourth were filled with a mix of 2 parts Epworth soil and one part ***Fossa alterna*** humus. By doing this some humus and nutrients were added to the poor sandy Epworth soil.

Five young spinach plants were added to each basin and kept watered. After 2 weeks 400mls of a water/urine mix (3:1) were added to two of the basins twice a week (one with Epworth soil and one with the mix of Epworth soil and ***Fossa alterna*** humus). This treatment was continued, twice a week for 28 days. On the 28th day the weight of each surviving plant was measured.

Results	Treatment	no.of plants	total weight (gms)	mean weight
Soil type				
Epworth	Water	4	6 (2, 1, 1, 2)	1.5gms
Epworth	Urine	3	33 (13, 10, 10)	11.00 gms
Epworth/FA	Water	5	34 (3, 9, 9, 10, 3)	6.8 gms
Epworth/FA	Urine	5	120 (11, 28, 10, 32, 39)	24 gms



Photos taken of the four basins on 15th and 24th December before urine treatment. The upper basins in both cases are plain sandy soil from Epworth, the lower basins are a mix of Epworth soil and *Fossa alterna* humus. The increase of spinach growth can already be seen in the lower basins. Urine treatment on two of the basins started on 31st December 2003.

The same basins photographed during at the termination of the experiment, 9 days and 28 days after urine application to the two lower basins in each case. In each photo the plain Epworth soil is on the right hand side and the mix of soils on the left hand side. The photos reveal the obvious result. Plants grow best when a combination of humus and urine is used.

Discussion

The experiment reveals that growth of even a hardy plant like spinach is very poor on the naturally occurring poor sandy soils of Epworth. 4 of the 5 plants survived with a mean weight of only 1.5gms. This must be compared to a mean weight of over 100gms per plant in similarly urine treated spinach in basins filled with better soil. The effect of mixing in ***Fossa alterna*** humus (ratio 2 soil to 1 humus) increased the mean weight of plants by about 4 times. The effect of adding diluted urine increased the mean weight of plants by about 7 times, although the survival of urine fed plants on plain soil was less. The greatest increase in plant growth (24 times) was recorded when both humus and urine were applied together, when the mean weight of plants after a 28 days period was 24 gms. This is still less than a quarter of what might be expected from urine treated spinach plants growing on better soil in basins.

These figures reveal the great challenge of improving vegetable production on very poor marginal sandy soils which are common throughout Southern Africa. It is clear that much greater increases in growth results from mixing very poor soils with ***Fossa alterna*** humus in equal proportions. In experiments carried out in 2002, spinach grown on a 50/50 mix of Epworth and ***Fossa alterna*** soil had a mean weight of 91gms compared to plants grown on plain Epworth soil (12 gms), an increase of 7.5 times. In another experiment a ten fold increase was recorded. The increased proportion of humus (50/50) clearly helped improve production in both cases. Clearly for very poor soils, ***Fossa alterna*** humus should be added in equal proportions to the sandy soil. Such increased production could be enhanced further by adding urine diluted with water. A weekly application of 5:1 would no doubt be very valuable. The slightly lower concentration of urine (5:1) compared to the 3:1 used in this trial would also increase survival rates.

The experiment reveals that urine alone is not effective at increasing vegetable production on poor sandy soils. A content of humus is essential for the effective use of urine on such soils. Whether this humus comes from the ***Fossa alterna*** or other sources is perhaps not important. Leave or garden compost would help and also mixing with more fertile soils or manure from elsewhere. The nitrogen in urine only becomes available to plants once it is converted by nitrifying bacteria present in the soil. One presumes that such beneficial bacteria is not present to any extent in these poor sandy soils.

Spinach (other trials)

Spinach, like rape and covo and various other green vegetables responds very well to urine treatment. It is a natural choice for plant trials involving urine treatment.

Two 10 litre basins planted with spinach. Soil in the left basin has been irrigated with a mix of 3:1 water/urine mix three times per week – the basin on the right just with water. The difference is very clear. Up to 2kg spinach can be reaped from a basin per harvest. Spinach can be harvested several times.

Vigorous growth of both rape and spinach in 10 litre cement basins. Both were irrigated with a 3:1 water/urine mix on the mornings of Monday, Wednesday and Saturday with all other irrigations just plain water. The photograph speaks for itself

This application of urine to spinach is a particularly successful one and many basins of spinach were enhanced in this simple way. Spinach, like covo can be cropped several times from the same plant. Like all the vegetables, spinach is also enhanced by the application of a 3:1 water/urine application even once per week – possibly a more practical way of applying it. The spinach in this trial was cropped after only 30 days growth, when the plants were still growing. Croppings of over 2kgs of spinach fed in the same way with urine have been made from 10 litre basins. Spinach is a very vigorously growing plant and responds well to the urine treatment.

Spinach, rape and tomato have been planted in these basins. On the left the plants are irrigated with a 3:1 water/urine mix and on the right with a fermented urine/comfrey mix. In both cases the growth is vigorous.

Covo. Trial. 1

Covo is a tasty and very popular vegetable, commonly grown in countless thousands of backyards in Zimbabwe. It is hardy and tolerates drought conditions better than most other leafy vegetables and is also more tolerant of low nutrient levels in the soil. Perhaps that it is why it is so popular as a vegetable grown on marginal soils. The leaves can be harvested for up to 2 years from the sturdy stem and new plants can be grown from cuttings.

In the trial, three covo seedlings were planted in each of two buckets of soil on 10th October, 2002. One bucket was fed with urine (0.5 litres 3:1 water/urine, 3 times per week), the other bucket being irrigated with water only. Two crops were harvested at monthly intervals. The total production of covo over the 2 month period was **153 gms** for water treated soil and **428 gms** for the urine fed plants, nearly **a three fold increase**. No individual plants were measured.

Covo. Trial. 2

This trial was conducted in 4 X 10 litre cement basins with three covo seedlings being planted in each on 11th October 2002. Two of the basins of covo were irrigated with water only and another with the U 1 urine treatment (0.5 litres 3:1 water/urine - 3 times per week for a ten litre basin holding 3 plants). Urine treatment started on 20th October. The fourth basin was fed with the U2 treatment (0.5 litres 3:1 water/urine – once per week for a ten litre basin holding 3 plants). All other irrigation was with water only to keep the plants turgid. The covo was cropped and weighed from each basin on 14th November, 13th December 2002 and 3rd January 2003. The total cropped weight of covo is given below:

Total weight of covo leaves cropped (11th October 2002 - 3rd January 2003)

Container	Yield gms
Basin 1 (water)	**134 gms**
Basin 2 (water)	**137 gms**
Basin 3 (U1 urine treatment)	**545 gms**
Basin 4 (U2 urine treatment)	**204 gms**

Notes With the Covo trial this same water/urine regine was fed 3 covo in a basin for about 8 weeks. The Covo was cropped three times, but on the first cropping only the combined weight of the 3 plants was recorded (127gms). Further crops of 108gms, 25gms and 25 gms were recorded on 3rd December and 148gms, 90 gms ands 22 gms were recorded on 13th December. Making a total of 545gms cropped for the 3 plants (181.6 gms per plant over the 8 week period).

The same recording pattern took place with the water fed plants. In this case 2 basins of 3 plants were watered and measured. The combined weight of plant reaped from one basin was 55 gms on the first weighing and 53 gms for the second basin. After this date individual plants were measured. On the 3rd December 12gms, 10 gms and 5 gms were reaped from one basin and 9 gms, 10 gms and 8 gms recorded from the second basin. On the 13th December 20 gms plus 24 gms plus 8 gms was reaped from the first basin and 15gms, 12 gms and 30 gms was reaped from the second basin.

So the total weight of covo cropped from the **3** urine and water fed plants was 545 gms (mean wt per plant 181.6gms. The total weight of covo cropped from the **6** water fed plants over the same period was 271 gms (mean wt per plant 45.16 gms). The average of the water fed plants over the period is 134 + 137 Div. 2 = 135gms). Thus the crop was increased by a factor of 4 times as a result of the water/urine treatment.

Significance of difference of crop of individually weighed covo.

Water Treated. 12, 10, 5, 9, 10, 20, 24, 8, 15, 12, 30. T = 163, N = 12, M = 13.58, SD = 7.44.
Urine treated: 108, 25, 25, 148, 90, 22. T = 418 gms, N = 6, M = 69.66, SD = 53.44.
The two samples are significantly different at the 95% level of confidence.

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Leaf growth in covo after a month of growth (just before second reaping). Picture shows basin with urine (U1) treatment (260 gms) and basin with water treatment only (57gms).

These results confirm that the stronger urine U1 application (3:1 water/urine X 3 per week) produced a better yield than the weaker U2 application (3:1 water/urine X 1 per week) and four times the yield of the water fed plants. The covo were able to cope with this urine dose, provided that normal watering was maintained at all other times to keep the plants turgid. However it is possible that the level of salt and nitrogen could build up to high levels in the soil held in small basins and restrict the growth over prolonged periods, i.e. several years. In practice the most efficient use of the urine was in the U1 treatment as shown below

Feed	**Weeks**	**Total urine/plant**	**Wt of covo**	**Increase**	**Mls urine/gm**	**ml/gm increase**
Water	10	none	**135.5gms**	-	-	-
U1	10	1250 mls	**545gms**	409.5	2.29 ml/gm	3.1
U2	10	400 mls	**204 gms**	68.5	1.96 ml/gm	5,8

There are various ways of looking at this result. By a small margin the U2 treatment was a more efficient way of using the urine. 1.96 litres were required to produce one gram of plant growth in the U2 treatment compared to 2.29 litres with the U1 treatment. But if one considers the increase in weight over and above the weight of water fed plants, then the U1 treatment was a more efficient way of using the urine.3.1 ml were required to gain one gram of plant growth above the water fed plants in the U1 treatment compared to 5.8 ml with the U2 treatment. In practice, an intermediate application of 0.5 litres of 3:1 water/urine applied twice a week (Wednesday and Saturday) on the soil with other daily applications of water being given may be effective and more practical.

Excellent crops of covo growing on 10 litre cement basins. Two plants are growing in the soil of each basin. The soil is actually a 50/50 mix of leaf mould and compost derived from organic kitchen waste, soil, and dog manure. Urine is applied twice a week as a 3:1 water/urine mi. 0.5 litres are applied with all other irrigation being plain water only. Grey water from a shower and wash basin is also applied. Self seeded tomato plants are also growing in the basins from seed found in the composted kitchen scraps.

Tomato

In this trial three tomato plants were grown in each of nine 10 litre buckets (total 27 plants) in garden topsoil. For the first month the plants were irrigated with water only to become established. For the next 4 months three buckets of tomato continued with the water treatment only. A further three buckets were watered with an application of 0.5 litres of water and urine (3:1 mix), 3 times per week (U1). The third series of buckets was fertilised with a urine/comfrey liquor containing a 5:1 mix of urine and water and fermented comfrey, also 0.5 litres per bucket of three plants, three times per week. The routine application of water was continued on all buckets at all other times to keep the plants healthy.

Less than one week after the application of the 3:1 water/urine mix the tomato leaves changed to a darker green colour and the growth of the plants was increased with leaves becoming far more fleshy and more numerous. The plants had more bulk - more stems, more leaves and potentially more fruits. This also took place with the 5:1 water/urine/comfrey application, but with leaves not so dark green in colour, revealing the lower input of nitrogen.

Yields of tomato over 4 month period

Plant	Liquid plant food	frequency of application	weight harvested
Tomato	water only	normal watering	**1680**gms (4 months)
Tomato	3:1 water/urine	0.5 litres, 3 X per week	**6084** gms (4 months)
Tomato	5:1 water/urine/comfrey	0.5 litres, 3 X per week	**6230** gms (4 months)

For the water fed plants, 41 tomatoes with a combined weight of **1680** gms were reaped (mean **40.97** gms) during the 4 month life of the plants. For the urine and water fed plants, 196 tomatoes with a combined weight of **6084** gms were reaped (mean **31.04** gms) during the 4 month life of the plants. Thus the total weight of tomatoes reaped from the urine fed plants was over three times the water fed plants, but the mean weight of each tomato was less. Thus the urine fed plants produced a higher number of smaller tomatoes. This may have been due to the higher proportion of nitrogen supplied by the urine which reduces potassium input which induces better fruit growth. The experiment lasted about 4 months. The first fruits were harvested on 23rd September 2003, with final fruits harvested early November.

Under the conditions of the trial, these results show a yield for tomatoes fed with the 3:1 water urine over **3.5 times greater** than similar tomatoes fed with water only. However the urine/water comfrey concoction did not provide yields much above the urine water mix.

Comments

These results do show that under the conditions of the trial, the applications of the 3:1 water urine mix, three times per week, resulted in a three fold increase in tomato production, although this larger harvest consisted of a larger number of smaller tomatoes. Nutrient levels in the soil picked up quickly after water/urine application and within one week the plants began to get larger and greener. An increase in fruit production followed. In fact all the tomatoes in the buckets which were fed water only used up the nutrients available in the buckets - they produced their fruits early and were also the first to die off – hallmarks of stressed plants. By comparison high levels of nitrogen fom the water/urine feed were maintained in the other buckets. Tomatoes fed in this way produced much leaf growth and also small fruit for a longer period. When plants like tomatoes are stressed they produce their fruits at a much earlier stage and less of them. Thus it is very probable that the tomatoes in the buckets fed with water only were responding to a stress situation brought on by a lack of nutrients, whereas those in the urine fed buckets were stressed by high levels of nitrogen.

The very poor yield of around 6 kg tomatoes from 9 plants (for urine/water and comfrey/urine liquor) is far below what can be expected from well fed tomatoes, and was most probably due to a combination of limiting factors. The soil used did not contain much humus, and it is certain that all tomatoes were stressed due to overcrowding. Also the high nitrogen regime in relation to the level of other nutrients will have reduced the full fruit forming potential of the plants. Tomatoes respond well to an initial boost of phosphate to help root growth and then subsequently enough nitrogen to boost vegetative growth, but also require potassium in generous quantities to produce the best fruit development. Urine, whilst high in nitrogen has much lower levels of potassium and even lower levels of phosphate and is certainly an unsuitable single plant food for the production of healthy tomatoes. A higher yield would have resulted from planting a single tomato in each bucket containing a more fertile, humus like living soil, with more potassium being made available.

The buckets on the right contain tomatoes irrigated with water only. Those on the left are being given the urine treatment.

Studies in Mexico with urine treatment of tomatoes also revealed that it was not the ideal plant food when used by itself, and after initially adding other chemical to urine to offset the deficiencies in phosphorus and potassium, chose to use the red worm (*Eisenia foetida*) to make fertile humus from kitchen waste in which the plants grew, which was high in available phosphorus and potassium. The urine, fermented by the addition of humus, was used as a liquid feed for tomatoes planted in a layer of enriched humus placed over a bucket of leaves - a method which produced excellent yields. Thus, where the soil is poor, compost or eco- humus is needed for soil improvement prior to the additional application of urine.

The tomato trial in particular reveals that whilst the application of urine can have a beneficial effect, plant health and an increase in crop yield depends largely on the plants growing in a healthy living soil, which contains a well balanced mix of nutrients. Indeed all these various trials reveal that the first priority should be to use soil which is fertile with compost mixed in to improve the content of humus and living organisms. Such compost already contains good quantities of phosphorus and potassium from the decay of vegetable matter. Tomatoes, onion, potatoes and beans all require a generous supply of potassium, as well as other nutrients. The high proportion of nitrogen in relation to other nutrients present in the urine, may prevent the plant from absorbing adequate amounts of potassium which it requires for the best fruiting and also for the overall health and vitality of the plants. A humus-like soil helps to balance the overall nutrients available to plants and this is particularly important when urine is added. Humus derived from ***Skyloo*** jars (see earlier) is a particularly good medium for growing tomatoes. It has a high content of humus and is full of living organisms. It also has high levels of phosphorus and potassium (the potash coming in part from the ash applied during the processing of the faeces). Tomato plants often spring spontaneously from these jars of humus and if well watered produce a good harvest. The application of a water urine mix (5:1 or 3:1) once a week, will help such well established plants along.

Plant trials with urine – summary for vegetables

The plants trials were performed on a variety of vegetables using urine diluted with water at a ratio of three parts water to one of urine as a liquid feed. Seedlings were planted in containers, either 10 litre buckets or10 litre cement basins and irrigated with water first. Fast growing vegetables like lettuce, spinach, covo and rape were irrigated with water first for 1 – 2 weeks before urine application after transplant and tomatoes were watered for a period of one month before urine application. Thereafter 0.5 litres of a 3:1 water/urine mix was applied to the buckets or basins on each urine application, this being the volume that the 10 litres of soil could absorb, interspersed with regular watering at other times to keep the plants healthy.

Summary of plant trials with urine for various vegetables & tomatoes

Plant and container	Urine/water application	Duration of growth	yield
Lettuce (10 litre bucket)	water only	30 days	230 gms
Lettuce (10 litre bucket)	3:1 urine. 0.5 li X 3 per week for 3 plants	30 days	500 gms **(2 fold increase)**
Lettuce (10 litre bucket)	water only	33 days	120 gms
Lettuce (10 litre bucket)	3:1 urine. 0.5 li X 3 per week for 3 plants	33 days	345 gms **(2.8 fold increase)**
Spinach (10 litre bucket)	water only	30 days	52 gms
Spinach (10 litre bucket)	3:1 urine. 0.5 li X 3 per week for 3 plants	30 days	350 gms **(6 fold increase)**
Spinach (8 X 10 litre basins)	water only 22plants	28 days	741gms
Spinach (8 X 10 litre basins)	3:1 urine. 0.5 li X 2 per week for22 plants	28 days	2522 gms **(3.4 fold increase)**
Rape (3 X 10 litre basins)	water only 9plants	28 days	160gms
Rape (3X 10 litre basins)	3:1 urine. 0.5 li X 2 per week for 9 plants	28 days	822 gms **(5 fold increase)**
Covo (10 litre basin)	water only	8 weeks	135.5gms
Covo (10 litre basin)	3:1 urine. 0.5 li X 1 per week for 3 plants	8 weeks	204 gms **(1.5 fold increase)**
Covo (10 litre basin)	3:1 urine. 0.5 li X 3 per week for 3 plants	8 weeks	545 gms **(4 fold increase)**
Tomato (10 litre bucket)	water only	4 months	1680 gms (9 plants)
Tomato (10 litre bucket)	3:1 urine. 0.5 li X 3 per week for 3 plants	4 months	6084 gms (9 plants) **) (3.6 foldincrease)**

Maize trials with urine treatment

Maize is by far the most important single plant species in Zimbabwe, and possibly throughout Africa. It provides the staple food for countless millions of people throughout the continent. Apart from where it is produced on commercial farms, it is usually planted in very marginal areas with poor soil. Manure can be used to enrich the soil - and also commercial inorganic fertiliser. But most rural and urban folk are not favoured with the ownership of cattle or the money to buy commercial fertiliser. Can Ecological Sanitation help? The results so far attained show that eco-humus alone, in economic amounts, does not hold sufficient nutrients to sustain many maize plants to full development. Urine was tried.

The soil on which maize is traditionally grown is normally fertilised either with cow manure or commercial fertiliser or a combination of both. With the commercial fertilizers the application is undertaken in two phases. The first application of the fertiliser has more phosphorus than nitrogen (the NPK ratio being 1:2:1). About 10 gms (a tablespoonful) are applied either to the seed as it is planted or near to the young plant after germination. Some farmers use double this amount. This sustains the growth of the maize plant for its first 4 – 8 weeks when a further application of ammonium nitrate (also 10 – 20 gms) is applied as a top dressing for each plant. If ammonium nitrate (up to 34% nitrogen) is not available a fertiliser with a high nitrogen content is used. This is a very standardised and well tested method of applying fertiliser to maize. Plants fertilised in this way look healthier, the leaves are more numerous, larger and greener and the resulting cobs certainly larger or also the number of cobs will be greater. More phosphorus than nitrogen is applied in the first phase of growth to assist in full root development. Subsequently the application of nitrogen takes over as the main nutrient required.

Most naturally occurring top soils in Zimbabwe require fertilisation if a good crop of maize is to be obtained, but cattle manure is not available for most people and nearly all those living in the urban and peri-urban areas. It should be noted that a huge amount of maize is grown traditionally in the cities and towns in both urban and peri-urban areas as well as in the farming and communal areas. Commercial fertiliser, is the obvious choice for soil fertilisation, but has become scarce in Zimbabwe (January 2003) and also prohibitively expensive. A hectare of maize may contain at least 30 000 plants, each requiring 10 gms of 1:2:1 (compound D or equivalent) and 10 gms of ammonium nitrate (or equivalent). Thus approximately 300 kg of fertiliser of both types would be required per hectare. The cost of this fertiliser, applied at this rate is high. A bag of 5 kg NPK 1:2:1 may cost up to Z$1700 and ammonium nitrate Z$1300 per 5 kg. This is a total of about Z$3000 (2002) which is enough to fertilise only 500 plants. For most rural and urban folk, this is an realistic price to pay.

The yield of maize is not only reliant on adequate fertilisation. Fields of maize require constant weeding to reduce competition for the valuable nutrients held by the soil. Also the time of planting is crucial. In Zimbabwe, the seeds should be planted by mid November so that the plants can grow during the wettest and hottest part of the year. If the planting day is delayed crop yields will fall. Also the pattern of rainfall is important. Late rains result in slow initial growth and wilting. Poor rains cause immense harm due to wilting. Very heavy rains cause leaching and loss of the nutrients held in the fertiliser. Because of the great variety of soils, nation wide – the recommended application of fertilizer does vary. The nation is reliant on a good maize crop, like no other plant.

Experimental design

A series of experiments were undertaken to test the effect of urine on the growth of maize plants and the yield of cobs. These initial trials were undertaken in containers - 10 litre basins and buckets. Further trials were also undertaken in shallow (plastic lined) back yard trenches and also in the open field. Seed maize was planted in seed trays and transplanted into buckets and basins with different soils and varying urine treatment. After periods ranging from 2.5 to 3.5 months the maize cobs were harvested and weighed. The basic aim was to establish what concentration and amount of urine could be used to sustain a meaningful growth throughout the plants life and one that would give the best yield of cobs. The efficiency of use of the urine was also tested. Urine has a high concentration of nitrogen and much less phosphorus and potassium. Thus in using urine as a source of nutrients, the balance of the main nutrients was not ideal. It is possible that too strong a concentration of nitrogen at an early stage may retard root growth, and thus hinder maximum plant growth. But after the initial phase, urine, with its high concentration of nitrogen is an ideal source of nutrients for maize.

For the maize trials the urine was diluted in the range 3:1, 5:1 and 10:1 with water. The plants were fed with urine either 3 times per week with the 3:1 mix (U1 application), once per week with the 3:1 application (U2), once a week with the 5:1 application (U3), once a week with the 10:1 application (U4) or with water only. Plants being fed the water/urine mix were also watered regularly at all other times to keep the plants healthy and turgid. After a specified growing period, the crop was harvested and weighed. A chart showing these various trials are given below. All watering was by hand - using a watering can – the old and reliable method.

Urine has a pronounced effect on maize, especially when grown in containers. In the trials, maize plants were grown in 10 litre cement containers and fed with varying amounts of urine. In this case the plant on the right is being fed with a 3:1 mix of water and urine (0.5 litres) three times per week. The maize on the left is irrigated with water only. The difference is striking.

Results of maize trials

A detailed account of the 16 maize trials that were conducted has been written in *Ecological Sanitation in Zimbabwe (Vol. IV).* These are complex and a detailed account is unnecessary in this book. A summary of the results and main findings is provided below.

Plant trials with urine for maize – summary of M8 and M14 trials

Plant and trial no.	Liquid application	Duration of trial	Mean cob weight
Maize (M8 trial) (10 litre basins)	Water only	3.25 months	21 gms (mean 3 cobs)
Maize (M8 trial) (10 litre basins)	3:1 urine. 0.5 li X 1 per week for 3 plants (U2)	3.25 months	135 gms (mean 3 cobs) **(6.4 fold increase)**
Maize (M8 trial) (10 litre basins)	3:1 urine. 0.5 li X 3 per week for 3 plants (U1)	3.25 months	318 gms (mean 3 cobs) **(15 fold increase)**
Maize (M14 trial) (10 litre basins)	Water only	3 months	6 gms (mean 9 cobs)
Maize (M14 trial) (10 litre basins)	10:1 urine. 0.5 li X 1 per week for 3 plants (U4)	3 months	62 gms (mean 8 cobs) **(10 fold increase)**
Maize (M14 trial) (10 litre basins)	5:1 urine. 0.5 li X 1 per week for 3 plants (U3)	3 months	138gms(mean 16 cobs) **(23 fold increase)**
Maize (M14 trial) (10 litre basins)	3:1 urine. 0.5 li X 1 per week for 3 plants (U2)	3 months	169gms(mean 18 cobs) **(28 fold increase)**
Maize (M14 trial) (10 litre basins)	3:1 urine. 0.5 li X 3 per week for 3 plants (U1)	3 months	211gms(mean 19 cobs) **(35 fold increase)**

Weights for M8 trial

Cob weight for water only (35, 17, 11g)T =63 N = 3 M = 21g, SD = 12.49
Cob wt for U2 urine treatment (170, 115, 121)T = 406, N = 3, M =135g, SD = 30.17
Cob wt for U1 treatment (290, 308, 356) T =954, N = 3, M = 318g, SD = 34.11

Weights for M14 trial

Water treated. 31,5,2/5,2,2/ 2,3,2. T = 54, N = 9, M = 6gms, SD = 9.46
U4 treated. 92,73,53/75,22/,60,81,40 T = 486, N =8, M = 62gms, SD= 23.05
U3 treated. 133,200,139/121,98, 212/225,150/90,140,40/212,155/132,125,38. T =2211, N = 16, M = 138g.SD = 55.94
U2 treated.205,162,132/122,175,225/126,197,211/155,208,150/160,122,133/218,172,180.T = 3053, N = 18, M = 169gms, SD = 34.87
U1 treated. 332,221,55/210,250,132/330,278,130/230,298,50/247,280,238/252,290,100,91. T = 4014g, N = 19, M = 211gms.SD = 90.47

In all cases the samples are significantly different at the 95% level of confidence.

In almost every case one cob was produced per plant, 2 cobs were produced on one plant. In the U1 series a few tiny cobs of less than 10 gms were visible, these were documented but not counted. The strokes between figures show the split of containers. From these figures one can deduce the means and standard deviations. The means shown are the total cob weight of all plants produced under that urine regime.

Discussion of results

Maize responds very well to urine application when grown in basins, under experimental conditions. Compared to maize grown in basins without urine application the yield increases by factors which ranged between **6 and 35 times** when fed urine. These are significant improvement in crop yield with the only source of available extra nutrients being released from the urine.

These and other results from an extensive series of maize trials reveal that the production of maize could be increased on poor sandy soil, by the application of urine alone, but that if the sandy soil had humus added, then the production went up further. Mean maize cobs yields of **4.3 gms** for poor sandy soil (Epworth) irrigated with water only went up to **82.3 gms** when soil was treated with urine only (125mls per plant per week) and to **131.28 gms** when the poor sandy soil was mixed in equal proportions with ***Fossa alterna*** humus and also treated with urine. This increase is partly due to the presence of the nutrients in the ***Fossa alterna*** soil, but also due to the increased number of nitrifying bacteria present in the humus which converts the urea and ammonia in urine into nitrate ions which can be taken up by the plants. The addition of ***Fossa alterna*** humus to poor Epworth soil in equal proportions, but without urine treatment, only increased mean cob weights from **4.3 gms** to **27.9 gms.** This indicates that the presence of humus is an import requirement if the nitrogen in urine is to be converted into a usable form which the plants can take up. It also shows that both urine and eco-humus enhance the value of the other and the optimum is to use them together.

Efficiency of use of urine

In all cases the yields of maize (and vegetables in earlier experiments) was the highest when the highest dose of urine was applied, but these were often wasteful of urine. The results reveal that a lower dose of urine was more effective in terms of grams of cob weight in relation to millilitres of urine applied. So a balance must be struck between yield and efficiency of use of the urine. This concept is best revealed in the large M14 maize experiment, which is described briefly below.

The M14 experiment

In this experiment 3 maize seedlings were planted in each of 24 ten litre basins filled with Woodhall Road topsoil (which has few nutrients - see soil analysis). The seedlings were planted on 30thOctober 2002. The following schedule of watering/urine treatment was given:

3 basins irrigated with water only
3 basins irrigated with 10:1 water/urine mix, once a week + additional watering (U4)
6 basins irrigated with 5:1 water/urine mix, once a week + additional watering (U3)
6 basins irrigated with 3:1 water/urine mix, once a week + additional watering (U2)
6 basins irrigated with 3:1 water/urine mix, three times a week + additional watering (U1)

The application of the water/urine mixes began on 4th November 2002. 0.5 litres of the water/urine mix was applied to each basin. The plants were kept turgid at all times with artificial watering by watering can. Thus plant stress resulting in wilting was avoided. For the first two weeks little difference was noted in the growth of plants. After one month, the water only fed maize began to lag behind all other plants, which all showed lush growth. As the plants grew and their nutrient requirement increased so did the appearance of the maize begin to change. After two months growth, the U1 treated maize were notably greener than all other plants. Maize plants in which the nutrient requirements were not fully met by the urine treatment showed the features of nutrient deficiency such as paler, smaller green leaves with basal leaf yellowing and smaller cobs. This occurred in all plants except those fed the strongest U1 treatment. As plants like maize mature, nutrients held within the plant itself may be redistributed into new growth. In this case, nutrients taken up by the plant and even within the plant are directed to new leaf and cob growth. Older leaves turn pale and wither. The cobs were harvested on 30th January 2003, three calendar months after planting the seedlings. This gave 12 weeks of urine treatment in this case. Each cob was weighed and means for each urine schedule were calculated. Figures are given below for urine application to maize with corresponding cob yield and also millilitres of urine required per gm. of cob yield.

Urine application to maize with corresponding mean cob yield

Liquid feed	No. weeks	Total urine applied per plant	Mean cob weight
Water	12	none	**6gms**
U4*	12	180 mls	**62 gms**
U3*	12	324 mls	**138.18 gms**
U2*	12	480 mls	**169.61 gms**
U1*	12	1500 mls	**211.25 gms**

These figures reveal, as in the M8 trial, that the maize cob output is related to the urine input and that the highest urine input results in the highest output of cobs in terms of overall weight. However the figures also reveal that the most effective use of urine is not found in this highest dose rate as the chart below shows.

Millilitres of urine required per gm. weight of cob yield

Liquid feed	Urine input per plant per week	Mls urine required per 1 gm cob yield
U4	15mls	2,90 mls per gm cob
U3	27mls	2,34 mls per gm cob
U2	40mls	2,83 mls per gm cob
U1	125mls	7.10 mls per gm cob

Thus in terms of the most effective use of urine, the U3 treatment was the most effective, as this used 20% of the maximum urine dose to produce 65% of the maximum cob output. The U2 treatment used 33% of the maximum urine dose to produce 80% of the maximum cob output. These figures indicate that high doses of urine are not the most effective way of using urine. But cob size is a factor of importance considered by the consumer, and cobs produced in the U3 trial might have been considered undersized. Thus one looks at the U2 treatment as the guide. If the same amount of urine used to feed the U1 application was used to feed three times the number of plants at the U2 application rate (about 40mls per plant per week diluted with 3 X water), then the overall yield of cobs would have been increased by a significant 2.4 times. In fact heavy doses of urine are wasteful and not efficiently converted. If urine is available in sufficient quantities, then an effective treatment for maize would be the U2 treatment for the 1st and 3rd third months and U1 treatment for the second month. This regime would use a total of 820mls urine per plant with the possibility of little wastage of urine and producing a good cob weight per plant. The largest cob produced in the trial weighed **356 gms**. Remarkably the plant grew 2.1 m high on just 100mm depth of soil.

Total yield of cobs from maize planted in three 10 litre basins in the M8 trial. On the left the maize was fed 1750mls urine per plant over the 3.5 month growing period, resulting in a crop of 954 gms. A reduced crop resulted from reduced input of urine (middle). Maize plants on the right were irrigated with water.

The M14 experiment

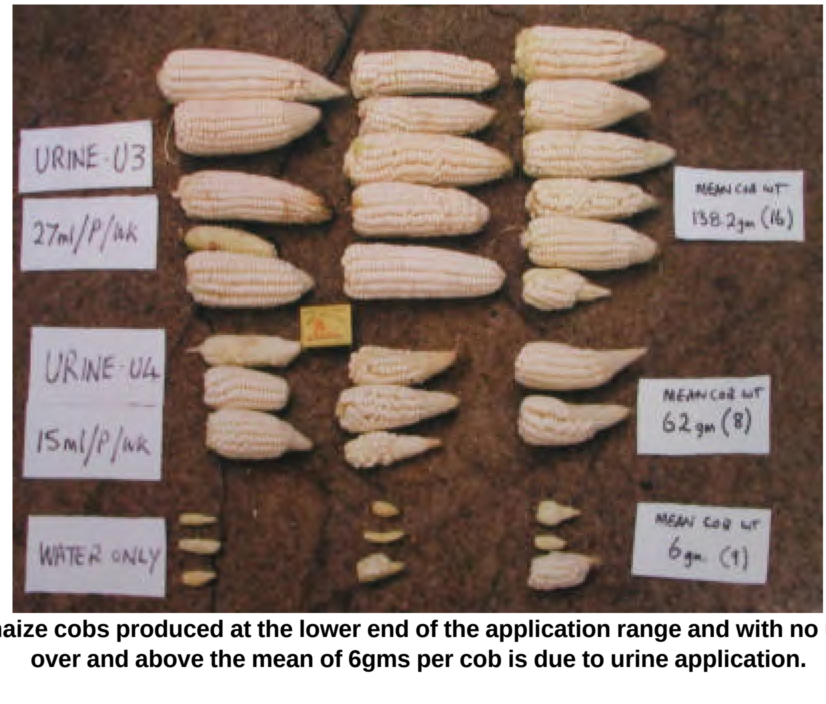
24 ten litre cement basins were planted with maize seedlings on 30th October 2002 and watered for a week. The application of varying concentrations of a water/urine mix then began.

Photo taken on 3rd December 2002 after about 5 weeks of water/urine application. The dramatic differences in growth rate of plants is easy to see – water treatment only on extreme left and maximum urine treatment on extreme right with intermediate applications between.

Photo also taken on 3rd December 2002. Vigorous growth of maize can be seen with the highest urine application on the right. The maize was harvested on 30th January 2003, nearly 2 months later.

The M14 maize harvest

A single photo shows the effect of different amounts of urine applied to maize plants over a 3 month period. On the left (U1) the plants have been fed a 3:1 water/urine mix three times per week (125 mls per plant per week). This has led to a mean cob weight of 211 gms. The 3:1 mix was applied to the U2 group once a week (40 mls per plant per week) and has led to a mean cob weight of 169 gms. A 5:1 mix was applied to the U3 group once a week (27 mls per plant per week) and has led to a mean cob weight of 138.2 gms. A 10:1 mix was applied to the U4 group once a week (15 mls per plant per week) and has led to a mean cob weight of 62 gms. Those plants fed water only produced a mean cob weight of only 6 gms. 99.4% of the total cob mass shown in this photo is derived from the nutrients provided by the urine.



Closer look at maize cobs produced at the lower end of the application range and with no urine. All growth over and above the mean of 6gms per cob is due to urine application.

Maize trials in the fields.

The result of maize trials undertaken in basins shows a dramatic influence of urine treatment. But the conditions are unusual. Maize is rarely grown in containers and more often in very large fields and backyard gardens where there is space, Also urine treatment works particularly well in containers because the nutrients derived from urine are confined in the soil held by the container. In the cases described in this book, that is just 10 litres of soil. When urine (or other methods of fertilising) are used in gardens or in the fields, the fertiliser is placed in the ground in unconfined conditions. That means that the full effects of the fertiliser may be partly lost. Heavy rain, for instance may drive nitrogen fertiliser down deeper in the soil and much of it may be lost to the plants. Also there may be a tendency to spread fertiliser too thinly if it is costly. Whilst vegetables may best be grown in containers, maize rarely is, so it is important also to test the effects of urine in working maize fields. This has been undertaken in the Marlborough vlei, Harare.

Two sections of the maize field are of particular interest, named areas A and B. At first urine was applied diluted with water to section A, as in the garden trials, but this quickly proved to be impractical. The water was too heavy to take to the fields. The urine was heavy enough. Neat urine was applied in a small hollow made near the plant - watered in by natural rainfall.

Area A.

Maize in area A was planted in mid November 2002. The area was divided into two sections. Urine application began on one section on December 11th 2002, with weekly applications being made until February 28th 2003. Urine was applied to the site of seed planting (planting station) where normally more than one seed is planted. No urine was applied to the second (control) section, this being irrigated with natural rainfall only. The first 3 urine applications were made with 125mls urine diluted with water, the remaining applications with neat urine, when the dilution method proved unpractical. A total of 1275mls urine were applied to each planting station during 12 weekly applications. The maize cobs were harvested on 31st March 2002 after 4.5 months of growth. Mean cob weight for the section without urine was **154.11gms** (n= 85). Mean cob weight for the urine treated section was **197.7gms** (n= 70). The urine treatment led to an overall increase in cob weight of 28%.

Photo of maize field (area A) taken on 19th December. The bamboo sticks are markers. On the left of the marker the maize was treated with 100mls urine per maize station per week in a single application. On the right of the marker no urine treatment was give.

Area B.

Maize in area B was planted in mid December 2002, which was late in the planting season. The area was divided into three sections. Section 1 (about 80 planting stations) was irrigated with normal rainfall only. Section 2, also of about 80 planting stations was treated with 100mls urine per week for 9 weeks (Dec.19th 2002 – Feb. 28th 2003). Section 3 (about 80 planting stations) was treated with normal fertilizer. 10gms of a NPK 1:2:1 fertiliser were applied on 28th December and 10 gms of a NPK 5:1:2 fertilizer were applied on 29th January 2003. This double treatment is standard for maize in Zimbabwe. A total of 900 mls urine were applied to each maize station during 9 weekly applications. The maize cobs were harvested on 15th April 2003 after 4 months of growth. Mean cob weight for the rainfall irrigated section was **103.07gms** (n= 104). Mean cob weight for the urine treated section was **143.87gms** (n= 102). Mean cob weight for the chemical fertilized section was **166.22gms** (n= 135). The urine treatment led to an overall increase in cob weight of 39% over the rain irrigated section. The chemical fertilizer urine treatment led to an overall increase in cob weight of 61% over the rain irrigated section.

Photo of maize field (area B) taken on 19th December. The bamboo sticks are markers. On the left of the marker the maize was treated with commercial fertiliser. On the right maize was treated with a single100mls application of urine per maize station per week.

Maize growing on area A in January. Urine treated on left, rainfall treated on right.

Area A (left) and B (right) at the time of cob harvesting.

Discussion on urine treatment of field maize

The field maize trials reveal that urine treatment at the rate of 100mls neat urine per planting station per week over a 3 month period does increase overall maize cob weight by between 28.2% (area A) and 39% (area B). This is less than the effect of conventional chemical fertiliser which increased overall cob weight by 61% compared to maize irrigated with rain only. However the urine treatment cost nothing, although some effort was used in applying urine to every plant once a week. It is possible that a similar effect might have been noted had larger amounts of urine been applied less frequently, but this has not been examined.

It is interesting to note that the final harvest of maize was not only influenced by fertilizer treatment but also by planting time. Rain fed maize planted at the recommended time (mid November in area A) yielded a higher cob weight (**154.11 gms**) than rain fed maize cobs planted late in mid December in area B (**103.07gms**). In fact rain fed maize planted in November produced a better cob weight (**154.11gms**) than urine fed maize planted in December (**143.87gms**) and nearly the same as chemically fertilised maize planted in December (**166.22gms**). These figures reveal what is already known – that the success of maize production lies largely in early and successful planting.

The pattern of the rainfall also plays a significant part in maize production. Early rains may prompt planting, but if the rainfall dies away, replanting may be required. During the season under test, the early rains faded away and led to plant stress which was later partly relived by heavy rains - but too late in the maize season. These rains continued but came too late, leading to some rotting in later planted maize.

The effect of urine treatment was greater with later planted maize (39% increase following 900mls application per station) compared to earlier planted maize (28% increase following 1275mls application per station). Inspection of the overall maize field revealed that in some areas plants grew better than in other areas. In area A, the natural soil condition led to a healthier crop than the poorer soil condition of area B. The effect of urine (or fertilizer) treatment may be more obvious in areas of poor natural soil. However the overall effect on growth results from a combination of effects caused by the natural soil condition and any influence by imported nutrients. Overall the best urine treated maize crop came from area A (**197.7 gms**) compared to **143.87gms** for area B. It is known that the effect of urine treatment varies considerably, depending on the nature of the soil, its phosphorus status and its capacity to convert urea into nitrate and also the soils natural fertility. Vlei soil was clay like and not the best medium for converting the nutrients held by urine into a form suitable for plant growth.

The effect of urine and other fertilizers on plant growth is also influenced by the dose and therefore the number of plants that take up a given dose. It is traditional in Zimbabwe that 2 or 3 maize seeds are placed in each "planting station" and both chemical fertilizer and urine were applied to each station as if to a single seedling. But in fact the dose, in each case was distributed between at least 2 and sometimes 3 plants, thus diluting the influence. Also in natural fields, the fertilizer, whether chemical or urine, is also utilised by weeds which often grow rampantly in maize fields. This was the case in this study.

Also in maize grown on the fields, heavy rains may flush away the nutrients available in the limited quantities of urine available, and this applies particularly to the nitrogen. Both phosphorus and potassium seem to bind better with the soil and are less easily flushed away. The relatively small quantities of urine applied close to each plant are dispersed by the rain over a larger volume of soil, as they are not contained in any way. Even for commercial fertilizer, heavy rains are known to reduce the effectiveness of the treatment, since the minerals, particularly nitrogen can be flushed down into deeper layers as the rainwater tops up the aquifer. They are then of no use to the plants.

With all these variable factors at play it is not surprising that the overall weight of harvested cobs in the natural vlei site was less than that harvested in the artificial environment of the cement basin when urine was applied. Mean cob weights for urine applied maize on the vlei are 197.7 gms and 143.87gms respectively (mean **165.78gms**). This is less than the mean weight of urine fed maize in artificial basins - **211gms** (U1 treatment) and **169gms** (U2 treatment), respectively. This is easy to explain because the conditions of growth were more closely regulated in basins, where plants were well watered, well fertilised with nutrients being retained in the basin. Also measured doses of urine were applied per plant and not per planting station, leading to individual plants being fed properly in basins. Also rampant weed growth was controlled in basins. Yet another effect with artificial irrigation is that the maize can be (and was) was planted early, which also helps to increase the final yield, as the hottest parts of the year (October and November) occur before the main rainy season starts.

Overall conclusions of urine trials

These various trials show quite clearly how valuable urine can be as a liquid feed for the range of plants studied so far. The study also reveals that application in small containers may be more effective than on beds, although this will not be the normal method of growing vegetables.

The trials show that for most leafy vegetables a significant increase in yield can be expected from the application of urine, which is best applied diluted with water at a ratio of 5 parts water to one of urine once per week. Higher yields are obtained with higher doses of urine, so a 3:1 application three times per week will give a higher overall yield than the same mix applied once per week. However, all experiments reveal that this high dose is wasteful of urine and urine application either once or twice a week is a far more effective use of the urine derived from a family. This is because it can lead to the production of greater overall yields, since the lower dose of a fixed volume of urine can be used on a larger number of plants, which overall will provide a bigger harvest. If more urine is available, a lower dose can be used at first followed by a higher dose during the main vegetative growth period, finalising with a period of lower application prior to harvesting. Prolonged use of a higher dose affects plant health and is not desirable.

Plant trials were also conducted with onion growing in 10 litre containers, and followed the routine employed in the other trials. Seedlings were grown from seed in seed trays and transferred to 10 litre basins at the rate of 10 or more plants per basin. Using a combination of humus like soil and the 3:1 application up to 1.4 kgs of onion could be reaped from a single 10 litre basin within 6 months. An average crop was 1kg per basin. This is a fair yield of onions per basin. Onions respond readily to urine treatment. As in all these trials leading to a practical application, the 3:1 water/urine, applied once a week, is perhaps the best guideline to be followed, as it is less demanding on the gardeners time and is effective. But a 5:1 application will work nearly as well. The same applies to flower beds. Many flowers respond well to urine, the hardy and colourful marigold being just one.

The enormous value of urine must be accepted without question, despite the fact that the proportions of the major nutrients held in urine are not ideal as a general liquid fertiliser (11:1:2 for NPK). A ratio of 2:3:2 for NPK might have been better for vegetables, where more phosphorus assisting the formation of root growth, and potassium in the formation of fruits, such as tomato would have been preferable. However urine is universally available at no cost and therefore its minor limitations must be accepted, because its advantages far outweigh its deficiencies. Urine can be manipulated in various ways, such as fermenting with humus (the Mexico method) or with comfrey. The phosphate proportion can also be increased by sedimenting out the salts of phosphate (struvite) by decanting the upper layers of urine after settlement and remixing with water. Also small amounts of single super phosphate fertiliser can be added to the diluted water/urine mix. . However, perhaps the easiest and most logical method is to use urine in combination with eco-humus derived from the eco- toilets. In this way the humus with its higher proportion of phosphorus and potassium, complements the subsequent use of urine with its very generous supply of nitrogen In the end the great value of urine lies in the undisputed fact that it costs nothing and there is no place on earth where people live that it is not available.

Potential yield of vegetables and maize using annual family urine production

In terms of urine output, an annual production of at least 2000 litres is theoretically possible from a family of two adults and three children, even with some wastage. However an average family may contain and use less than 400 litres per year in practice (Edward Guzha pers.comm.). There are many ways of collecting urine in the homestead, filling bottles, plastic containers and potties perhaps being the most likely in the absence of a urine diverting toilet. It is interesting to speculate how much vegetable growth and maize cob yield would result from the application of 2000 litres of urine. The following figures are calculated using data from the experiments described in this book.

Crop	mls urine required per gm of crop.	Potential annual crop	
Lettuce	5.5 mls per gm of crop	362 kg/yr	or
Spinach	5.0 mls per gm of crop	400 kg/yr	or
Covo	7.3 mls per gm of crop	274 kg/yr	or
Tomato	4.1 mls per gm of crop	486 kg/yr	or
Maize	2.8 mls per gm of crop (U2 application)	704 kg/yr	

It is clear that the potential gain in yield resulting from total annual family urine application to green vegetables and maize is far greater than for eco-humus application alone. It is interesting to compare the figures above with the improvements in the potential annual production of tomato (73 kg), spinach (27kg), covo (17 kg), or lettuce (45 kg) derived from the humus alone. Thus, the total potential value of applying urine for increased crop yields of maize ands green vegetables is far greater than eco-humus by itself. The difference perhaps is that the entire volume of the eco-humus taken from the toilet can be easily stored and put to use by mixing into vegetable beds, whilst only part of the urine may be used because it is far more difficult to store in bulk. Also urine is less effective on poor sandy soils which are common in Africa and best used in combination with humus of some sort to get the desired effect.

Whilst such figures are impressive, the fact remains that currently most urine goes to waste, even in projects using urine diverting toilets. It is possible that promoting the enrichment of soil with eco–humus first, which is already widely practiced by owners of the ***Fossa alterna***, and then building on to this the practice of applying urine to increased of vegetable production further, will make a lot of sense to the users. Such a process is currently being encouraged.

In the homestead there are many ways of collecting urine and a urine diverting pedestal or squatting platform is not essential. In several countries in East and South East Africa (Malawi, Mozambique, Zambia), the decision about which eco-san technology to use, where a choice is give, is based on factors such as affordability and ease of construction and management. Very often the urine diverting method is rejected on account of its relatively high cost and complexity. In practice people respond very positively to the production of humus derived from their toilets and this is willingly applied to the land. The demonstration of a rich, crumbly and pleasant smelling humus formed by mixing excreta, soil, ash and leaves is a powerful selling point for ecological sanitation and has led to the main developments and uptake of low cost ecological sanitation in Malawi, Mozambique and Zambia. This reaction is positive for the uptake of recycling and its effect should never be underestimated.

The limited volumes of humus, and to a lesser extent urine produced by a family, means that these products are better used in the backyard garden environment rather than on larger fields. In the backyard there is more control on the precious resources and the result is more easily seen and appreciated. This applies to both eco-humus from the family latrine (***Fossa alterna*** and also urine from various sources. The combined effect of the application of these resources may represent, for each family, a huge increase in vegetable production, especially in areas where the soil is poor or access to manure or commercial fertilizer is difficult or expensive. Barren gardens may be turned into gardens of plenty over the years. Such a possibility, coupled with the convenience of an effective and low cost toilet system makes good sense to townspeople and villagers alike. But as always – ***Time will tell!***

16. Gardening techniques that assist eco-san supported food production

We have now discussed the methods of building and using eco-toilets and how their produce may be used with beneficial effect in the garden. But some extra technique will also help too. The production of vigorous healthy vegetables requires effort and also a knowledge of the soil and the plants themselves. Some vegetables are easier to grow than others. Most basic top soils do not have sufficient nutrients in them to provide healthy vegetable growth. Such soils require extra ingredients added to them in the form of humus, compost, manure or organic liquid food or ideally a combination of these. A good soil texture as well as an adequate level of soil nutrients is also very important. And the other vital component is water - without it no plants can grow and plants supplied with insufficient water become stressed and cannot provide an abundant harvest.

Countless thousands of books have been written on vegetable gardening, and there is little need to repeat what has been written so many times before. However the writer has used a few special techniques which he has found particularly valuable in eco-san assisted vegetable production. These include the production of compost, leaf mould, liquid plant foods, seedling production, mulching techniques, worm farming, watering techniques, etc. A few of these are described here.

1. Compost making and application

The compost heap is a familiar site in most well run vegetable gardens. Compost can be made in piles, pits and every sort of container imaginable (drums, tyres, wooden and brick enclosures, buckets etc). A compost heap is a bacteria and fungus farm which breaks down all sorts of organic matter - with the presence of both air and moisture being essential.

Compost heaps

These are the most common. The largest component is vegetable matter, with smaller amounts of soil and manure being added in layers. Typically a 150mm deep layer of vegetable matter (chopped up vegetables, leaves, crop residues, weeds, grass, tree prunings, straw, organic kitchen wastes etc.) is laid down first. This vegetable matter is covered with a 50mm deep layer of manure, which can be taken from the urine diverting toilet or from the droppings of various animals (chickens, goat, horse, dog, cattle etc). Then a thin third layer, about 25mm deep of soil or soil and wood ash is added over the manure layer. Then another 150mm deep layer of vegetable matter is added on top and the process of building up the “sandwich” is repeated until the pile is about a metre high. The pile should be kept moist at all times but not wet.

The use of urine as an activator is recommended - it should be diluted with water about 2:1 or 3:1 and applied to the heap. Air vents can be added and ideally the pile should be turned twice during the three month period when the compost is forming. However this may be easier said than done. The resulting compost is dug into beds and mixed with other soils to enrich them.

Full compost heap at the Eco-Ed Trust, Mutorashanga. The base layer of vegetable matter has been laid down to a depth of about 150mm and has been coveted with a 50mm deep layer of manure (including human). This has been covered with a thin 25mm layer of soil (with a little lime). The next layer is vegetable matter again and the process is repeated. Thanks to Jim Latham and Eco-Ed Trust.

Compost pits

The same process can be carried out in pits below ground level. In fact, during its first year of operation, the second pit of the ***Fossa alterna*** can be used to make compost. However it is equally well used to make leaf mould. It can also be filled with a mix of leaves, soil and animal manures and used to grow comfrey or other vegetables. There are many uses of small shallow pits, not least that used for making humus from human excreta, soil, ash and leaves.

The second pit of a *Fossa alterna* in its first year can be used as a compost pit.

Compost baskets

A simple compost maker can be made from a tube of chicken wire. A piece of 12mm chicken wire 0.9m wide and 2m long is formed into a tube. The ends of the wire can be brought together and the twisted together to make a tube. Such a basket is self supporting if leaves alone are added to make leaf mould, but it will not be self supporting when a mix of vegetable matter, leaves and manure and soil is held within. So four stakes or cut bamboo must be held firm in the soil around the basket to keep it upright. Once the basket is secure add leaves and a variety of other vegetable matter to the base - about 150mm deep. Then add a layer of manure about 50mm deep (this can include buckets of human faeces and soil taken from the ***Skyloo***) topped up by a layer of soil 25mm deep. Fertile topsoil is best. As an activator, a mix of urine and water (about 4 litres urine to 8 litres water) can be added when the basket is half full. Then repeat the additions of vegetable matter, manure and soil. Add some more of the diluted urine when the basket is full. Adding some compost from another pile helps. Keep moist by watering with the water/urine mix or plain water from time to time. After about three months the end result should be pleasant smelling crumbly dark brown compost which can be applied to the vegetable garden at the rate of a 10 litre bucket full per square metre.

Chicken wire baskets held up with bamboo poles contain compost - a mix of vegetable matter, manure and soil in layers. Behind there are two similar baskets made of chicken wire which are particularly useful for making leaf mould. The leaves are placed inside the basket with very thin layers of soil added. Often no soil is added at all. They are much lighter when filled with leaves only and do not need support. A very useful size is where these baskets are cut in half and about 45cm high. The baskets are about 65cms in diameter. The baskets can be scattered about in the garden where the leaves are falling.

Cement compost jars

A combination of vegetable matter, thin layers of soil and manure can also be built up in composting jars made of cement. In fact split cement jars (30 litres capacity) are ideal for composting human faeces together with soil (see section on ***Skyloo***). Larger 80 litre jars can also be made in cement. A mould made from a plastic dustbin is ideal. The plastic dustbin is cut in half and used as a mould. The two halves of the resulting cement jar, once cured are wired together and the build up of ingredients inside can begin. Vegetable matter (from garden and kitchen), manure and soil are added in layers and watered down. It is this watering which can contain urine - a mix of 3 parts of water to one of urine will help to activate the pile and also add nutrients to the final compost.

The writer has used this method to utilise dog manure in his garden. The dog manure is swept up and added to the 80 litre split cement jar composter. Vegetable matter discarded from the kitchen and elsewhere is also added and covered with a layer of soil The compost produced is rich in nutrients as the table below shows. Four such jars have been built and the soil, dog manure and kitchen wastes are placed in each in rotation. It takes a year to fill all four jars, thus the period of composting before subsequent extraction is one year. The compost when mixed with topsoil is an excellent growing medium for vegetables. The ideal mix for growing a variety of vegetables consists of 50% of this jar compost and 50% leaf mould. 80 litre jars of this type could also accept the buckets of faeces and soil from the ***Skyloo*** to replace the dog manure. Currently a series of smaller 30 litre split cement jars are used for this purpose and have proved over several years to be perfectly satisfactory for this task.

. **80 litre cement composting jars**

Nutrient levels in jar compost

The following table shows how the combination of dog manure and organic kitchen wastes in combination with garden topsoil can be used to make a valuable compost. Nitrogen and phosphorus in ppm and potassium (K), calcium (ca) and magnesium (mg) in ME/100gm sample

Soil source	pH	N	P	K	Ca	Mg
Woodhall Road base soil	6.2	27	32	0.63	9.68	2.30
80 litre jar soil	7.2	314	171	1.00	67.38	17.52

When the jar soil is combined with Woodhall Road topsoil, all nutrient levels are increased together with soil texture. It is a good way of getting some benefit out of dog manure!

2. Leaf compost making and application

Leaf compost (sometimes called leaf mould) is the humus like material formed when leaves break down. The process takes place in nature constantly under trees or in the woodland or forest. Forest humus is the complex material originating from the decomposition of both animal and plant residues by micro-organisms. It forms the fertile "forest floor" in which so much life abounds. Humus provides food for bacteria and fungi and also a medium in which they can work. Different groups of microbes are vital for transforming organic residues to nutrients which can be used by plants. Microbes associated with the root system encourage mycorrhizal association - channelling of nutrients into plant roots through the fungal threads. Humus also improves the texture of the soil making it more crumbly and also improves its water and nutrient retaining capacity.

Leaf compost is the end result of a natural decay of leaves and is performed mainly by action of fungi, but there is also some bacteriological breakdown. The normal compost heap in which vegetable matter, manures, and soil are mixed in layers is also broken down as a result of fungal activity, but bacteria are very active in this process and the presence of air is essential.

If plenty of leaves are added to the ***Fossa alterna*** pit during the filling process, then there may be little need to add any more humus (including leaf compost) to the final mix of eco-humus and soil to make an ideal growing medium for plants. However if a poor soil is added to the pit, there will almost certainly be a need for additional humus to be added. Leaf compost is one source of humus which is easily made, costs nothing and may be readily available. Its effect on improving the soil, texture and level of nutrients is very significant.

Leaf compost helps to improve the soil by improving its physical characteristics, making it more crumbly and also improving its water retaining properties as well as releasing plant foods into the soil. It is thus a most valuable material and every effort should be made to utilise it in vegetable production associated with ecological sanitation.

How to make leaf compost

Leave compost can be formed artificially when leaves are stacked up in heaps and watered. Leaf compost can be formed by watering leaves contained in chicken wire baskets, half drums, brick enclosures, pits, plastic bags etc.

If dry leaves are stacked up in piles, or even in chicken wire baskets and left dry they do not change much. Like paper, they retain their characteristic for years. If the leaves are soaked in water they begin the rot and break down and the temperature rises. It is the fungi (*Ascomycetes, Paco Arroy, pers.comm)* present on the leaves which multiply and do much of the breakdown of the leaves, but also bacteria are active too. The formation of leaf compost is a relatively slow process because the cellulose in the leaves must be broken down and this takes time. However there is much variation. The temperature increase varies from one leaf type to the next, and this also relates to the rate of breakdown. Indeed in terms of leaf compost production there is a great variation between leaves, some are easier to process than others. Thinner leaves like bougainvillea and Mexican apple are easy to process and actually heat up quickly when water is added. Temperatures of 60 degrees C can be reached in just a few days, indicating that bacteria are very active in this stage, but are not maintained and temperatures between 20 - 35 degrees C are more common during the formation of leaf compost. Leaves like Kenya coffee, guava and avocado seem to heat up less and take longer to form the leaf mould - they have thicker leaves.

Making leaf compost in wire baskets

This may be the best way of making leaf compost. A piece of 12mm chicken wire 0.9m wide and 2m long is formed into a tube. The ends of the wire can be brought together and the twisted together to make a tube. When filled with leaves the wire basket is self supporting. This tube can be cut in half to make two leaf mould baskets each 0.45m high. The shorter baskets are actually more convenient. Experience has shown that if dry leaves are broken up first then leaf mould production is accelerated. One way is to stack them in the "basket" and pound them with a pole. For the luckier ones, an excellent method is to stack the dry leaves in a pile in the garden and run the lawn mower over them. The technique involves raising the mower over the leaves and gently lowering the rotating blades over the leaves. They will immediately be cut up. This process is continued until all the leaves are cut up. The volume of cut up leaves may be one third or less of dry un-pounded leaves. It is these leaves which are introduced into the basket and compacted. They are then soaked with water and covered with a sack. Water loss can be reduced further by wrapping plastic sheet around the basket.

Within a day the temperature starts to rise significantly, but the temperature attained will depend on the type of leaf. A mixture of Bougainvillea and Mexican apple leaf was ideal and rose from ambient temperature of around 20 degrees C up to over 60 degrees within 4 days of packing in a basket and soaking. Leaves of Kenya coffee, guava, and avocado only reached temperatures in the 20's having been processed in the same way. Both Bougainvillea and Mexican apple leaves are thinner than the leaves of Kenya coffee, guava and avocado, and thus more easily broken down. The chart beneath provides a temperature chart.

Date	**Bougainvillea and Mexican apple**	**Kenya coffee, guava, avocado**
5th August 2002 (5.00pm)	leaves placed in basket	leaves placed in basket
5th August (ambient temp.)	20	20
7th August (8.40 am)	54.6	22.4
8th August (7.00 am)	60.2	22.2
10th August (9.10 am)	56.0	20.9
11th August (noon)	41.9	20.5
12th Augsut (8.15 am)	41.3	22.2
15th August (noon)	38.6	27.1
16th August (5.30 pm)	36.9	26.1
18th August (9.00 am)	27.2	25.2
20th August (9.00 am)	23.2	23.3
21st August (7.30 am)	22.7	22.3
25th August (9.00 am)	20.8	20.0

The rate of leaf compost production is accelerated considerably if the leaves are cut up first and then enclosed in the basket and surrounded by plastic sheet. Leaves can even be contained within large plastic bags within the basket. Whilst leaf compost may take several months to form heaps or even open baskets, if the leaves are soaked and contained within baskets surrounded by plastic sheet or contained in plastic bags, thus retaining constant moisture, the rate of production is increased. An excellent leaf compost made from Bougainvillea and Mexican apple leaves was ready for use after six weeks in the basket surrounded by plastic sheet and after 4 weeks when the leaves were enclosed in a bag within the basket. In both cases the dried leaves had been chopped up before being placed in the basket.

Soil analyses were undertaken on both the leaf compost made in the basket and one processed in the bag. In both cases an excellent leaf compost was made which were very rich in nutrients. Figures for pH, nitrogen and phosphorus in ppm and potassium (K), calcium (Ca) and magnesium (Mg) in ME/100gm sample are shown below.

Soil source	pH	N	P	K	Ca	Mg
Leaf compost (in basket)	8.2	256	344	13.92	29.86	9.42
Leaf compost (in bag)	7.8	267	294	8.50	25.40	6.35

These figures show what a very valuable product leaf compost is, rich in all the important plant nutrients.

Making leaf compost in steel drums

A 200 litre steel drum can be cut into half and also used as a leaf composter. This method was tried at Woodhall Road with success. Layers of leaves were placed in the half drum and covered with a thin layer of soil and then more leaves were added. A good leaf compost was prepared in about 6 months. This leaf compost was analysed at the soil testing laboratory. Figures for pH, nitrogen and phosphorus in ppm and potassium (K), calcium (Ca) and magnesium (Mg) in ME/100gm sample are shown below.

Soil source	pH	N	P	K	Ca	Mg
Leaf compost (in drum)	7.6	239	255	0.60	40.20	14.80


On left chicken wire baskets used to make leaf compost. This is the most effective method. Water is applied to the leaves to keep them moist. They retain water better if the basket is surrounded by a plastic sheet or sack. It also helps to cover the leaves with sacking or plastic. On the right two half steel drums with leaf compost. Later they were turned into worm farms

Making leaf compost in brick composter

Bricks can also be used to contain the leaves. These are built up without mortar to form a brick box. The unit used at Woodhall Road measures 0.95m X 0.70m X 0.3m deep. The leaves are stacked in the brick box and watered and covered with newspaper. Within a few days they contract in size and more leaves are added, being covered with the newspaper again. After several months the decomposed leaves can be removed and bagged ready for mixing with other soils used in eco-san and other gardening projects. This leaf compost was also analysed at the soil testing laboratory.

Figures for pH, nitrogen and phosphorus in ppm and potassium (K), calcium (Ca) and magnesium (Mg) in ME/100gm sample are shown below.

Soil source	pH	N	P	K	Ca	Mg
Leaf compost (in brick composter)	7.4	540	266	9.00	29.1	12.90

The overall conclusion is that leaf compost is a valuable and indeed even vital component to eco-san. Obviously where there are no trees there can be no leaf compost, but where trees are growing it is readily available form of humus and also nutrients which are of the greatest value to the organic farmer. What is so important is that leaves are added to the shallow pits systems used in eco-san - like the ***Arborloo*** and the ***Fossa alterna***. When soil alone is added, nutrient levels of the final humus can rise significantly. The addition of leaves as well, and as many as possible, improves the texture of the final product considerably. In the initial trials of the ***Fossa alterna*** at Woodhall Road in mid 1999, leaves were added to the pit contents together with soil and human excreta. The humus like qualities of this mix were much appreciated and led to the use of the word "humus" as a description of the product. Without leaves (or other vegetable matter) being added to the shallow eco-pits, the soil produced tends to be similar to the soil added, sandy, clayey grey, dark and light etc. The addition of humus forming matter like leaves provides the extra qualities that good soil requires. Leaf compost added to sandy soils also assists in the conversion of ammonia to nitrate which the plants can use.

Unmortared bricks stacked up in a box shape make a good leaf compost maker

Use of leaf compost in eco-san

The final leaf compost is mixed with other soils and also can be mixed with soil from the *Fossa alterna*. An excellent combination is one third *Fossa alterna* humus, one third leaf compost (or other compost) and one third topsoil taken from the vegetable garden. This has been tried in several experiments. The leaf compost provides improved physical properties to the soil as well as providing extra nutrients which are released over time. Another excellent mix is 50% compost jar humus and 50% leaf compost. The jar humus can include human faeces as well as animal faeces. In this case it is allowed to compost for one year before use. But the greatest value of leaves in eco-san is when they are allowed to compost in the shallow pits of the *Arborloo* and the *Fossa alterna*. As we have seen they provide many improved properties to the final humus, not least improving nutrient level and air content and thus improving composting efficiency but also absorbing urine which greatly assists in the composting process.

3. Liquid plant food

Plants grow best when there is a good balance of nutrients available. According to the organic farmer Lawrence Hills, if you have too much nitrogen available at once, you “lock up” the potassium,, as well as wasting nitrogen. Use too much phosphorus, and this too locks up potassium, whilst excess calcium is locks up boron. In tomatoes pale green leaves denote a shortage of nitrogen. Small blue green leaves turning purple shows a phosphorus shortage. This is particularly noticeable in rape - the leaves tips or sometimes the whole leaf turns purple as a result of a phosphorus deficiency. This often affects the older leaves and plants have the ability to transfer nutrients from one part of the plant to the other - providing the younger leaves with a higher proportion of nutrients. This obviously only happens if the soil is deficient in nutrients.

Swedish work which is well documented shows how valuable the urine is for providing quite a full range of nutrients (Wolgast 1993, Jönsson 1997 etc). However some plants, notably tomato and onion and even potato are known to require quite high levels of potassium and it is useful to investigate methods of bringing these special nutrient requirements to the vegetable garden. The Mexicans (Paco Arroyo pers.comm.) have shown that whilst urine is an excellent source of nitrogen, readily absorbed by plants and essential for leaf growth, when used on deficient soils there is not enough phosphorus and potassium which can reduce fruiting, particularly in those plants which have a high requirement for those elements. The Mexicans solved this by employing the red worm *(Eisenia foetida*), which produce castings containing a lot of phosphorus and potassium and also minor nutrients which the plants need and are not supplied by urine. Apart from garden humus and compost, liquid feeds made from manure and other materials rich in nutrients can be very valuable. The use of supplementary liquid plant food to satisfy the requirements of a wide range of vegetables is therefore of interest. One method is to add wood ash to the soil or even to the liquid feed. The writer has used this method and also turned to the comfrey plant as a valuable supplier of a wide range of nutrients. This can be supplied as a mulch or a liquid feed. The eco-humus is perhaps the most valuable supplier of these elements.

The value of comfrey

The comfrey plant (*Symphytum officianale*) has extraordinary properties of being able gather a wide range of minerals from the ground and hold it in the leaf. The leaves can be used in compost heaps directly or can be used as a mulch, but a valuable technique involves making a liquid feed from the comfrey leaves and applying this to plants. There are several methods available. One involves mixing water with cut up comfrey leaves and allowing the mix to ferment. The other involves adding cut up comfrey leaves to urine first, allowing the mix to ferment and then diluting with water. The method with urine is interesting because it produces a product which has the value of urine in it with an extra dose of potassium and other minor minerals.

This method of providing extra nutrients is interesting and particularly valuable for tomato and onion, which require a lot of potassium for the best results and it seems more than the urine alone may provide. Potatoes, beans, cucumber, squash, marrow and peas also require a lot of potassium and this may not be available in sufficient quantities in the urine alone. The urine and comfrey combination ensures that the best use is made of the urine which is a great nitrogen producer and comfrey which is a great producer of potassium. Both products do yield a wider rang of nutrients but in differing levels according to Hill.

3.1. Making comfrey liquor with comfrey and water

The simplest method is to chop up comfrey leaves and add them to water in a container with a lid and small hole drilled in the lid to let off gas. The comfrey is added at the rate of 1.5 kg chopped comfrey to 20 litres water. The mix is allowed to ferment for about four weeks before use. It can then be applied directly on the soil in which plants are growing. Application of about 0.5 litres per three plants or in a 10 litre container containing the plants three times a week can make a big difference to the plants.

3.2. Making comfrey liquor with urine and water

In this case a 24 litre bucket with lid is used. 1 kg of comfrey are cut up and added to 4 litres of urine. The mix is allowed to ferment for 10 days. A fermentation takes place and the leaves are rendered down and break apart. After 10 days an additional 20 litres of water are added to the mix which makes up the final liquor. This liquor, which should be stirred before application can be added to tomato at the rate of 0.5 litre per 10 litre container containing two or three plants (or two or three plants in a bed) once (or even 3 times) a week. Significant increases in the production of tomatoes can be achieved using this liquor as the chart below shows.

Production of tomato using urine/comfrey liquor

Plant	liquid food	frequency of application	weight harvested
Tomato	water	0.5 li X 3 per week	1680gms
Tomato	water/urine (3:1)	0.5 li X 3 per week	6084gms
Tomato	comfrey liquor	0.5 li X 3 per week	6230gms

These results show that the 3:1 water/urine mix was almost equally as good, urine/comfrey/water mix and more easily made From what Hill had said in his book and proven by much evidence, the tomato/comfrey mix should have produced a large crop. But it did not. Clearly other conditions were not ideal, like overcrowding in buckets and a soil which may have had too little humus. However the wide reputation of comfrey as an excellent plant food makes it a good choice where gardeners are not prepared to use their own urine. The recipe where cut comfrey is added to water alone is used in this case.


The comfrey plant is a most valuable addition to the garden. It can be used as the nutrient supply for a liquid plant food, with and without urine and also as a mulch. It is also an excellent addition to the compost heap. It also has medicinal properties. On the left cutting up comfrey and adding to water. This will ferment and provide a good plant food.

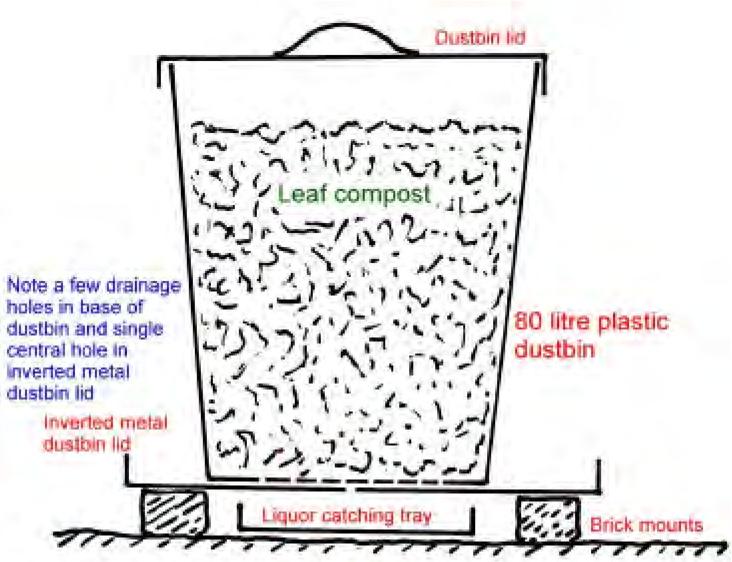
3.3. Making liquid plant food from manure

It is possible to make a liquid plant food from cow, horse, goat or chicken manure. It involves taking a bag of the manure and suspending it in a container full of water. A ten litre hessian bag of manure suspended in a 200 litre drum will work. The manure is bagged and suspended from a string into the water, and left for a week. It is best to cover the drum with a lid to stop any smell or fly problems. After a week the bag is removed, allowed to drain off and the brown liquid in the drum is stirred and then diluted with three parts of water to make the liquid feed. This can be applied to the vegetables with a watering can. The bag of manure can be placed back in a new drum of water and after a week used again diluted with about two parts water. If the bag is used a third time, the resulting liquor can be used neat on the plants. The manure can then be added to the compost heap. This method advocated by Tom Manson (see bibliography), which I have tried, works well. Eventually the bag rots – but a new one can be found.

There are several plant foods available on the market, the one known as Groesia is well known in Zimbabwe and has been available from the Marlborough Nursaries for decades. The secret formula no doubt has liquid manure in it, plus an assortment of additives. Even chemicals are sometimes added to the liquid manures and Manson recommends adding 2kg per 200 litres of ammonium nitrate for green vegetables or one high in potassium for tomatoes and potatoes.

3.4. Making liquid plant food from leaf compost

This a simple and effective technique for making a good liquid plant food which can be applied directly to seedlings and young plants as well as more mature plants. It is made by composting leaves of various sorts in a covered bin composter (such as an 80 litre plastic dustbin), which is kept moist by the periodic addition of water from above. In this case the liquor which drains through the composting leaves is directed to a liquor catching tray and retained and can then be applied to seedlings and more mature plants as a plant food. The liquor has the appearance of tea.



On the left photo the leaf compost liquid plant food maker can be seen next to a leaf mould basket covered with a plastic sheet to retain moisture. The liquor catching tray can be seen with the jug inside it. On the right the liquor catching tray and the inverted metal dust bin lid can be seen more clearly.

It has already been seen that composting leaves have a high content of valuable nutrients suitable for plant growth. The range and nutrient content of the leaf compost can be improved further by adding comfrey leaves which contain a wide range of nutrients including a high content of potassium, which is valuable for plants like tomato, potato and onion. Worms may develop naturally in such a composting pile, and if not can be added artificially. They flourish. So the resulting compost mix contains not only nutrients derived from composting leaves, but also from the worm castings which are also rich in valuable nutrients. Water is added every few days to the mix and the resultant liquor collected. When water is passed through this mix it picks up a valuable range of plant nutrients. The liquor can be used neat or diluted with water on plants with beneficial effects. After some months the leaf composted can be harvested from the composter and recharged with fresh leaves. The harvested material can be used as a mulch or mixed with other soils before planting vegetables.


The leaf compost liquor maker is filled with semi composted leaves taken from the leaf composter basket and extra comfrey leaves are added (right). Worms can also be added. Those flourishing in this system were not added deliberately, they were already present in the leaf compost. In this case the composted leaves are mainly bougainvillia. Thin layers of soil can also be added.


Five litres of water (from a pond in this case) is added to the top of the composting leaves. This drains down though the mix of leaves and worms. On the right healthy worms living in the leaf compost.

On the left photo spinach seedlings on the right basins have been fed with the leaf compost liquor and are growing more vigorously than the water fed seedlings in the left basin. On the right photo, healthy spinach have been grown in basins by the combined use of diluted urine (2 treatments of 3:1) and the remaining 6 treatments (2 per week) of leaf compost liquor. The liquor contains less nitrogen than urine, but more minerals of other sorts. The crop was more healthy, than similar crops fed with diluted urine alone.

The leaf compost liquor is also excellent for feeding seedlings and can be used undiluted. Here seedling tomatoes which have grown from compost are transplanted into seed trays. They are transferred again to buckets to grow to full maturity. The leaf liquor can also be used to feed the larger tomatoes. The humus formed from human manure invariably contains tomato seeds which germinate when watered.

4. A worm farm

The writer has made excellent potting soil which is rich in nutrients by farming worms in manure and leaf mould, using leaves placed on the surface as a worm food. Small red worms are used, but in general most worms will do. The technique involved cutting a 200 litre steel drum in half (various other containers, sometimes known as “worm bins” can also be used) and using these to make the “worm farm.”

Holes are made in the base of the drum for drainage. The drum with the open side up, is mounted on three bricks to raise it above ground level. These bricks, surrounded by wood ash, help to reduce the nuisance from ants. A layer of river sand 50mm thick is added to the base of the drum. Then a layer of manure (in this case goat manure) is added about 75mm deep, followed by some leaf mould. Then a hand-full of worms are added. Further layers of manure and leaf mould are added followed by more worms. This layering is continued until the drum is nearly full. Finally the manure is covered with a mix of fertile soil and leaves. The leaves act as food for the worms and more leaves are added to the top of the pile from time to time. The drum is watered down and kept moist from time to time. It should never be flooded with water.

In a few months the worms will have turning the manure and leaves into rich potting soil. They will also have multiplied and new small worms will start to grow. The worms take the leaves down into the manure which turns into a rich and valuable potting soil. The potting soil can be removed in small amounts from time to time as it is required. The worms can also be harvested and used to seed more worm farms.

The earth worm is nature’s farmer. Earthworms are tireless workers turning over the soil, and taking down fresh vegetable matter, such as leaves, from the surface, down into the soil. The burrowing of the worms aerates the soil and the worm’s faeces (worm castings) are also very rich in nutrients. Where earthworms are present in the soil, you can be sure that the soil is good and fertile.

Worms are Nature's gardeners

The well researched and widely used art of farming worms to increase soil fertility, known as vermiculture, and its used in ecological sanitation, has been described in many books and magazines. Perhaps the best known is the Worm Digest (email : mail@wormdigest.org). A comprehensive list of sources of information is available in the Sanitation Promotion Kit (WHO – 1997 see bibliography).

5. Modifying urine as a liquid plant feed.

As we have seen urine is an excellent plant food rich in nitrogen and is particularly valuable for maize and green leafy vegetables. The technique of diluting with water in ratio's of 3:1 or 5:1 and applying to maize and vegetables once or twice a week can produce very positive results. But care is required because of the high ratio of nitrogen compared to other major nutrients. If over applied, urine can be toxic to plants and is quite capable of slowing down plant growth as well as accelerating it, if the urine is applied in too concentrated a form or when the seedlings are still young. For instance if young tomato seedlings are planted in potting soil and watered just with water only, the growth will be good. If a 3:1 mix of water and urine is applied to the seedling which are too young, the growth may become stunted.

However it is possible to manipulate the urine to increase the proportion of phosphorus in relation to nitrogen – a technique which may be useful for young seedlings. One technique which as promise, but still needs more investigation is to sediment out the *struvite* (the mix of phosphorus salts contained in urine) and then dilute these with water. When shaken the sediments rise up in the water and can then be applied as a liquid feed for young tomato.

A technique which I have tried with some success is to add banana skins to the raw urine in bottles and then allow the sediment to form. These skins are high in phosphorus and may help to promote the sedimentation, but I have no proof for this. A second, taller bottle is prepared and a small plastic pipe introduced in the side wall one 6th of the way up. This is stoppered or bent to close it off. The urine from the holding bottle is then shaken up to release sediment and poured into the tall bottle and allowed to sediment over a few days. The top 5/6th of the urine is then drained off through the pipe and can be used as a nitrogen liquid feed, diluted with water. The tall bottle is then topped up with water and shaken, making a mix which contains more phosphorus and less nitrogen than the original urine. This is shaken up before applying to the soil. I have found this concoction helps the tomato seedlings a lot. However the phosphorus in *struvite* is released slowly and its effects are felt over a period of time. The proportion of phosphorus can be increased further by repeating the process.

The covo seedlings on the upper layer have been given the *struvite* mix as described above. Those covo below have been given water only. An increase in growth of the seedlings can be seen. This may be due to the higher proportion of phosphorus in the *struvite* mix and the greater dilution with water (5:1). compared to the normal diluted urine, (3:1) which can stunt very young seedlings.

Once the seedling is well established and during the later vegetative stage of growth, the 3:1 water/urine mix can be applied to the plants (leafy vegetable) once or twice a week. In Mexico, a small hand full of humus is applied to the raw urine and allowed to ferment. This is also reputed to enhance the properties of the urine as a liquid plant food. It seems there are many ways of manipulating and diluting urine, so it becomes more effective as a plant food. It is also possible to add some single super phosphate fertiliser to the diluted urine mix, about 10 gms per litre of a 3.1 or 5:1 mix of water and urine. This will increase the ratio of phosphorus, with positive results. Also wood ash can be added to this mix (also about 10gms per litre of a 3.1 or 5:1 mix of water and urine. This will increase the proportion of potassium, which is good for fruiting vegetables like tomato. In practice a teaspoonful of single super phosphate fertiliser can be added to 0.5litres of a 3:1 or 5:1 mix of water and urine and applied once a week to 10 litre containers. This is useful earlier on in that plants growth. Later on wood ash (to provide potassium) can be applied with the diluted urine. In practice a tablespoonful of dry wood ash can be added to 0.5litres of a 3:1 or 5:1 mix of water and urine and applied once a week to 10 litre. Wood ash and other sources of potassium are particularly good for tomatoes.

6. The usefulness of mulch

Mulch is name for material like leaves or leaf compost which are placed over the soil's surface where plants are growing.. The advantages of mulch are many. These include reducing water loss from the soil's surface, protecting the soil's surface from baking hard after watering in direct sun, thus increasing aeration, also weed formation is reduced, so the competition for nutrients is reduced - the planted vegetable gaining what the soil can provide. Also the variation on surface soil temperature is reduced and is more moderate – an important factor in hot climates – reducing stress on plants. But one of the most valuable properties of mulch is the extra nutrients it can provide. We have seen how many nutrients there are in leaf compost, and when this material is applied to the surface, the rain or watering will slowly release these nutrients into the soil beneath for plant use. The same applies to leaves which will remain moist in an environment where the plants are being regularly watered. The use of comfrey leaves is a good example. These are cut up and applied to the soil surface around the plant and slowly release their valuable nutrients into the soil for plant use. Comfrey leaves are rich in many nutrients, notably potassium, so mulching tomato with comfrey leaves can work wonders for the crop. The leaves are placed over the soil around the plant, once the soil's surface has been loosened to help aeration. Mulching is a simple but most effective technique.

The soil in this 10 litre basins of onions have been covered with leaf mulch. The mulch helps in many ways. It conserves water, adds nutrients and reduces weeds. Well worth the effort of applying.

17. Some special constructional techniques related to eco-san activities

Several techniques have been described in this book which support the practice of ecological sanitation. Eco-san is partly concerned with building toilet structures and partly with recycling the humus and urine to grow vegetables and other plants. The details of latrine construction and methods of applying the humus and urine to improve crop production have already been described. What remains is a brief description of some allied constructional techniques which are valuable in supporting the practice of ecological sanitation. These include the construction of cement jars in which humus can be formed from human excreta and also cement basins in which plants can be grown. It also includes various low cost pedestals, both urine diverting and non urine diverting. Also low cost ventilation pipes for latrines and hand washing devices. None of these have so far been described in this book.

Making cement jars and basins

The most economical method of making containers that will last year after year (if treated carefully) and be recharged many times is to use off-the-shelf buckets or basins as a mould and caste replicates in concrete. The concrete containers are heavier than the plastic bucket or basin, and thus more cumbersome to move, but in the long term they are very durable, being made of concrete, particularly if they are well made and cured and cared for. Split cement jars can be made of 30 or 80 litre capacity and a good concrete basin of 10 litres capacity. The best shape for growing shallow rooted vegetables (lettuce, spinach, rape, covo, onion)is broader and not so deep, so the concrete basin of 10 litres capacity is possibly best and most economical. The ten litre basin about 38cm in diameter and 14cm deep serves this ideally. Up to 50 ten litre concrete basins, can be moulded from a single bag of cement and river sand. Each basin will contain 2 or 3 rape or spinach plants, 1 or 2 tomato plants or 5 – 10 onion plants. This is quite an economical way of containing precious eco-humus and using it efficiently for vegetable growth. Maize can also be grown on shallow basins of this type.

1. Making 10 litre cement basins for vegetable growing.

This method is very simple and effective. The ingredients are river sand and cement. The mould is a standard 10 litre plastic basin. The mixture is 3.5 parts river sand to 1 part cement, using a pea tin container as a measuring device (400ml containing 500 gms cement). Two tins of cement (1 kg) are mixed with 7 tins of sand and water is added to form a moderately stiff but workable mix. The mix can be made in a separate basin. A piece of plastic sheet (plastic bag) is cut into the shape of the base of the basin and laid down within the basin. The cement is spread and drawn up the inner sides of the basin using hands and trowel. A layer is also trowelled evenly over the base. The cement mix is spread out evenly. Several of these can be made at one sitting depending on the number of basins available. Six is a good number and can be made in less than one hour. The concrete work is covered with a plastic sheet and left overnight. The following morning the concrete is watered and left under the plastic sheet for another 24 hours. The following morning the basins are turned over, exposing the base, and laid in the sun. This heats the plastic, which expands and the plastic basin mould can easily be lifted off the concrete replica. The concrete basins are then immersed in water or kept wet under plastic for several more days - the longer the better - to gain strength. Once cured three or more 8 - 10mm holes can be drilled in the base with a masonry drill for drainage. With care nails and hammer can also be used to make holes. The concrete basin is now thoroughly washed down and is now ready for filling with a suitable growing medium.

On the left six plastic basins are lined up ready to have the concrete mix added. A disc of plastic sheet has been added to each basin to ease the extraction of the cement basin later. On the right the mix has been made up (2 parts cement, 7 parts river sand and 2 parts water – made into a stiff mix). The mix is trowelled on the base and up the sides and smoothed down. It is then cured over a period of days.

2. Making a 30 litre split cement jar for excreta processing or vegetable growing

Where a family is using a urine diverting toilet and processing its faecal matter into humus held temporarily in buckets (see ***Skyloo***), the 30 litre split cement jar is a very good option as a "secondary processing site". The section below describes how a cement jar can be made in two halves (shells) so that it can be used to contain the combination of faeces, paper, wood ash and soil from the toilet - it can also be used to grow vegetables.

A 30 litre plastic bucket is carefully cut exactly in half with a hacksaw blade along a line marked on the bucket. The bottom surface and the top rim are retained to keep the shape of the bucket. In addition it is useful to cut a wooden spacer and attach to the top rim of both halves of the bucket to ensure that the rim keeps its shape. It is best that the two halves cast in concrete on the bucket mould keep their shape and match each other when fitted together. Once cut in half the bucket handle mounts are cut off and trimmed. The outer surfaces of the bucket are then sanded down to roughen the surface slightly. A layer of grease or thick oil is then applied to the outer surface. The concrete mix is then prepared. This is a mixture of river sand (3 parts) and cement (1part). A small tin (volume 450mls) containing about 500 gms of cement can be used as a measure. 15 tins of sand and 5 tins of cement are used for each split jar (2 pieces). The cement is applied to a thickness of one cm and smoothed down.

The castings are allowed to set overnight and the following morning they are watered and placed under a sack or plastic sheet. They are kept wet for another 5 days mounted on the moulds. Then they are carefully separated from the moulds to provide two halves. The longer cement is kept wet, the stronger the jar will become. It is best to immerse them in water for another week. The moulds are cleaned down and coated with another layer of grease to make another set of castings. About 18 split cement jars can be made with a single bag of cement. Cement when properly cured is a very strong and long lasting material and a makes a very valuable container.

Plastering the two shells of the 30 litre split cement jar on a mould made from a 30 litre plastic bucket. After a few days of curing the two cement shells can be separated from the mould.

Making the lid

The same mixture (3:1) is used to make the lid. This will require about 3 tins of sand and 1 of cement). A 15 litre plastic bucket is toped up with soil and a sheet of plastic paper is cut and placed on the soil. The cement mix is then added to the top surface about 1.5cm deep and a handle (such as a steel chain link) is set in a raised section in the middle. Only 1 or 2 lids are required, as only one will be filling at one time. The rest will be holding plants or will be empty. Lids are required to protect the excreta from flies and animals.

Assembling

The two shells are then placed on the ground together in a suitable place in the garden, possibly in a flower bed. They are then wired together to make the shape of the container. In this case the container is erected so that the broader base is at the bottom. This allows for good drainage from the container. The additions of soil and excreta are then made over some days or weeks. These may be the contents from buckets containing excreta coming from the urine separating toilets or even dog/animal manure. Layers of soil are added between the additions of excreta as the layers build up. The lid is kept in place at all timed when the fresh material is being built up. Good drainage is important on containers holding fresh excreta and soil.

30 litre split cement jars are ideal for processing faeces. The two shells are held together with wire. A lid is made to fit over the jar. Painting makes the jar more decorative.

3. The 80 litre split cement jar

This is made in a similar way to the smaller jar but on a bigger scale. An 80 litre plastic dustbin can be used as a mould. The handles of the dustbin are cut off and the outer surface smoothed down. The bin is carefully marked and cut in half with a saw. The same process is followed as for the 30 litre jar. A thin layer of grease or oil is applied to the outer surface and the mix of river sand and cement made up. The mix is 3 parts river sand and one part cement. In this case 18 (450 ml) tins of sand are mixed with 6 tins of cement for each of the two shells made. The mortar is built up to 15 - 20mm thickness. The curing, removal and further curing are carried out in the same way as for the smaller jar. It is important to allow sufficient time for the cement to cure by keeping it wet for several days under plastic sheet. Once fully cured the two shells are carefully separated from the mould and then wired together with the wider end at the base. A cement lid should also be made to fit the jar. This jar makes an excellent container for composting manure of several types. If four are made, the processed manure, together with kitchen wastes can be used in sequence continuously, with one being filled with another two processing and the fourth reaching a stage where it can be emptied.

Making the larger 80 litre split cement jar using a plastic dustbin as a mould.

Four 80 litre jars were made and used in rotation to process compost from kitchen wastes and manure

Low cost toilet pedestals

There are several ways of making low cost pedestals for use in toilets. In each of the methods described here a plastic bucket is used as a mould and insert for the pedestal. That is the pedestal is built up around in the bucket in cement, which acts as a mould, but also the bucket is left in place to provide a smooth surface inside the pedestal which can be cleaned down.

1. Very low cost pedestal

There is a pedestal which can be made cheaply from a 10 litre bucket. In this case the base of the ten litre bucket is sawn off and laid wide end down on a sheet of plastic. A line is drawn around the base rim of the bucket about 75mm out. Some strong cement mortar is now made 2 parts river sand and one part cement. This is built up along the inside along the line drawn on the plastic and up the side walls of the bucket. With care this can be done in one sitting. This is left to cure for two nights and then the bucket and its concrete surround is lifted up and turned into a base mould made of wood measuring about 40cm X 40cm. The base is cast in 3:1 sand and cement and left to cure. The seat is formed by the rim of concrete laid around the bucket on the plastic. It can be shaped and smoothed down with sand paper and once it is dry painted with an enamel paint. This is really a low cost but practical method of making a pedestal with easy to wash down plastic insert.

Very low cost pedestal made from a ten litre plastic bucket and cement only. It is durable and with suitable painting can be made very smart.

2. Low cost pedestal with concrete seat

This method uses a 20 litre bucket - and to reduce cost - a seat made of concrete. In this case a mould is first made in concrete for the seat. This is made by mixing cement and river sand (about 1:3) and building up a “slab” about 50 mm deep inside some bricks (dimensions about 50cm X 60cm). The commercially made plastic seat is then pressed into the cement and held down with a weight. It is left there until the concrete is stiff and then the plastic seat can be removed, leaving an impression of the seat. This should be done with care. It may be necessary to finish off the mould with a small trowel to get it smooth. The mould is left to cure for a week, being kept wet at all times. Once cured and dry, it is smoothed down with sand paper. Then it can be used to make more concrete seats. These are made by taking very thin plastic sheets and covering the seat part of the mould. A very strong mix of river sand and cement (2:1) is then used to fill the depression to make the seat.


The toilet seat mould is covered with very thin plastic sheet and a layer of high strength concrete is laid in the depression which will form the toilet seat. A loop of wire is laid within the concrete. After levelling off, L shaped wires are then inserted into the concrete. An upturned plastic bucket (with base removed) is then placed over the mould with the wire arranged around the outside of the bucket as shown above. Cement is then built up around the sides of the bucket. The wires strengthen the cement work.

A loop of wire is introduced to provide strength. L shaped wire inserts are now placed in concrete to strengthen the link between the seat and the side walls of the pedestal. This is done by laying the wider end of the 20 litre bucket (with the base already sawn off) on the seat. L shaped pieces of wire are then introduced into the cement around the rim of the bucket. The bucket can be left in place whilst the seat cures. Next a layer of strong cement mortar (2 parts river sand and one part cement) is built up around the bucket till it reaches the top. This is left to cure overnight and some thin wire is wrapped around the cement work (in a spiral form) and another layer of cement is applied. This is left to cure for another day or two, then the seat and the side walls of the pedestal can be removed. The pedestal (right way up) is then mounted within a wooden base mould (dimensions - outer 50cm X 50 cm - inner 40 cm X 40 cm) and the space between the wooden mould and the side walls of the pedestal are now filled with a 3:1 mix of river sand and cement with some wire reinforcing. This left to cure for another few days being kept wet at all times. Once cured and washed down, the pedestal seat can be sanded down and any small holes filled with neat cement slurry (nil) and then allowed to dry. The pedestal is then painted with an enamel paint and put to use by cementing in place within the latrine.


Very low cost and durable pedestals can be made with off-the-shelf plastic buckets and cement. With care and paint they can be made into very attractive units.

3. Low cost pedestal with plastic seat

This is easier to make and smarter, but more expensive. A commercially made plastic toilet seat is required. First holes are made with a hot wire in the supporting plastic ribs under the seat, so that a ring of wire can be threaded through under the seat. The "hollow" under the plastic seat can then be filled with a strong 2:1 river sand/cement mix with the wire inside. At the same time the 20 litre bucket (with base sawn off) is placed over the seat in a central position and L shaped pieces of wire inserted around the rim of the bucket into the cement. This is left to cure for a few hours. Then the side walls of the bucket can be covered with a 2:1 sand/cement mix. This is left to harden a little. Later some thin wire is laid spirally up the side walls of the pedestal to strengthen the unit. A further layer of mortar is then applied to the side walls. This is left to cure, being kept wet at all times. The pedestal is then overturned into a base mould made of wood, and the base made with more strong concrete - and left to cure. This procedure makes a neat, comfortable and long lasting pedestal.

Sequence of making pedestal

Finally a strong durable pedestal is made

4. Home made urine diverting squat plate

Squatting is the preferred position for defecation over much of Africa. It therefore makes sense to use a squatting type urine diverting device, if urine diversion is the chosen method of taking up ecological sanitation. The urine diverting squat plate is used almost universally in China and commercially made units are also available in Kenya. A home made copy of this effective unit can be made using off-the-shelf buckets and cement.


Make a mould in wood to make a small concrete slab 60 cm long by 30cm wide. Before pouring concrete cut a ten litre bucket, using the lower part to make rear squat hole, 20 cm wide and the upper part of the bucket to make the front hole (about 23cm wide) for later insertion of urine receiver. The strong concrete mix can be made from 3 parts river sand and one part cement. Reinforcing wires are laid in the cement for additional strength. This is left to cure for a few days, being kept wet after the concrete has set.


To make the urine receiver, take another 10 litre bucket and drill hole in lower end and attach a small 20mm plastic pipe fitting. This can be attached by welding the plastic or by using an epoxy adhesive. The bucket is cut so the upper edge at the front is higher than the rear. The rear edge should be at slab level.


Before the bucket is finally cut, it is inserted in the front hole of the slab and tilted so all urine will drain into the urine exist hole and the forward part of the bucket is higher. The bucket is marked and cut ands then placed in the hole and strong cement mortar is laid all around the bucket on top and beneath. This is also allowed to set and cure.


1. **After curing the unit is allowed to dry and is painted with an enamel paint. Note the side view of the unit on the left photo. See how the front of the urine collector is raised and the rear is low allowing good drainage of urine into the urine pipe. A raised front end catches urine better. The great advantage of the urine diversion squat plate is that males can urinate whilst standing above the unit. This offers a larger target for urine compared to most urine diverting pedestals. It is important however that males urinate in the correct hole. The urine diverting squat plate is fitted over a concrete slab in which a rectangular hole of suitable size has been made. Cement work does absorb urine, so the cement parts should be well protected with enamel paint.**

5. Home made urine diverting pedestals

This can be an adaptation of the pedestals which have been described earlier in which a urine diverter, made from a plastic bucket, is inserted in the front part of the chute of the pedestal. This urine diverter can be attached to the main bucket of the home made pedestal by welding, gluing, bolting or by wiring.

There are many ways of doing this, the main aim being to catch and divert as much urine as possible so it can be piped to a plastic storage container. The faeces can then drop into the vault below.


In this method a piece of plastic from a bucket is bolted to the side wall of the larger chute bucket to make the urine diverter. At the base of the diverter a polyethylene pipe is fitted in place with epoxy putty. Urine passes down the diverter, through the pipe into the urine storage vessel. This plastic unit is then built up in cement and a seat is fitted as described earlier.


In this method the urine diverter (yellow) is made from a 10 litre bucket and fitted inside the larger chute bucket (25 litre) with wire straps. These wires pass through the plastic and later cement work. The rest of the pedestal is then built up as described earlier. A plastic pipe fitting is then attached to the yellow bucket to lead the collected urine into a urine storage vessel.


On the left the completed urine diverter fitted to a Skyloo. The bucket which collects the faeces, soil and ash can be seen directly beneath the pedestal. On the right a home made urine diverting pedestal made in Kenya.


Once again a 10 litre bucket is cut to shape as shown to make a urine diverter which can fit into a standard (non urine diverting) pedestal as described earlier. A urine outlet pipe is fitted through a hole made in the bottom of the urine diverting bucket. When fitted on to the pedestal, the bottom of the urine bucket is sloped so that urine drains towards the outlet pipe. On the right the wire loops formed in the pedestal to hold the urine diverter. These can be fitted when the pedestal is being made or threaded through holes drilled later through the bucket and cement work.


A side view with the pedestal upside down showing how the lower part of the urine diverter slopes downwards so that urine will drain into the pipe. The lower part of the urine diverter must be able to pass through the hole made for the pedestal in the slab in such a way that the pedestal itself sits on top of the slab. The part of the diverter which holds urine before it drains through the pipe is actually held underneath the slab. On the right the finished urine diverting pedestal.

Method of making a urine diverting pedestal with urine pipe above slab level

Normally the urine diverting pedestal directs urine into a pipe which is held beneath the toilet slab or floor. In this way the pipe is protected and is able to safely lead the urine either to a soak pit, into a garden or a urine collecting chamber made of plastic. Great care is required to ensure that the pipe allows urine to flow freely downwards to avoid air locks occurring in the pipe, as these can cause problems with the free flow of urine from the diverter to the collector. When a double vault system is used, care is required in disconnecting the urine pipe linked to one vault with the urine pipe of the second vault.

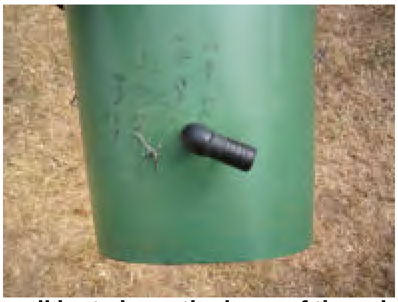
These problems can partly be overcomes by making a urine diverting pedestal where the urine outlet pipe is placed above the floor or slab level. Thus it is possible to connect a pipe directly to a fitting on the pedestal and lead the pipe away and to the rear above ground. This method is particularly suitable where the urine diverting pedestal is placed over a shallow pit toilet. Once the pedestal is fitted on top of the toilet slab, the urine pipe can be led away to the rear of the toilet and direct urine either into a a seepage area around a tree, or vegetable garden or into a urine container which can be dug in a shallow hole below ground level.

Sequence of making a urine diverting pedestal with urine outlet pipe above slab level


The material requirements are a 20 litre plastic bucket, a 20mm polyethylene bend, a plastic toilet seat and cement, sand and wire. First the base is sawn off the bucket squarely.


Next the plastic base of the bucket is sawn in two, one of these halves will be used to make the urine diverter within the bucket.


The half base is fitted within the bucket about half way up the walls at an angle. It is secured in place by drilling small holes through cut base and bucket walls and passing wire through and tightening.


A hole is drilled through the bucket wall just above the base of the urine diverter. The 20mm polyethylene bend is fitted through the hole as shown. It is placed at the angle shown above.


The toilet seat is now prepared. Using a hot wire, holes are drilled through the plastic ribs which support the seat. These allow a wire to be threaded in a loop under the seat.


A strong mix of concrete using 3 parts river sand and 1 part cement is mixed and added to the toilet seat as shown. This will add strength to the seat and form a bond between the seat and side walls of the pedestal. The bucket is now fitted centrally over the toilet seat as shown.


8 pieces of bent wire are now introduced into the cement supporting the seat. This is allowed to cure overnight. Next a further mix of 3:1 sand and cement is made and plastered half way up the walls of the bucket. This is left overnight again to cure.


The following morning the upper half of the bucket is cemented with a 3:1 mix and allowed to cure overnight. The next morning the bucket and seat are overturned into a base mould made with wood, about 60cm X 60sm and 40mm deep. It is laid over a plastic sheet.


The base mould is filled with the same 3:1 river sand/cement mix. Some wire is added to the base. Also some thin wire is also coiled around the pedestal. Next a final later of 3:1 mix is plastered up the side walls of the pedestal over the wire. The final layer can be made with cement watered down to make a thick paint and is applied with a brush. This is allowed to cure for several days being kept wet at all times. It is covered with plastic sheet and sacking.


The space between the bucket side wall and urine diverter is now sealed. Any type of pliable putty can be used for this job. Even chewing gum will do. It is pressed into the gap from underneath first. The putty should also be pressed into the gap from the upper side too. Urine passing into the urine diverter should find its way through the plastic bend and through the plastic pipe.

The urine outlet pipe has been added to the polyethylene pipe bend. This is led back over the concrete base of the urine diverting pedestal to the rear of the toilet.

The pedestal can be made more attractive by coating with enamel paint once the concrete is completely cured and dry. Once dry it can be mounted into the toilet.

The urine diverting pedestal can be fitted into a single or double vault dehydrating or composting toilet. It can also be fitted over a shallow pit toilet. The urine pipe can be led into a soakaway or into a vegetable garden, preferably beneath ground level. It can also be led to a tree like a banana, as shown above. The urine can also be led to a plastic container placed in a hole dug in the ground. It is advisable to protect the pipe in some way by covering with soil etc. Here the pipe is exposed for the photo.

Final note on this method

Where the urine is led through the pipe to a tree or vegetable garden, it is possible to add more water through the urine diverter to cleanse the pipe and dilute the urine. When the diverter is used over a shallow pit toilet, it is advisable to add soil and ash to cover the deposit to encourage dehydration. If composting is required in the pit, as in the ***Fossa alterna***, the pit contents must be moistened by adding urine or water, with soil and ash and preferably leaves.

6. Home made vent pipes.

A vent pipe is a valuable part of any pit toilet. It draws out air from the pit, mostly by the action of wind blowing across the top of the pipe. The air that flows out of the pipe is replaced by air passing down the squat hole or pedestal. This is most efficient when the slab and pit collar are sealed and airtight. The effect is that any foul odour from the pit does not escape into the structure, but is diluted by air and passes out of the pipe into the atmosphere. The effect is that the toilet becomes almost odourless. The other property of note is that, if the top of the pipe is screened with a corrosion resistant screen made of aluminium or stainless steel, and the structure is fitted with a roof, the pipe also acts as a flytrap. Where the interior of the toilet is semi dark, flies will enter the pipe from inside and are trapped. This is because flies are attracted to light when they leave the pit and enter the pipe which is the most obvious light source. From the outside, flies are attracted by odours coming from the pit and most of these are expelled through the head of the vent. If the head of the pipe is screened, they cannot enter the pit. This simple effect can dramatically reduce fly breeding in the pit toilet and thus reduce the passage of fly-born disease. So the vent helps to reduce fly breeding and odour. Toilets fitted with a vent are generally known as VIP's (ventilated pit latrines). There are over half a million in Zimbabwe alone.

Even on shallow pit eco-toilets like the ***Arborloo*** and ***Fossa alterna***, venting helps. Whilst the addition of plenty of ash and soil, helps to reduce odours and the potential for fly breeding considerably, the action of the pipe also helps to remove excess moisture from the pit chamber, as well as removing odours and reducing fly breeding. Vent pipes can be made from bricks, steel, asbestos and PVC. Asbestos is more durable than PVC, and the most efficient are smooth walled round pipes, asbestos and PVC being the most common. 110mm is a minimum acceptable vent diameter, although 90mm may just pass for eco-toilets which already have some degree of fly and odour protection from the regular addition of soil and ash. Commercial pipes are very expensive, but there are ways and means of making then at the homestead.

Several methods are available, one being the use of hessian cloth (sacking) soaked in a mix of cement and sand (ratio 1:1). The cloth absorbs the cement slurry which is best cut into strips about10cm across. The slurry filled strips are then wrapped around a suitable mould. This can be made of a wire or reed tube or even a bundle of grass suitably wrapped. Alternatively a PVC tube can be used as a mould to make many cement pipes. In this case the PVC tube is covered with plastic sheet and the hessian strips wrapped around it and spiralled up the tube. Four length of thin wire (about 2 – 3mm thick) are then placed down the length of the pipe and held in place with thinner wire. Then the strips of cement filled hessian are then wound spirally back down the pipe again with strips overlapping. The final layer is painted with the slurry using a brush. It is left to set overnight and then made wet in the morning and covered with plastic sheet. The pipe is kept wet for at least 7 days before it is moved. The PVC pipe is then twisted out of the cement pipe and the plastic sheet extracted. A suitable screen is then fitted by wrapping around the head of the pipe and fixing with wire. Plain steel screens corrode quickly and are of little value in fly control. Aluminium screen is best. If well made and cured, such cement pipes are very strong and durable – far more so than PVC.

A durable home made vent pipe constructed from Hessian and a sand cement slurry with some wire reinforcing. Very effective and longlasting.

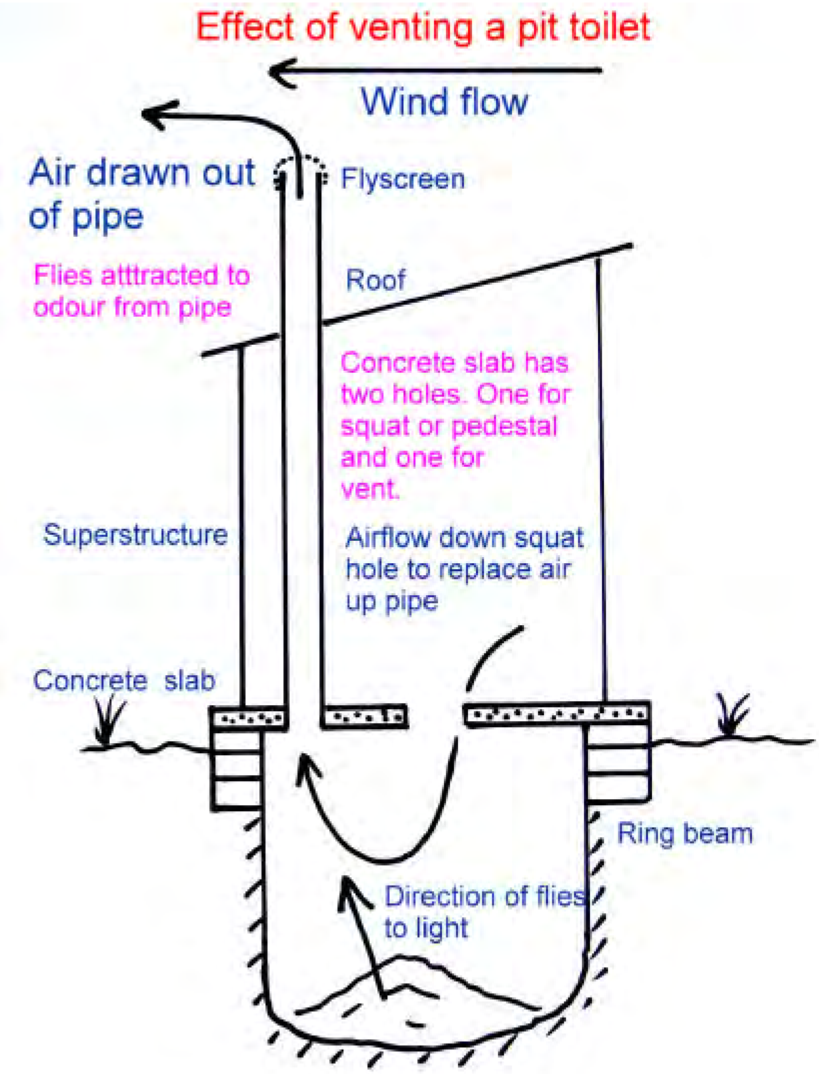


Diagram showing effect of vent pipe on functions of pit toilet

7. A steel framed superstructure for use on a range of on-site toilets

We have read in the book about the huge range of superstructures which can be used with these eco-toilets. Grass and poles through to brick, or iron sheet. All work, their primary aim is to provide privacy. One particular technique has proved itself to be particularly adaptable to a wide range of conditions and is described here. It consists of a light steel frame welded together using a combination of 25mm angle iron and 25mm flat bar. The durable hinge is made from old car tyre. The roof panel is covered with chicken wire and then a plastic sheet. Grass can be placed on top or thin iron sheet. The walling can be covered with any suitable material, which can include grass, reeds, plastic sheet, sacking or hessian, thin plywood or even wooden slats or other timbers. Whilst the frame is not particularly low cost (the steel costs around US$50 and a similar amount for labour), one made it will last afamily for many tears and can be covered with locally available materials which can be collected freely or cheaply.

Front and side views of the superstructure frame covered with grass

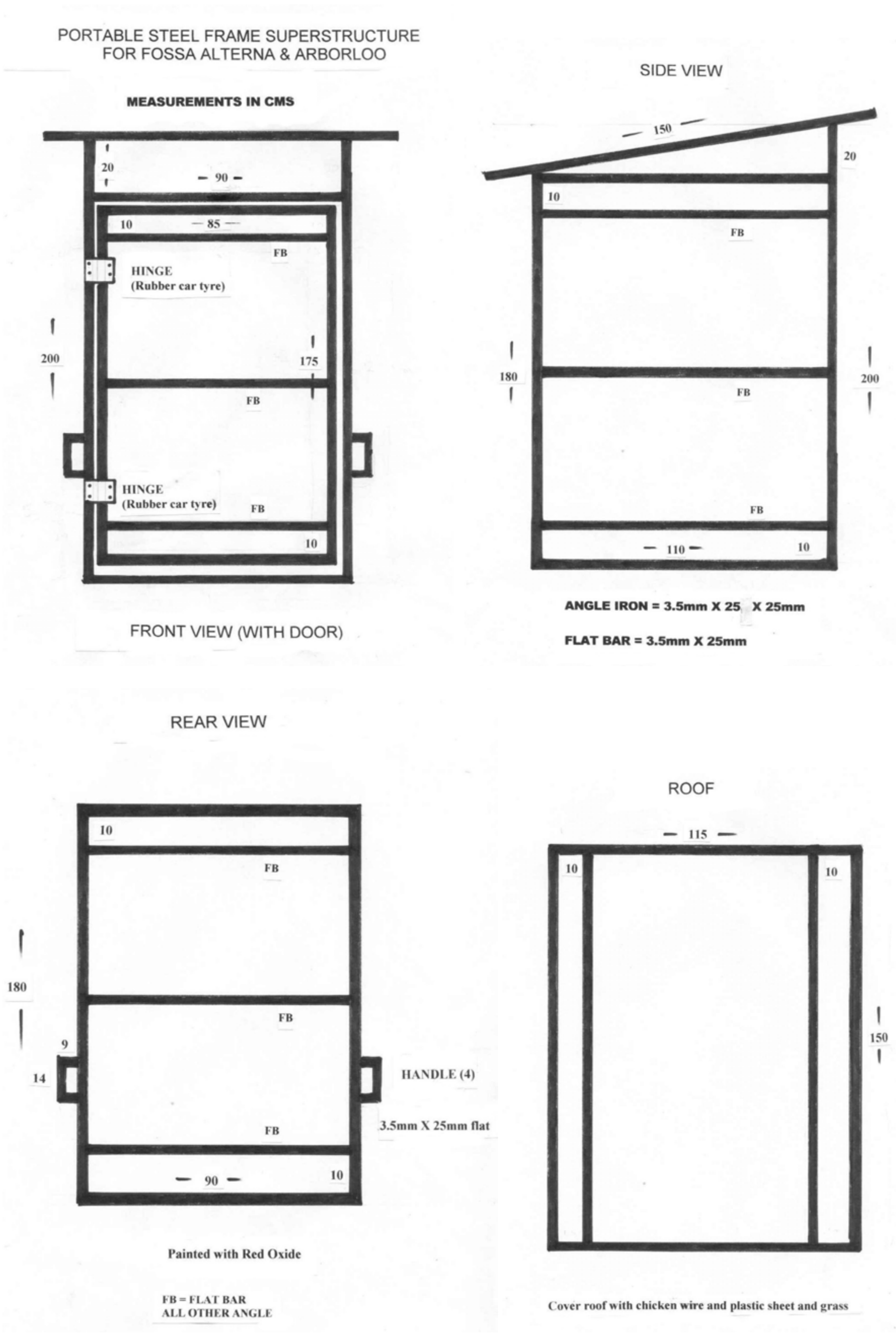
Rear view of structure and close up of carrying handle and rubber hinge

Close up of hinge and carrying handle and arrangement of steel work.

Close up of upper parts of the frame and roof

The asbestos pipe passing through the roof and a neat seat made from a bucket and concrete work only.

The frame dimensions



8. Hand washing devices

Hand washing facilities are vital if any hygienic value can be expected out of a toilet system. Hand washing is perhaps the most vital part of the process of improving personal hygiene. In fact hand washing is essential if an improved state of health is to be achieved in relation to toilet use. So all eco-toilets (and any other toilet) should be fitted with a simple hand washing device. There are several ways of making them.

8.1 Using a 5 litre plastic oil container and pill bottle.

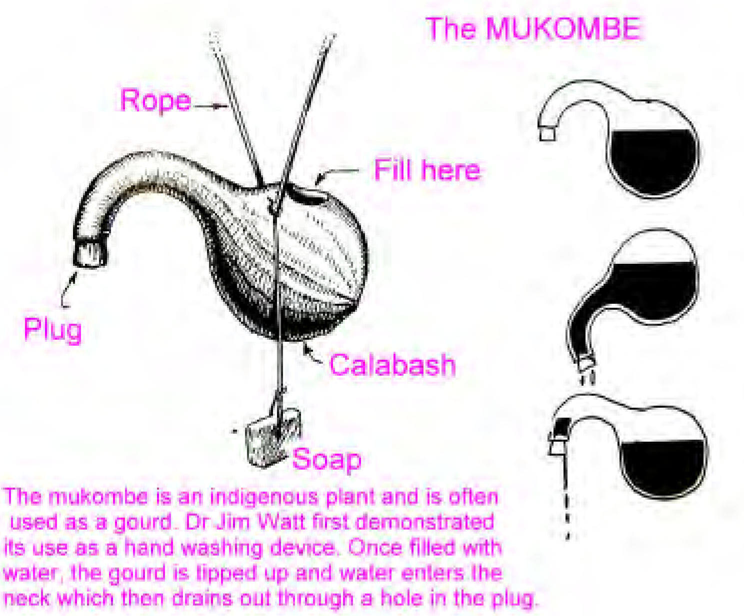
In this design a discarded pill bottle and an old 5 litre plastic oil container are used.

Hand washing device made from an old 5 litre oil container and pill bottle

The pill bottle is chosen to fit into the neck of the oil container. Cuts are made in the pill bottle lid and side wall as shown - one in the bottle cap, one in the bottle base and a 2mm hole is also drilled - see photo. The 5 litre container must be suspended on a wire or string so that it is balanced. A hole is drilled in the handle section and the container suspended on a wire placed through this hole.

The container is then thoroughly washed out and filled with water and the modified pill bottle inserted in the neck of the container. When the water container is tilted forwards, water will flow into the pill bottle through the cut made in the lid and slowly drain out of the small hole. The second opening in the pill bottle allows air out of the bottle whilst water is entering. Otherwise there would be an air lock. The small amount of water released is sufficient to wash the hands - one or two charges may be necessary. There are several variations on this theme of putting together a novel hand washing device using discarded plastic containers. Local innovation is required. There is no end to the variation of design.

8.2 The Mukombe hand washing device



8.3 The milk bottle hand washing device

Another type of hand washing device made from a milk bottle. In this case the lower part of the neck of the handle is blocked off and a small hole drilled above this level. The device hangs on a string attached to a wire passed through the bottle. When the bottle is tipped up, water enters the upper side of the handle and drains out through the hole.

8.4 Making a hand washing device from tin cans or plastic cups

This is perhaps the simplest and most elegant hand washing device and the idea originates in Malawi where it is used in both the CCAP and COMWASH ecosan programmes. It consists of no more than a plastic cup, tin can or aluminium beer can with two or three 3mm holes drilled in the base. A nail can also be used to make the holes. The cup or tin is suspended with string from either the toilet itself or from a simple wooden structure near the toilet. Water is taken from a nearby basin or bucket with a cup or scoop and poured into the device just prior to washing. Water can also be held in a plastic bottle nearby and poured into the device. A bar of soap can also be suspended nearby. Hard soap is best since a hole can be drilled through the soap and suspended on a string near the hand washing device. This simple hand washer can be made in minutes, costs almost nothing and can cleanse the hands of dangerous bacteria after toilet use. It should be fitted to every toilet made. In fact several should be mounted around the homestead at convenient places. It should always be used prior to eating or handling food. Regular hand washing is vital if improvements to health in water and sanitation programmes are to be effective. Remarkable that something so simple and cheap to make can be so valuable.


Simple hand washing device used in the CCAP ecosan programme in northern Malawi. No more than a suspended plastic cup. Water is carried from a nearby earthenware pot in a gourd and poured into the device. Used water falls on to plant below.



Simple hand washing device used in the COMWASH ecosan programme in southern Malawi. Discarded tins or plastic bottles can be used. Several small holes can be drilled into the base of the tin or container. Water held in a jar or pot is poured into the device with a mug.

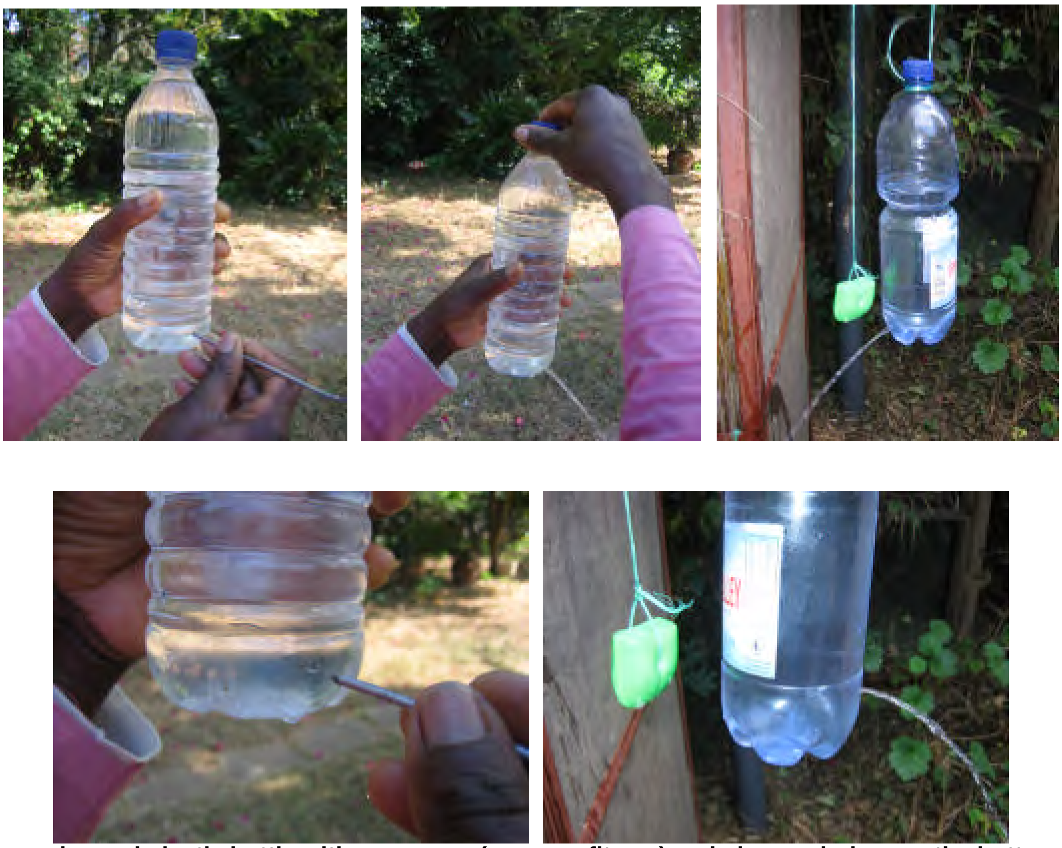
These hand washing devices, made from tins or beer cans, can be suspended directly from the toilet roof on a string as in this case. It can also be suspended by a simple wooden device near the toilet. Water can be poured into the device from a cup or from a plastic bottle. Small holes are drilled in the base of the tin or can to allow the water to drain out slowly over the hands.

Two or three 3mm holes are drilled in the upper rim for attachment to suspension strings – two holes in the base. On the right a flower pot placed directly below the washer to catch and use washing water. Two sources of water – a plastic bucket and small plastic cup and a capped plastic bottle.

Hand washing is more effective if soap is used. Here soap is suspended on a string near the hand washer

8.5 Making a hand washing device from a round plastic bottle with screw cap.

The second type of simple hand washing device is made from a round plastic bottle with screw cap. Any size will do but the larger the bottle, the more hand washes can be made before refilling is necessary. A short length of 3mm steel wire is taken and a point filed down on one end. The used bottle is filled with water and a hole pierced near the bottom with the wire. It may help to wrap some cloth around the wire to hold it firmly. The wire is pushed though the plastic and withdrawn. When the cap is screwed up water will not come out of the hole. When the cap is unscrewed water will come out of the hole, enough for hand washing. The device is hung up near the toilet. Put more in the bathroom, kitchen and eating areas.



Take a used round plastic bottle with screw cap (or press fit cap) and pierce a hole near the bottom with a pointed piece of 3mm wire. This is best done with the bottle full of water. The filled bottle is hung up on a string near the toilet. When the screw cap is closed water will not come out. When the screw cap is open water will come out and can be used to wash the hands. Soap helps.

Clean hands for Health!

The benefits of improved sanitation can never be fully realised unless personal hygiene is improved too. Regular hand washing lies at the heart of improved personal hygiene.

An Ecological Approach to Sanitation in Africa

A compilation of experiences

Peter Morgan

(2004)

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18. Health implications of handling compost derived from human excreta

The health and welfare of people results from many diverse factors influencing the life of each individual. The availability of food, shelter, freedom, improved water & sanitation and the regular application of personal hygiene all provide their positive influences to help individuals gain the ideal of a healthier life.

Thus the provision of improved sanitation plays its part. In terms of providing sanitary facilities, the main aim of the pit latrine is to confine the excreta, as a preferred method to indiscriminate defecation. But even when confined, excreta can negatively influence the life of individuals. Flies can breed and carry pathogens on to food. Excreta stored in pits too close to domestic wells can contaminate the water, and without adequate hand washing facilities, soiled hands can pass on pathogens in a variety of ways.

We have seen in preceding chapters that many of these factors can be overcome in eco-toilets. Fly breeding (and odour) can largely be overcome by adding plenty of soil and ash to toilet pits and vaults. A screened vent pipe will also help in this way, and will also take away some excess moisture and smell. Excreta stored in shallow pits is less likely to pollute underground water compared to that stored in deep pits, since the potential source of contamination is further away from the water table. The encouragement of the conversion of excreta into humus (by the addition of soil and ash) may also greatly reduce the potential of underground contamination of water supplies, since the life of pathogens may be considerably reduced. The provision and regular use of simple hand washing will also cut off another potential pathogen carrying pathway. Hand washing facilities are a vital part of any toilet system.

However in ecological sanitation one factor is encouraged, that in most other sanitary disposal systems is discouraged. That is the handling of processed excreta in the form of composted or dried faecal matter. So it is important to assess the potential hazards of coming into contact with processed excreta. And also perhaps, what are the hazards of coming into contact with excreta which is thought to be fully processed, but is in fact not so.

The handling the compost withdrawn from urine diverting vaults, composting jars or humus derived from the ***Fossa alterna***, will always create a dilemma concerned with health and safety. It must be accepted that handling these products may pose a potential health risk, especially if the facilities have not been managed properly. Only where the ***Arborloo*** is used, are the risks of handling almost non existent – that is simply because the processed human excreta are not handled at all and lie below a generous layer of topsoil in which the young tree is planted.

In all other cases the handling of processed excreta is encouraged - more so if the products are introduced into agriculture, which is the recommended practice. The topic of health risks related to handling or coming into contact with excreta is a large and well documented subject (see bibliography: Feachem et al. 1983, Stenström 1999, Stenström 2001). The health risks associated with handling these products can largely be divided into those resulting from the persistence of pathogenic bacteria, and those resulting from the persistence of helminth (worm) eggs. The survival of bacteria may largely depend on the correct management procedures of the toilets being followed. Thus in the ***Fossa alterna,*** if soil is not added to the shallow pit at all, or in very small amounts, the conversion of the excreta/soil mix into a safe compost will be much slower than with the recommended mix of soil, ash etc being added. However bacteriological die off can be assured if the correct procedures are followed as the results below show. In promoting the ***Fossa alterna,*** in particular, every means should be taken to ensure that the simple management procedure of regularly adding soil and ash to the shallow pit are followed. This also applies to urine diverting systems.

The Bacteria

In order to give some sort of indication of "comparative risks" in handling different materials, the writer rubbed his hands in humus taken from a 30 litre ***Skyloo*** jars (after 3 months composting) and also in ***Fossa alterna*** humus (after 12 and 14 months of composting). The hands were rinsed in tap water after "soiling" and tested for *E. coli* and Salmonella. None of these bacteria were found. However large numbers of pathogenic bacteria were found in a tiny sample of raw excreta attached a pin head and also placed in tap water for sampling. This tiny sample of raw excreta was much less than the amount sometimes left on the fingers after anal cleaning. Not all hand wipes leave the hands clean, even with paper. This simple experiment reveals that the compounded daily risk of soiling hands by anal cleansing is far greater than risk of handling well composted faeces. That is why the availability and use of hand washing facilities next to the toilet is so important.

Further samples of humus taken from both 30 litre ***Skyloo*** composting jars (*mix of faeces, soil, ash and toilet paper*)and ***Fossa alterna*** (*mix of faeces, urine, soil and paper and composted for 12 and 14 months*) and also humus taken from 80 litre composting jars (*mix of organic kitchen scrap, animal manure, and soil*) were analysed by incubating samples on agar plates to reveal the presence of *Escherichia coli, Shigella sp, and Salmonella sp.* The following results (below) show that none of these organisms survived the processing in ***Skyloo*** jars after 3 months or compost pits of the ***Fossa alterna*** after 12 – 14 months. These preliminary results indicate that from a bacteriological perspective there were very minimal risks involved in handling humus derived from either of these sources after a specified period. However it is acknowledged that the presence of *Shigella* and *Salmonella* were not tested in the excreta before the composting stage. *E. Coli* is well known to be sensitive, and *Faecal Streptococci* (Enterococci) are more sturdy, but were not tested.

Die-off of some pathogenic bacteria in *Skyloo* jars and *Fossa alterna* pits

Material tested	Material processing time, pH and temperature	Organisms
Humus from 30 litre composting jars from ***Skyloo.*** *Mix of raw faeces,soil, wood ash and paper.*	3 months pH 6.72 Temp. 21 deg. C at sampling time	*E.coli (none)* *Shigella sp. (none)* *Salmonella sp.(none)*
Humus from 80 litre composting jars from kitchen composter. Mix of organic kitchen scraps, dog manure and soil (no human material)	9 months pH 7.2 Temp. 24.8 deg C	*E.coli (none)* *Shigella sp. (none)* *Salmonella sp.(none)*
Humus from ***Fossa alterna*** 1 Mix of human faeces, urine and soil (bagged)	12 months pH 6.75 Temp. 18.4 deg. C	*E.coli (none)* *Shigella sp. (none)* *Salmonella sp.(none)*
Humus from ***Fossa alterna*** 2 Mix of human faeces, urine and soil (bagged)	14 months pH 6.75 Temp 18.4 deg. C	*E.coli (none)* *Shigella sp. (none)* *Salmonella sp.(none)*

Further studies were also made of the die-off of *E. coli* in samples of a mix of faeces/soil/ash/paper removed from ***Skyloo*** composting jars. A total initial count of 325 000 colonies per gram of sample were recorded on the day of final addition of raw excreta and soil, with counts being reduced to 6 600 after one month of ambient temperature composting and no bacteria growth was observed on agar plates after 2 months of composting. The same samples were also analysed for Salmonella after 2 months of jar composting and no Salmonella could be found. The pH of these jars was near neutral. Jar temperatures varied during the day and night and also with season. Lowest temperatures recorded were around 11.3 degrees C. (July early a.m.) with higher temperatures of 21.5 being recorded early pm in mid August, 2003. The hottest month occurs in October.

Material tested	Material processing time	Organism. *E. coli* (colonies per gram)
Humus from 30 litre composting jars from ***Skyloo.*** *Mix of raw faeces, soil, wood ash and paper*	0 months (initial mix)	325 000
Humus from 30 litre composting jars from ***Skyloo.***	After 1months composting	6 600
Humus from 30 litre composting jars from ***Skyloo.***	After 2 months composting	zero


Keeping the jar of contents moist helps the composting process. The photo on right shows one method of sampling humus from a 30 litre jar with teaspoon. The uppermost soil is removed and soil a few centimetres down is taken and placed in a sample bottle.

In a repeat of earlier analysis of soil taken from ***Fossa alterna*** pits, humus was removed from a pit 3 months after the pit was finally closed off. Samples were withdrawn using an earth auger (see photos below). This toilet had been used by a family for 9 months. The slab and structure were moved over to the second pit and the pit contents were covered with soil and leaves. In this case soil and leaves had been added regularly to the pit, but no wood ash. The total depth of the soil/excreta mix was 64cms, 3 months after covering with soil. Samples were extracted from the pit at two levels – 30cms and 60cms. The hole was drilled and the samples withdrawn about 15cm from the central drop zone directly beneath the pedestal, so there could no doubt that the samples were indeed a composted mix of excreta and soil, with some leaves. As with the composting jars, the laboratory analysis showed no evidence of the presence of either *E. coli* or Salmonella in the extracted soil samples, at either level.

Material tested	Material processing time, pH and temperature	Organisms
Humus from ***Fossa alterna*** 3 Mix of human faeces, urine, leaves and soil sampled direct from pit. 2 Samples taken from 30cm and 60cm depth.	3 months pH 6.75 Temp at time of extraction 16.8 deg. C (upper sample) and 15.9 deg. C (lower sample)	*E.coli (none) Salmonella sp.(none) For both samples*

On the left samples of *Fossa alterna* soil are taken with an earth auger. The auger is drilled down to specific depths and samples withdrawn and placed in sample bottles. On the right the hole has been drilled down to 60cm (total soil depth was 64cms).

Each plug of soil removed is placed on one side in sequence. Once the samples have been taken the remaining soil is placed back down the hole. On the right the series of plugs placed on lids in sequence. After sampling, these plugs are placed back down into the pit for further composting.

Obviously further analysis is required on a much larger number of ***Fossa alterna*** samples, to establish what happens when the toilet is managed under a variety of conditions, and particularly when less care is taken over management. When the addition of soil, ash or leaves is irregular and a larger bulk of faecal matter accumulates without the addition of soil, ash or leaves, then the material takes much longer to convert. In the case sited here, the toilet had been well cared for and additions of soil and some leaves had been undertaken regularly. Thus the contents of the pit were able to compost under conditions which were more aerobic than the normal pit latrine. This helps the conversion of excreta into humus considerably.

However it is not known if *Salmonella* was present in the initial samples tested, although the ***Fossa alterna*** humus tested after12 and 14 months composting had originated in heavily used communal units. It is also acknowledged that *E. coli* is a sensitive organism, and likely to die off quickly.

Consequently a preliminary experiment was undertaken on jars of composting faeces and soil derived from the ***Skyloo,*** where the *Salmonella sp (not S. typhi), Staphylococcus pyogenes, Pseudomonas aeruginosa, E. coli, Klebsiella sp and Shigella flexner* were artificially introduced into the composting humus in a the form of a "lethal cocktail" prepared by the clinical laboratory. This "cocktail" prepared in a vial was diluted with water and applied to the soil within the jar. In this case there could be no doubt that the jar soil contained the range of species indicated. The soil in the jar was analysed one month after the "lethal cocktail" had been applied and none of the organisms originally applied could be detected.

Ilona Howards special "cocktail" of pathogenic bacteria. This was added to a bottle and diluted with water

The "cocktail" was then added to a jar of composting soil and excreta taken from the Skyloo.
After one month the soil was tested in the laboratory and none of the lethal bacteria could be found.

Whilst *Escherichia coli* is a sensitive bacterium, not well known for surviving outside the human body environment for long, it is the most widely tested indicator bacterium, showing the presence or absence of many enteric bacteria associated with disease and human suffering.

Salmonella is known to survive for longer outside the human body, and no doubt a series of more exhaustive tests need to be carried out. But these preliminary tests do indicate that from a bacteriological perspective the humus is relatively safe to handle provided that sufficient time is allowed to elapse for composting – that would be 6 months for composting jars and 12 months for ***Fossa alterna*** pit soil. Or putting the problem in another and far more practical way, the threat of picking up pathogenic bacteria on the hands is significantly greater from the daily routine of anal cleansing practiced by all people compared to the infrequent handling of composted faeces formed in jars and shallow pits.

Whilst pathogenic bacteria exhibit a natural tendency to die off when outside the human body, this dramatic change probably also resulted from the action of soil organisms at levels between pH 6 and pH 7 and at ambient temperatures between 10 - 22 degrees centigrade. The simple conclusion to be drawn is that the soil, when in close contact to human excreta acts as an excellent eliminator of enteric bacteria, with the process becoming more efficient if ash and other compostable material, like leaves, are present. This subject is still being investigated in more detail. In the real world, there will be few gardeners who do not wash their hands after handling the soil and planting vegetables, and certainly before eating or preparing food. The main problem may lie in the indiscriminate behaviour of very young children who have the habit of consuming many undesirable materials from their immediate living environment.

Parasitic worms

On the question of parasitic worms, worm eggs and cysts which will be present in excreta deposited by infected people may remain viable in the humus for a much longer period than pathogenic bacteria. The risks of hookworm (*Ancylostoma sp.*), roundworm (*Ascaris sp.*), tapeworm (*Taenia sp.*), *Giadia*, and other parasites must therefore form a part of this discussion of eco-san and health. Thus in areas where parasites like hookworm and round worm are common, there is potentially a much bigger risk in handling the humus. It is certain that worm eggs may survive in the soil for periods longer than 12 months, but this may depend on climate and other factors. Soil is known to be an excellent environment for the maturation of *Ascaris* eggs. Their life is known to be shorted at higher pH and higher temperatures, and the application of lime or ash has been recommended and is widely used in urine diverting toilets in Mexico and elsewhere (Stenström, 1999, 2001). However the widespread application of lime, or even very heavy doses of wood ash, may not be so practical for many areas in Africa where low cost sanitation is used. Certainly this problem is more common in hotter and damper climates and thus at the coast. Existing data shows that the viability of most worm eggs is eliminated or greatly reduced after 10 - 12 months of composting in tropical conditions (EAWAG/SANDEX information sheet on Pathogen Survival Periods in faecal sludge). For the East and Southern African region, 6 months composting is considered adequate in at least one authoritative account (*Communicable Diseases*. (Eshuis and Manschot 1978. African Medical and Research Foundation). In South Africa, Scott demonstrated a die off of *Ascaris* in 100 days (Richard Holden pers.comm.). So even with worm eggs, the threat is greatly reduced after the recommended 12 month period of composting. *Ascaris* eggs must be injested before an infection can take place. Infected soil must be taken in by mouth. For this reason *Ascaris* is most common in young children who eat infected soil. According to Eshuis and Manschot, except for the temporary symptoms during the lung passage, infection with *Ascaris* may be symptomless with vague abdominal discomfort. Complications may occur in very heavy infections.

By far the simplest and most practical way of dealing with this potential problem of worm (helminth) infections, is simply a matter of extending the time of composting the faecal/soil/ash mix in a protected environment. Thus extending the time of composting from 6 months to 1 year in composting jars will considerably reduce any health risks due to viable worm eggs being present. In the case of ***Fossa alterna*** humus, the material can be transferred from the pit directly into a series of bags for storage for a further period of 6 – 12 months before application to vegetable gardens. The process of "bagging" keeps the humus out of the reach of young children who are the most vulnerable (ref: S. Benenson 1990). After such an extended period of composting (2 years) the risks of viable worm eggs being present will be very low indeed. However the greatest potential threat will have been overcome within 12 months of composting.

In fact the bagging process will help to improve the humus further as well as making it slightly safer, as the turning of material improves aeration and this helps the composting process. It is also possible at this stage to add more soil and leaves to improve texture. The mix is bagged watered and left to mature further, with the bag closed off. Worms may naturally breed in such composting bags, or can be introduced. The end result will be humus of an improved quality and a potentially safer one. The process of bagging is a simple way of secondary composting of ***Fossa alterna*** humus.

The other alternative if there is doubt about the safety of the compost taken from shallow compost pits like the ***Fossa alterna*** is to transfer the compost directly from the composted pit into a pit dug nearby for planting a tree. Protective gloves can be worn if necessary and the period of time of exposed faecal compost is short. The transferred compost is covered with a generous layer of top soil (15cm) and a young tree can be planted.

Where the facility is used as a strictly family unit, such parasites will be recycled largely within the family itself, and family treatment of worms may reduce the potential of loading the pit with viable eggs considerably. It is wise therefore to assess the potential parasite risk in any area where ecological sanitation is being promoted. In Zimbabwe, problems associated with parasites have been relatively low over a period of two decades or more, but as health services deteriorate, the frequency of these and other health related problems is on the increase. Poverty is linked to poor health and the general state and stability of a nation is reflected in the health of its people. Hotter and more humid areas, as may be common in most coastal regions of East and South East Africa, may be associated with higher parasite rates and thus more care is required in such areas. Children may be particularly vulnerable.

It is important to reiterate again, that any risk of handling composted human excreta must be put in its rightful place amid many other risks that toilet users are subjected to. In particular it is important to compare, once again, the risk of handling eco-humus with the risks of spreading disease from hands soiled in the toilet. The potential risk of soiling hands occurs every time we use a toilet for defecation. And without appropriate hand washing facilities being available close by, the risk of passing on the pathogens contained in raw excreta to other people and to food is a very real one. The stark fact remains that in Africa countless millions of people to not have access to any form of improved toilet at all. And even for those fortunate ones that do, a hand washing facility is rarely available. And this situation poses a very real threat which promotes the spread of enteric diseases. It is quite likely that the hands of users may be badly soiled with raw human excreta many times during a single month. One must compare this health threat with the threat of handling processed toilet compost on far fewer occasions. The compost itself is dug out of the pit and also mixed with other soils with a shovel, which distances it from the hands. But the hands will be involved in planting seedling vegetables directly in the mix of soils. Even when mixed with topsoil again, the health threat is reduced further as the composting process continues.

Thus in any discussion of health in relation to the promotion of ecological sanitation, it is important to see the overall picture. Every step should be taken to make the compost as safe as possible, and every step taken to ensure that hand washing facilities are available and used. In this process of enlightenment, a good educational component is vital. The process of "passing on the message" not only about how to build and maintain eco-toilet, but also about health and hygiene in relation to the provision of improved sanitation is a vital one. This is the subject of the next chapter.

19. Training methods to support ecological sanitation programs

Passing on the message!

Most people in this sub-region of Africa will be accustomed to the pit latrine, which is the most common of all excreta disposal systems in the world. Whilst poorly built pit latrines often develop reputations for collapsing during the rains, and of smelling or producing large numbers of flies or mosquitoes, improved pit latrines can provide an excellent means of excreta disposal being both safe and pleasant to use. Improved pit latrines like the VIP, can offer a simple method of disposing of human excreta which is almost free of odour and fly problems. And VIP's do not necessarily need to be expense - some of the best are the simplest and cheapest. Whilst pit latrines can contaminate underground water in areas of high water table in areas where the population density is high and wells are used for supplying domestic water, the great majority of improved pit latrines do not pose a serious threat of contamination to ground water supplies. Improved pit latrines are safe and easy to use and require the minimum of maintenance. A latrine pit, 3 metres deep, will last a family for a decade and the only requirement in terms of maintenance is to keep the toilet clean, and to keep the vent pipe (if fitted) in good working condition. For these reasons the pit latrine is often the logical first choice for families living in both peri-urban and rural areas in this part of Africa. Indeed, the pit latrine has served the continent well and will continue to do so for many generations to come.

Thus, in introducing ecological sanitation to areas where the pit latrine is common, good reasons must be sought for introducing something new, which although relatively low in cost, requires a higher degree of management than the common deep pit latrine. Its practical advantages must be proven beyond doubt in the minds of the new potential future users. What are the selling points of low cost ecological sanitation?

The first point of interest is that the concept of recycling human excreta is not new at all in this part of the world. Whilst the great majority of pit latrines are abandoned after the pit is full, a small but important proportion are used for planting trees in countries like Mozambique, Malawi, Kenya and Uganda. Indeed, the traditional practice of planting trees on filled latrine pits has been used for generations in the sub-region. This method is perhaps the simplest and most elegant way of recycling the nutrients held in human excreta, although until recently, it was not recognised as such. The fact remains that huge volumes of humus formed in pit latrines from human excreta have been lost to agriculture – an estimated 1.5 million cubic metres formed in the 500 000 VIP latrines built in Zimbabwe alone! Had this potential loss been recognised 30 years ago, the course of low-cost sanitation may have taken a different route. Fortunately the methods of tapping this underground resource have now been improved and officially recognised as part of a range of ecological sanitation options.

In fact two of the three toilet systems described in this work (the ***Arborloo*** and ***Fossa alterna***) are themselves variants of the pit latrine. If they are fitted with ventilation pipes, they are also variants of the VIP latrine. Such technical developments were undertaken deliberately in Zimbabwe to form strong links between existing sanitation practice (pit latrines) and the newer concept of ecological sanitation (the ***Arborloo*** and ***Fossa alterna***). By bridging the obvious technical gap that lies been a pit latrine and a urine diverting system with these pit latrine upgrades, there is hope that the transition from a disposal system to a recycling system can more easily be made.

Thus in introducing ecological sanitation to new recruits, it make sense to offer a range of technical options of varying complexity and cost into any programme of eco-san promotion in this part of Africa. In Mozambique under a programme undertaken by WaterAid and ESTAMOS, a choice of latrine types is offered to people living in both rural and urban communities in Niassa Province (Ned Breslin et al., 2001),. The range included traditional and improved pit latrines fitted with a sanplat, VIP latrine's as well as ecological toilets like the ***Arborloo***, ***Fossa alterna*** and urine diversion systems. The ***Fossa alterna*** was found to be most popular, because, unlike earlier pit toilets introduced into the programme, they did not smell or produce flies (due to regular addition of soil and wood ash). Also the new eco toilets were considered to be permanent facilities unlike earlier toilets which often collapsed or filled up quickly. There was also the added perceived benefit of a yearly supply of compost, useful to restore the fertility of worn out soils. In Malawi, where the ***Arborloo*** is most popular eco-san option, intensive community mobilisation has been undertaken in Embangweni (CCAP Report by T. Munkhondia, 2003). The ***Arborloo*** is the simplest and lowest in cost within the Eco-san range, and planting trees on filled latrine pits is common in Malawi. Clearly it makes sense to build on tradition.

New recruits to the world of ecological sanitation are unlikely to be convinced by word of mouth alone. They must be given the opportunity to view working examples of the various toilet options and talk to the users who can inform them of any practical advantage they have experienced. This means that demonstration units, which have been in use for some time, must be available for inspection locally. Thus forward planning is required. Enthusiastic individuals or key community leaders must be selected and encouraged to participate in the construction of new eco-toilets in their own back yards - well ahead of more extensive implementation programmes. At this stage an element of faith is required. For most people, travel excursions to see examples in other provinces or countries may not be possible. Thus the first stage of passing on the message about eco-san is to set up a range of technical options to willing participants, within the proposed area of future implementation.

Many of the benefits of ecological sanitation are not immediately apparent. For instance, improved crop and vegetable production, by the use of humus derived from the toilets, can only be seen in the third year after an eco-toilet such as the ***Fossa alterna*** is first put to use. One year is required to fill a shallow pit, another year of composting and then, during the third year, the humus can be put to use. Also fruit trees grown on ***Arborloo*** pits may only produce fruit after a few years of growth. So even demonstrating the usefulness of the humus may take years to fulfil. Time is required and forward planning.

Intensely practical aspects of promoting eco-san are of thus of supreme important. Trainees must participate in constructing slabs, rings beams, superstructures, hand washing devices, pedestals etc. Ideally they will also plant trees if that is practical at the time and tour sites where trees are growing on ***Arborloo*** pits or where vegetables have grown well on mixes of eco humus from toilets and top soil. They will handle processed humus and be told how it was formed. Every aspect of ecological sanitation should de described in training and extension courses, and that means not just building toilets but also demonstrating how eco-san fits into the broader field of agriculture and forestry. How back yard gardens, small orchards and wood lots can benefit from the introduction of the concept of eco-san. The widespread and successful uptake of ecological sanitation will depend on skilled and dedicated people passing on the message in a meaningful and practical way which makes sense to the potential users. The theory alone is simply not good enough.

Eco-San training in the East and South Eastern Africa Region

Passing on the message of "closing the loop" on a flip chart at Kafunda Village, Ruwa, Zimbabwe.

Practical training exercises in construction at Ruwa, Zimbabwe (left) and in Kusa, Kenya

Lining the upper end of a pit in Malawi (left) and explaining the value of humus in Mozambique (right).

Passing on a practical message - about ecological sanitation.

Ecological Sanitation is a system that makes use of human excreta and turns it into something useful and valuable with minimum pollution of the environment and in away which is no threat to health. The basic concept is to take something which is a waste and most unpleasant and turn it into something which is pleasant to handle and useful in agriculture as well. Special toilets are used for this process. The aim is This is then followed by demonstrations of how the resulting products, both urine and humus can be used in agriculture to grow more vegetables and trees etc.

Ecological sanitation may not be an easy subject to get "converts." Toilets are often a "non subject" in local conversation and as for human excreta - well it is just very nauseating and unmentionable. People simply do not talk about these things and have no wish to. For most, it is something to be avoided. And most families have many other priorities. So training in this subject is very challenging. The overall aim of the training is to somehow make people interested in the subject, to demonstrate how easily the toilets can be made and how the conversion from excreta to valuable products can be achieved. And most importantly, how the use of this "eco-humus," together with urine, can have a real value for the family by enhancing food production in the back yard. And food will be found on every family's list of priorities. Very often in a community there may be a small number of enterprising people who are very keen and willing to take up the new methods in their homes. Nothing is so infectious as success.

There are certain "trump cards" available to the trainer of Eco-san. He or she can make use of these "needs." We can list these advantages as follows:

1. Every family needs a toilet
2. The ecological toilets described are relatively simple and cheap to construct and can be made at home by the users themselves or by relatives.
3. The toilets are almost free of flies and odours and therefore pleasant to use
3. The toilet system can last for many years. Small investments in making concrete slabs can last for generations. Local materials can be used for the structures.
4. Valuable products in the form of humus for the garden are produced. The humus can be mixed with a poor local top-soil to make a new soil in which vegetables grow well.
5. Urine can be collected in several ways and when diluted with water makes a good plant food, especially for vegetables.
6. Once the system has been set up – these plant foods cost nothing and can increase food production significantly. There is a never ending supply at no cost!!!

Simply put:

The new eco-toilets are simple, and cheap to make and they are easy and pleasant to use. As toilets, they also provide humus for improving backyard soils and help to grow better vegetables. Thus they have special value.

TRAINING TOOLS

But people will need to be convinced. And that means practical demonstration. This is done by showing people working toilets in the field and also describing in the class room by means of flip charts and models. But the most important part is getting things going in the field and reaping the local knowledge gained and transplanting this knowledge elsewhere. There is nothing so infectious as example and enthusiasm for passing on a knowledge about something that is quite simple and intensely practical. That is the message contained in this work.

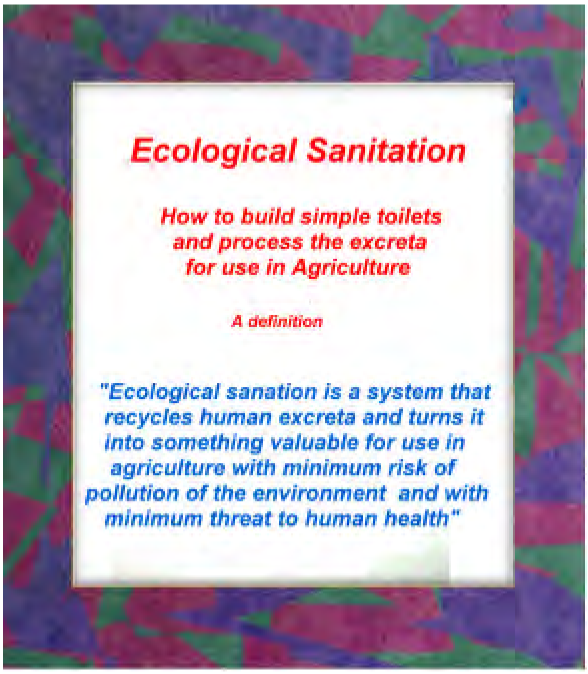
Moving a *Fossa alterna* structure

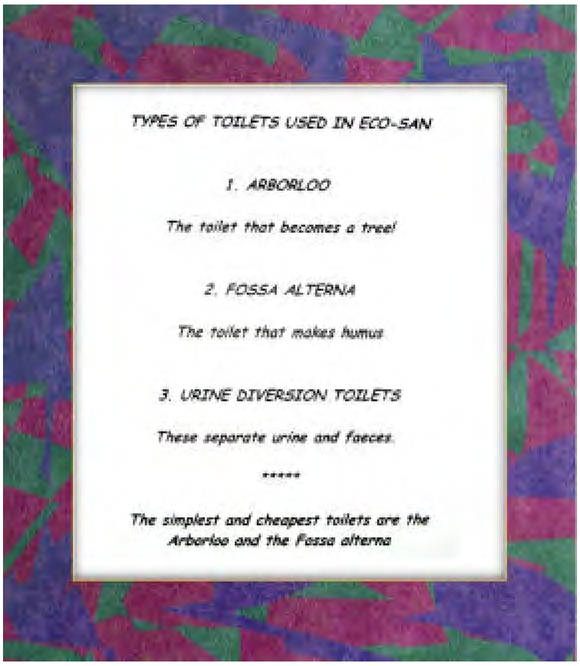
During the training sessions there are certain “tools” which the trainer/educator can use to help him or her to get the message across more easily. These “tools” include:

1. Prepared Flip charts

Small flip charts which describe the basics can be distributed & copied

Actual pages of the flip chart, which can be copied and enlarged





THE FOSSA ALTERNA

This uses two shallow pits which can be protected with "ring beams." The toilet slab and superstructure alternate between one pit and the other at yearly intervals. Only one pit is used at one time. The superstructure is designed so that it can be moved easily. In Mozambique a single structure is mounted over both pits.

* Dig and protect both pits at time of construction.
*The pit is shallow - about 1.2 to 1.5 metres deep.
*Add soil & wood ash regularly into the pit with the excreta. Also add leaves.
*Do not add rags, bottles, plastic etc
* Once the pit is nearly full move the toilet slab and structure to second pit.
* Cover excreta/soil/ash mix with good layer of fertile soil and leave to compost for at least one year.
* After one year or more dig out the humus and store in bags for later use in the garden.
*Return the toilet slab and structure back to first pit.

THE FOSSA ALTERNA (continued)

With a small to medium sized family the pit will fill up in just over one year. The humus will have formed in less than one year. Once the used side has almost filled up, empty the humus from the composting pit and place in bags for storage. Later use humus on garden direct by digging in or mix with local topsoil. If the family is large use three or more pits and rotate between them. It is important that the composting pit has at least one year to work.

FORMATION OF HUMUS

*When human excreta is mixed with good soil, wood ash and leaves etc, it turns into compost or humus. This forms in the shallow pit. The pit should be well drained and not too wet.
* This humus is dug out of the Fossa alterna pit after one year or more of composting and bagged for later use. The eco-humus can be used in the following ways:

1. Mixing with topsoil direct in vegetable gardens
2. Measured mixing with poor soils (50/50) and adding to shallow trenches or shallow beds for vegetables.
3. Mixing with other soils and growing vegetables in containers like buckets or jars and pots.

The volume of eco-humus formed per year is small - about 0.6 cu.m. so it will not go far on a big field. The eco-humus is best mixed with other soil in equal amounts (50/50) and used on backyard vegetable gardens.

SOIL IMPROVEMENT WITH "FOSSA" HUMUS

The eco-humus formed in the Fossa alterna pit is very rich in nutrients. If we compare the NITROGEN (N - ppm), PHOSPHORUS (P - ppm) and POTASSIUM (K - ME/100g) we find big improvements over natural topsoil.

Source of soil	N	P	K
1. Natural topsoil (9 samples)	38	44	0.49
2. Fossa alterna soil (10 samples)	275	292	4.51

* If the Fossa soil is mixed with poor topsoil in equal proportions, the poor topsoil becomes much enriched and vegetables can grow on it very well. The weight of vegetables grown on the mix of soils is many times the weight of vegetables grown on the poor soil alone. It behaves like a good compost or fertiliser. The addition of Fossa humus also improves soil texture.

* So we see that the mixture of converted excreta and poor soil (50/50 mix) makes a "new soil" which is very valuable to the family because vegetables will grow in it very well.
* We can also add liquid food like a mix of water and urine to enhance the growth of vegetables and maize even more.
The combination of eco-humus mixed with poor soils and a water-urine liquid feed is best.

MIXING FOSSA HUMUS & SOIL HELPS

If we mix fully composted Fossa humus from
the toilet with poor topsoil,
in equal proportions
vegetables will grow far better

In some experiments it was shown that
by adding the Fossa humus to local soil:

Spinach growth was increased up to 7 times
Covo growth was increased 4 - 8 times
Lettuce growth was increased up to 7 times
Onion growth was increased up to 2.7 times
Green pepper growth was increased 4.6 times
Tomato growth was increased up to 10 times

These are very good increases
in vegetable production!

Why?

Because the Fossa humus improves the
soil nutrients and also soil texture.

URINE DIVERSION

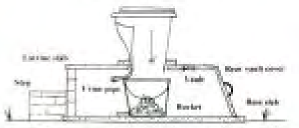
Urine diversion is a system where the urine and faeces are separated from each other. This is usually done with a special pedestal or squat plate where the urine passes into a pipe which leads to a reservoir and the faeces fall directly down into a vault or bucket beneath. Soil and ash are added to the faeces to help them dry out or compost. The faeces are then composted separately.

**The urine is diluted with water and used as plant food.*

** The faeces, soil and ash are either allowed to dry out or are combined with more soil and moistened to make humus.*

**The humus can be made in shallow pits or cement jars. Like the Fossa alterna humus it is very rich in nutrients.*

Urine diverting pedestal



More care is required to look after the urine diversion system, and it is also more costly than the Arborloo or Fossa alterna systems, but it is very effective.

THE USEFULNESS OF URINE

Urine is rich in nutrients and has many uses in the family garden. It can be used in the following ways:

1. Used as a liquid plant food mixed with water. The best are 3:1 (water to urine) and 5:1 (water and urine). These dilutions of urine can be added to the soil where vegetables (and plants like maize) are growing - once a week or even twice or three times a week provided that the plants are also watered frequently at other times. This addition of urine makes a very big difference to the growth of plants and adds much nitrogen, and also some phosphorus and potassium.

2. The urine can also be added to soil beds before planting. The urine can be added neat but it is best also to dilute. Bacteria in the soil change the nitrogen in urea into nitrate which can be used by the plants. Best to leave stronger urine added to the soil for a month before planting.

3. The urine has much nitrogen in it and can be used as an "activator" for compost heaps - it helps the process.

Collecting urine:

** Urine can be collected in several ways:*
1. Urine diverting toilet
2. In plastic bottles (for men)
3. In 20 litre containers fitted with funnels (for men)
4. In special "potty pedestals" (for women)
5. In "potties" placed in the flush toilet (for women).

THE FERTILIZING EFFECT OF URINE

If neat urine is diluted with water it makes an excellent liquid feed for plants. 3 parts water to 1 part urine is a good mix. This mix can be applied once or twice a week to vegetables with additional watering.

In some experiments it was shown that by adding the 3:1 water urine mix to vegetables:

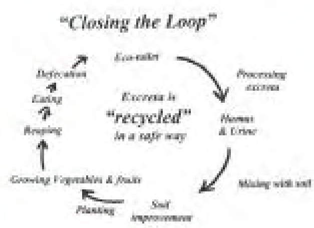
Spinach growth was increased up to 6 times
Covo growth was increased 1.5 - 4 times
Lettuce growth was increased up to 2 times
Tomato growth was increased up to 3.6 times

Also the weight of maize cobs grown in fields was increased from 28% to 39% over maize cobs grown without any fertilizer.

This was done by adding 100mls neat urine per plant every week and allowing the rains to dilute wash into the soil.

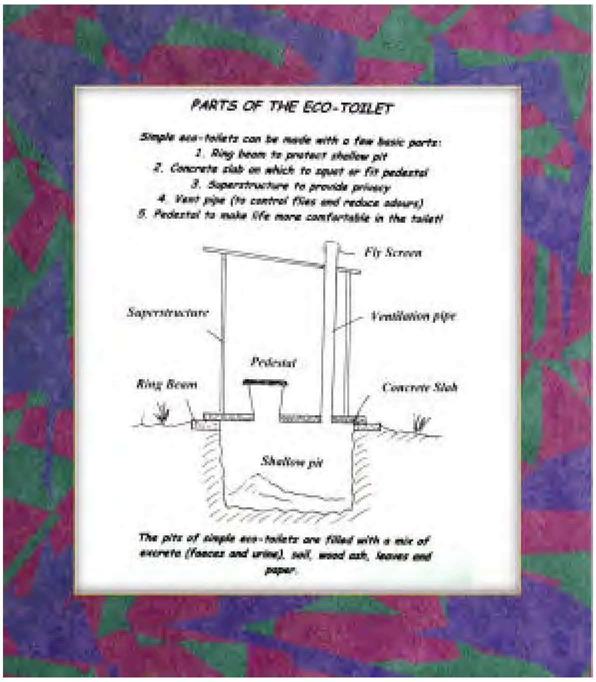
"CLOSING THE LOOP"

The "loop" is closed when what we excrete (urine and faeces) is processed to make eco-humus and plant food (diluted urine) which helps improve the soil which helps plants grow better - which we eat and then excrete again in the eco-toilet.



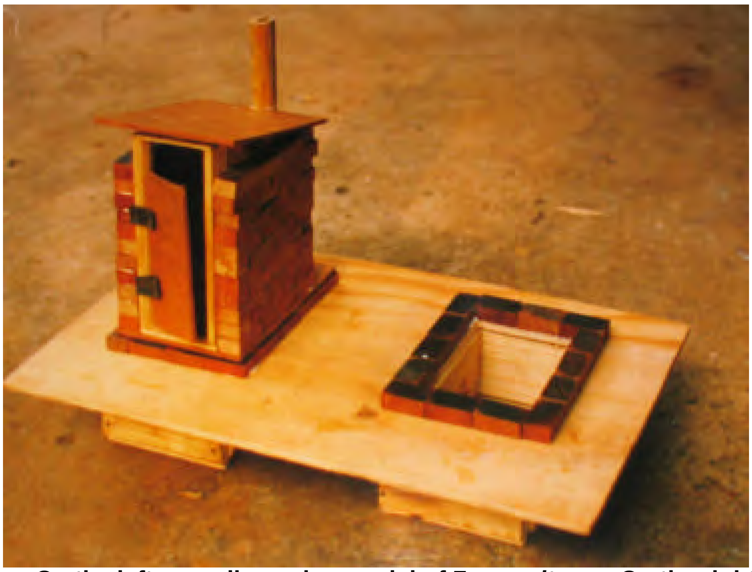
Normally we do not close the loop at all!

We waste all the nutrients in the excreta which goes to waste into the latrine pit or down the flush toilet. There is no re-use, no recycling, no closing the loop - all is wastes and lost.



Flip charts and models help a lot in training

2. Models




On the left a small wooden model of *Fossa alterna*. On the right a one third scale model of the *Fossa alterna* with concrete ring beams and slab, and wooden from a vent pipe.

3. Photo displays

It is also possible to place photo prints on a board to demonstrate toilets used in different places and also the effect of humus and urine on vegetable growth.

4. Samples of the soils and humus


Humus from *Fossa alterna* **pits varies a great deal in texture depending on the amount and type of soil added. On the left a sandy almost humus free soil has been added. On the upper right of the left hand photo some dried out fly cocoons have seen separated off – proof that once this material was excreta. On the right photo a more humus like soil has been extracted, a mix of excreta and more fertile soil. This sample has also been sieved making at an excellent potting soil for planting seedlings. The demonstration that human excreta can change into these soils and humus can be an important step in convincing people that something good can come out of practicing ecological sanitation.**

5. Samples of hardware that can be home made


Hand made examples of urine diverting devises. On the left, a urine diverting squat plate and on the right a urine diverting pedestal. Both use plastic buckets as part of the construction.


A home made hand washing devise makes a popular demonstration. Also home made non urine diverting pedestal in use on a working *Fossa alterna* impresses people.


On the left chicken wire baskets used to make leaf compost. On the right two small worm farms with drip feed water dispensers. Eco-san is made more valuable and interesting by making part of developing the organic garden

6. Demonstrations of the toilet range

Demonstration of various ecological toilets in Harare

6. Handouts - small booklets on basic information to be handed out.

The are also other ways of passing on the message, and that is to distribute information in what ever format is suitable, in the written word, by email, on Websites, on CD's and disks.

Pamphlets, booklets or manuals can help to pass on the message, although they may be expensive. There is a need for simple low cost booklets or pamphlets which people can take away, read and understand.

The training sessions

Suggested notes

These notes form the basis of training programmes undertaken At Kufunda Village, Ruwa. They have also been used in Mombasa, Kenya. The material in them is extracted and condensed from earlier written works placed on this CD. The manual on "Passing on the Message" can be used as a separate manuscript.

SECTION 1. LECTURES

PART 1. Introduction

The world in which we live is not always in balance. People often lack food because their soil is poor and barren. Often it cannot support the growth of food in the form of vegetables or maize without the addition of expensive fertilizers and compost. Extra fertility and nutrients are required. Trees can help preserve the soil and reduce erosion, but in many areas there are few trees for shade or ground cover. These are serious problems facing millions of people living in Africa. Thus promoting the growth of new trees serves many useful purposes.

The safe disposal of human excreta is also another problem faced by millions of people living in Africa. Human excreta is offensive and when not disposed of properly can contaminate the places where people live. Disease can be spread from human waste. This can also pose a huge problem. So we have the twin problems of disposing of human waste properly and trying to improve poor soils which cannot grow food properly.

Both of these problems can be solved by dealing with both of them at the same time and by using the human excreta to improve the soil. Toilets are specially designed so that the waste products can be converted into a safe and valuable resource in the form of humus which can be used to help raise the fertility of the soil. In fact human excreta, both faeces and urine, contain many nutrients which are valuable to plants and can increase the level of production of food considerably. The ways and means in which this is done come under a subject called *Ecological Sanitation.*

***Ecological sanitation* is *a system that makes use of human excreta and turns it into something useful. Both the urine and humus derived from human excreta can be used to increase the fertility the soil and enhance the growth of food with minimal risk of pollution of the environment and with minimal threat to human health*.**

The aim of ecological sanitation is to recycle the nutrients available in human excreta. Thus human excreta can be converted by a process of composting into a safe product (humus) which can be used in agriculture and forestry. The urine can also be recycled by itself and can be diluted with water to make a plant food. The overall aim is to "close the loop." This means that one eats food (say fruit or vegetables) that have grown better by using nutrients available in processed human wastes. These foods are digested and pass out of the body as urine and faeces. These "waste products" are then processed by the toilet and turned into something useful (humus) which the new plants can grow in. The new plants, grown in part from the converted excreta, are then eaten again and the cycle is repeated. That is "closing the loop.

***Flip Chart of closing the loop and the cycle which includes the toilet, the humus, food production and food consumption and back to the toilet*.**

A series of simple toilets have been designed specially for the purpose of recycling human wastes. We may call these eco-toilets. There are three basic types.

1. The *Arborloo* (toilet which becomes a tree)
2. The *Fossa alterna* (the alternating pit toilet which makes humus)
3. The urine diverting toilet. These separated the faeces and the urine and processes each separately. Some urine diverting toilets process the faeces by dessicating them and others by composting them into humus. Methods of collecting urine separately in containers may be included in this category.

Flip chart of basic types of eco-toilets

PART 2. The toilets

We shall discuss the two simplest and cheapest latrines, the ***Arborloo*** and the ***Fossa alterna*** which compost human excreta in shallow pits. Also we shall talk about single vault and double vault urine diverting toilets. These use urine diverting pedestals or squat pans.

The Arborloo

The simplest toilets used in ecological sanitation are simple pit latrines, but they are built over shallow pits and the parts of the latrine are designed to be portable. The simplest, called the ***Arborloo,*** is made up of a concrete slab and a superstructure. The slab sits on top of a shallow hole dug in the ground - the pit is dug about one metre deep. The pit is built up around the top so that rain water cannot flow into it during the rains. It is normally surrounded by a square "ring" of concrete or plastered bricks called a "ring beam." This helps to hold up the top of the pit and also elevates the pit head above ground level. In other words it makes the structure on top of it more stable. A concrete latrine slab with a squat hole or sitting pedestal is mounted over the ring beam. Since the slab will be moved, this has steel handles fitted in it.

The superstructure is placed on top of the slab. This provides the privacy and protection from rain. It is light enough to move so is normally made of wood, bamboo, reeds or frames made of wood or steel and covered with grass or reeds.

FLIP Chart - diagram of parts of the Arborloo

The ***Arborloo*** is used like a pit latrine with two important differences. First soil and wood ash are added frequently down the squat hole and even vegetables scraps from the kitchen or leaves. Second, things which will not compost are not thrown down the hole like rags, plastic, bottles etc. The pit must fill up with materials which will compost. It is the addition of soil and these other materials to the pit which helps to change the excreta in to humus or compost.

These additions will also cut down on the smells and fly breeding commonly seen in pit latrines. The smells and odours can also be reduced by using a vent pipe which has a screen on the top.

The ***Arborloo*** is used for about one year or for however long it takes to almost fill the pit. For a family the pit may become almost full in a year, but the actual filling rate depends on the size of the pit and the number of users. When the pit is nearly full, the structure is taken off and the slab and ring beam are also removed. A new site is chosen and the ring beam is laid down flat and a new hole dug inside the ring beam. The slab is laid on top and the structure on top of this. The new site is now used. The contents of the old pit are now filled with topsoil. It is best to use good soil if this is available. The pit can then be left to settle to left until the rains arrive if water is short. However if water is available a young tree can be planted straight away. A hole is made near to the centre of the pit and a young tree planted there. The roots of the young tree must not come any where near the waste matter. The tree is watered and the soil covered with a mulch. It is very important to also protect the tree against animal attack like goats and chickens.

Thus with the ***Arborloo,*** the latrine slab and superstructure move on a never ending journey from one pit to the next. Once the used pit is nearly full, it is topped up with a good layer of fertile soil and planted with a suitable young tree, time and time again. Guava, paw paw, mango and mulberry are examples. But almost any tree will survive and grow well if planted properly. The end result is a "sanitary orchard" or woodlot. The tree grows in the humus formed from the composted human excreta. With this method there is no handling of excreta so it is very safe. Because the pits are shallow and the excreta changes into humus quite quickly, the risk of ground water contamination is reduced. Because space is required for this concept - it is used mainly in rural areas or peri-urban areas where there is space. The nutrients in the human excreta are used because they are taken up by the tree and help tree growth considerably.

FLIP CHART - show how the Arborloo works and moves from one site to the next. Also to show how the trees are planted.

MODEL DEMONSTRATION *- If possible small models could be prepared beforehand to show the effect. These can be made in cardboard or wood etc. A small model can be made with ring beam, slab and structure to show how the* ***Arborloo*** *works. The miniature ring beam is laid down and a small hole dug within it. Some of the soil is laid around the beam to hold it in place. The slab is placed over the beam and any spaces between the beam and the slab are filled with some soil. A weak mixture of cement will normally be used to make this seal. The* *model vent can be fitted and the action of the vent pipe can be described. How it draws air and how it traps flies when a structure with a roof is fitted. Different coloured soils can be used to show different types of materials added. When the pit is almost full the model structure and slab and ring beam are moved to another site and the hole is filled up and a small miniature tree planted. Methods of mulching and protecting against animals can be described.*

The range of trees which has been used with the ***Arborloo*** is described. These include banana, mulberry, gum trees, avocado, orange, lemon, guava, paw paw. Trees with nitrogen fixing properties like *Leucaena* also grow well and indigenous trees *Brachystegia, Acacia* and *Swartzia* etc.

In several countries like Mozambique, Malawi, Kenya, Uganda and Rwanda people plant trees on old pit latrines in their traditional way of life. However the pits filled with only excreta take much longer to convert to humus which the tree can tolerate.

On the left, *Arborloo* built by Mvuramanzi Trust in Mashonland East, Zimbabwe. On the right, *Arborloo* built in Kusa village, Kenya.

On the left, *Arborloo* built by Eco-Ed Trust in, Zimbabwe. On the right, *Arborloo* builtby Partners in Development, Maputaland, Natal, South Africa.

WE NOW MOVE TO THE SECOND LATRINE TYPE

The Fossa alterna

The second type of toilet built over a shallow pit is called the ***Fossa alterna***. This is similar to the ***Arborloo*** in so far that the toilet structure (including slab and pedestal) is portable. However two shallow pits are dug close to one another and the slab and structure alternate between the two pits - they move from one to the other and then back to the first pit at yearly intervals. In Mozambique a single permanent structure is built over both pits. These pits are often dug within a "ring beam" made of cement mortared bricks or concrete which elevates the slab above ground level and protects the head of the pit. The two ring beams also stop rainwater flowing into the pit. The single toilet slab, which is made of concrete, is fitted over one of the ring beams. As with the ***Arborloo,*** regular additions of soil and wood ash are made to the pit as well as excreta. If possible leaves should also be added. Things like rags, plastic, bottles and other wastes which cannot compost should not be added to the pit. These various materials added to the pit help to convert the human wastes into "humus" which is rich in nutrients and good for the garden. During the first year the second pit within the second ring beam, which has also been dug, is best left empty and covered with a wooden lid.

Each pit is used for one year by the family. This will allow for the pit which is dug between 1.2 to 1.5 metres deep to be nearly full of the mixed materials. At 12 monthly intervals or more the superstructure changes pits and the contents of the used pit are topped up with good layer (150mm thick) of fertile soil and left for a year to compost. This soil, which contains micro organisms (bacteria and fungi) and small animal life, also helps to convert the waste products into humus. To get better mixing it is possible to ram the new soil in with a pole. This filled pit is usually covered with a wooden lid or can be covered with grass like a mulch. The contents should be kept moist, but not flooded, by occasional watering during the year.

During that year when the first pit of excreta and soil is composting the second pit is used. After the second year, the first pit will be filled with humus and the second (used) pit will be 3/4 full of mixed materials. Then the humus or compost is dug out of the first pit and placed in bags for later use on gardens and in beds and containers.

The structure and slab are then removed from the second pit and placed over the first pit which has now been emptied. Now it is time to cover the contents of the second pit and allow this one to make compost while the original pit fills up again.

So every year it is possible to excavate some rich compost from the pit. Normally a one year cycle is used. The humus is rich in nutrients and can be mixed with less fertile soils to make plants grow better.

This concept has a value for use in peri-urban areas since the area required is relatively small - about 2.5m X 1.5m and makes available a source of excellent humus every year, which serves as a soil conditioner, which can enhance the production of vegetables on small family plots. If there is no immediate use by the householder, the humus can be stored in bags and may even generate an income.

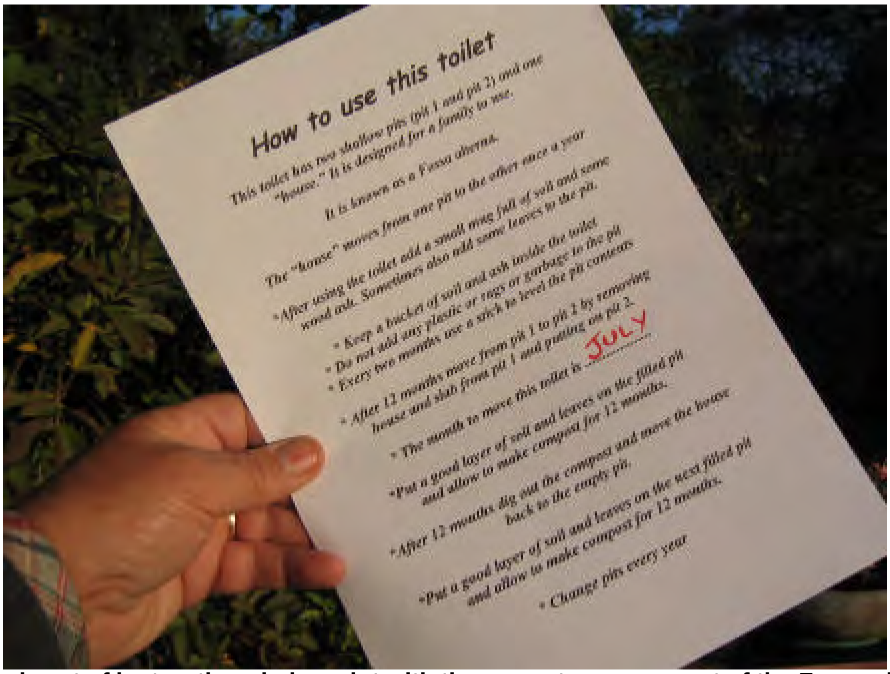
FLIP Chart - *showing diagram of parts of the* ***Fossa alterna***

FLIP CHART - show how the Fossa alterna works and how the slab and structure alternates between the two pits. The cycle of use and excavation is shown.

***MODEL DEMONSTRATION** - As with the **Arborloo** it is good to have a small model available for demonstration with two ring beams, a slab and structure to show how the **Fossa alterna** works. The miniature ring beams are laid down and a small hole dug within each. Some of the soil is laid around the beams to hold them in place. The slab is placed over one of the ring beams and any spaces between the beam and the slab are filled with some soil. A weak mixture of cement will normally be used to make this seal. Different coloured soils can be used to show different types of materials added. When the pit is almost full the model structure and slab and ring beam are moved to the other ring beam. The used pit is topped up with soil. The contents can be rammed with a miniature pole to mix.*

The model can be used to show how the slab and structure move from one pit to the other at yearly intervals.

INSTRUCTION NOTICE PLACED IN TOILET



A simple set of instructions helps a lot with the correct management of the Fossa alterna


Also to have seen and participated in a "change of pits" helps the memory.

NOW WE MOVE TO THE THIRD TYPE OF ECOLOGICAL TOILET SYSTEM

Urine diversion toilets

In a third range of latrine designs, the concept of **urine diversion** is used. These use a special pedestal or squat platform (or squat plate) in which the urine enters the front part of The pedestal or plate and is then diverted through a pipe and is thus separated from the faeces. The faeces fall down directly into a brick lined vault or container beneath. Some soil and wood ash are added to cover the faeces after every visit. This partly dries out the faeces and makes them easier to transfer. This is the most widely used ecological toilet system in the world.

There are several types of urine diverting system that can be used. Most will use a double vault system in which the urine diverting pedestal or squat plate is placed above one vault whilst the second vault is closed off. Dry soil, wood ash (or in some cases lime) is added on a regular basis to the faeces after they have been deposited in the vault. The aim is to dehydrate the faeces and then store them for a year and then remove them and use as a soil conditioner. The urine is taken off through a pipe and collected in a container or allowed to drain into a subsurface irrigation system with a tree nearby. In the double vault urine diverting system the urine diverting pedestal or squat plate is moved every year and placed over the vault which has been just emptied of its dried faeces.

The *Skyloo*

In a latrine called the "***skyloo***" faeces are also collected in a vault built above the ground, but they enter a bucket or basin and not the vault itself. Urine can be taken to a seepage area but is best collected in containers for use as a plant food. A mix of soil (4 parts) and wood ash (1 part) are added to the faeces once they are in the held in the bucket and are then transferred from time to time to another site called a secondary processing site, where the excreta turns into humus. Thus the raw excreta is not held in the toilet system itself for long. The bucket contents may be introduced into shallow pits or trenches, or placed into jars or other containers together with fertile soil, and leaf mould. In each case the mixture of soil and faeces is converted into a pleasant and nutrient rich humus like soil within a few months. It is then used in agriculture, preferably in combination with the urine.

***MODEL DEMONSTRATION** - As with the **Arborloo** and **Fossa alterna** it is good to have a small model available for demonstrating the **Skyloo**.*

Small model of theSkyloo


Models are useful as they can be taken apart to show the various parts

FLIP Chart - *showing diagram of parts of the urine diverting system and how the faeces, soil and ash are composted in a secondary composting site, by the addition of further soil which is kept moist.*

Site visit

The best demonstration of all is to show people the actual working ***Skyloo*** *and how the mix of faeces, soil and ash so readily converts into humus in a secondary composter like a cement jar. This can be a memorable experience for the observer. The conversion of excreta into humus is remarkable.*

Visitors inspecting a Skyloo in Harare.

PART 3. The use of eco-humus and urine in vegetable and tree production

Fossa alterna humus

The humus is formed in the ***Fossa alterna*** pit because the micro-organisms (bacteria and fungi) and miniature animal like in the soil (insects and worms) digest or otherwise convert the waste matter and turn it into humus. The process appears to be more effective if the pits are lined with soil rather than bricks and the process is also more efficient the more soil, ash and leaves are present. Pits filled just with excreta alone change very slowly indeed - years. The humus dug out of the ***Fossa alterna*** is very rich in nutrients and when mixed with poor soil can enrich it enough to make plants grow well.

At this point samples of the humus should be shown and handled by the students. Next follows a brief description of the nutrients in the humus and this is compared to the natural levels of nutrients in some soil samples taken from Ruwa, Epworth and several locations in Harare. Samples of the mixed soils can also be shown.

SOIL SAMPLE ANALYSIS

These show figures for Nitrogen, Phosphorus and Potassium in various soils and the humus taken from *Fossa alterna*

Location	Nitrogen(ppm)	Phosphorus(ppm)	Potassium (ME/100g)
Natural soils (Mean of 9 samples)	**38**	**44**	**0.49**
Fossa alterna soils (Mean of 10 samples)	**275**	**292**	**4.51**
Samples of humus from Skyloo jars (Mean of 8 samples)	**232**	**297**	**3.06**

When the ***Fossa alterna*** soil is mixed (50/50) with poor soil, the levels of Nitrogen, phosphorus and potassium are all raised

Examples of mixing Fossa and ordinary topsoil

Location	Nitrogen(ppm)	Phosphorus(ppm)	Potassium (ME/100g)
Sample 1.	**91**	**337**	**1.45**
Sample 2.	**91**	**247**	**0.88**
Sample 3	**78**	**356**	**1.01**

These results show that by mixing the humus from the ***Fossa alterna*** and poor soil, a much richer soil can be produced on which vegetables will grow well. The major nutrients found in soil are nitrogen, phosphorus and potassium.

The **Nitrogen (N)** is the leaf builder of plants, Nitrogen promotes leaf growth and increases the final yield of crops.

The **Phosphorus (P)** helps the fruits of plants to build up and ripen. It gives a good start in life to crops and assists in strong root and shoot growth and encourages early maturing.

The **Potassium (K)** builds up fibre in the plant and gives healthy growth. It also helps the plants resistance to disease, drought etc and improves the quality of the crops.

Ways of using the humus in vegetable gardens.

A brief description of how to apply this humus to small vegetable gardens is now given. Remember the volume of humus is not large - about 500 to 600 litres (half a cubic metre) per year per family.

This humus is best mixed with other soils.

1. It can be dug into vegetable beds
2. It can be mixed by volume with the same volume of sandy soil from Kafunda, for instance. This doubles the working volume of the fertile soil but reduces nutrient levels, but there is still plenty of nutrients left for good plant growth.
3. The diluted humus can be used in small vegetable gardens like the one in Woodhall Road or the trench type in Woodhall Road.
4. The diluted humus can also be placed in containers to grow a variety of vegetables. Rape, tomato, pepper, spinach and other vegetables can be grown in containers very successfully. Buckets or basins can be used as containers or cement replicas of the buckets and basins.

Cement basins

One way of making cheaper containers is to use a 10 litre plastic basin as a mould. River sand and cement is mixed in the ratio 3:1 (6 pea tins sand to 2 tins cement). Apply the cement to inside of basin. Leave overnight to set. Cover with plastic sheet. Water following morning and leave. The following, day place upside down in sun. Sun will heat the plastic basin and it can be separated from the concrete basin. Water and cover for a day. Then transfer into water to cure. Keep wet for several days. Once cured drill three 12mm holes in base for drainage. 40 - 50 basins of this type can be made with a single bag of cement. We can grow about 2 tomato, 5 rape or up to 10 onion in each container.


Nice crops of onion and tomato growing on in 10 litre cement jars,

Evidence of enhanced vegetable growth.

In a series of simple experiments vegetables like spinach, covo, lettuce, green pepper, tomato and onion were grown in 10 litre buckets or basins of Epworth or Ruwa soil and their growth was compared with plants grown in similar containers filled with a 50/50 mix of Epworth (or Ruwa) soil and ***Fossa alterna*** soil. In each case the growth of the vegetables was monitored and the crop weighed after a certain number of days growth. The following chart showed the results of these trials. FA* denotes soil taken from ***Fossa alterna*** pit. The extra growth is due entirely to nutrient enhancement by ***Fossa alterna*** soil.

Plant. Top soil type. Growth period.	**Weight at cropping Top soil only**	**Weight at cropping 50/50 mix topsoil/FA*soil**
Spinach on Epworth 30 days.	72 grams	546 grams (7 fold increase)
Covo on Epworth 30 days.	20 grams	161 grams (8 fold increase)
Covo 2. on Epworth 30 days.	81 grams	357 grams (4 fold increase)
Lettuce on Epworth. 30 days	122 grams	912 grams (7 fold increase)
Onion on Ruwa 4 months	141 grams	391 grams (2.7 fold increase)
Green pepper on Ruwa 4 months	19 grams	89 grams (4.6 fold increase)
Tomato on Ruwa 3 months	73 grams	735 grams (10 fold increase)

All these results clearly show a dramatic and meaningful increase in vegetable yield resulting from the enhancement of poor spoil (Epworth and Ruwa) with the ***Fossa alterna*** humus.

The usefulness of urine as a plant food

The urine is also valuable as it contains a lot of nitrogen and some phosphorus and potassium which are useful for plant growth. It can be diluted with water - about 3 parts of water to one of urine and applied to the soil in which plants grow. It is especially good for leafy vegetables like rape and spinach, turning them very green and leafy.

There are several ways of making use of human urine - it is a valuable product with much nitrogen and other nutrients contained in it. The huge potential of urine as a plant food is wasted every day by most of the world's population.

There are several ways of collecting and using the urine.

For collection the urine diverting latrine can be used. This is where the urine and faeces are separated (demonstrate one of these if available). Also for men a urinal or a urine collector such as a desert lily can be used. The "desert lily" is a name given to a funnel sitting on a plastic container (normally 20 lire) which holds the urine. This can be mounted in a small structure for privacy. Men can also urinate in smaller 2 litre containers and collect and contain the urine that way.

Plant trials with urine for various vegetables & tomatoes

In these trials plants were grown in 10 litre cement basins and some were fed with 0.5 litres of a 3:1 water/urine mix, three times per week, whilst others were irrigate with water only.

Plant and growth period	Weight at cropping (water application only)	Weight at cropping (with a 3:1 water/urine application 3X per week)
Lettuce. 30 days	230 grams	500 grams (X2)
Lettuce. 33 days	120 grams	345 grams (X 2.8)
Spinach. 30 days	52 grams.	350 grams (X 6)
Covo. 8 weeks	135 grams	545 grams (X 4)
Tomato. 4 months.	1680 grams	6084 grams (X 3.6)

The increase in production is very significant. Even the application of a 3:1 water urine mix once a week can have a significant effect on plant growth. The onions and tomatoes held in cement basins shown on the photo earlier were fed a 3:1 water/urine mix once a week.

In further experiments on maize in the field, 100mls of neat urine was placed on each plant with rain soaking it in to the soil. This increased the maize cob size 28% in one area and 39% in another area, but both were less than the 61% increase from conventional fertilisers. However the fertilisers were expensive while the urine cost nothing. Where fertilisers are too expensive, which is often the case, urine acts as a fine substitute and costs nothing and is always available where people live.

Urine is easily collected by men in plastic bottles.

Leaf Compost (leaf mould)

This is wonderful material and is made by composting leaves in chicken wire baskets and keeping moist. Different leaves compost in different amounts of time. The composted leaf mould can be mixed with other compost or topsoil or ***Fossa alterna*** humus to make an excellent medium for growing vegetables. Urine application works much better if the soil is humus life and has a living content.

SECTION 2. PRACTICAL DEMONSTRATIONS

Part 4. How to build the latrines

Now we have talked about the latrines and how they work we must now look at how they are built. This is a very practical part of the training exercise. We shall now look at the parts of the latrine and how they are made. However it is important first to allow participants to see for themselves the various toilet options that are available before the actual construction exercise begins.

Preliminary site tour of toilets and other facilities before practical work begins

The parts of the latrine.

The construction of the following parts of the latrine will now be demonstrated. The ring beams, slabs, structure and pedestal and pipe are common to both ***Arborloo*** and ***Fossa alterna***. The ***Arborloo*** has one ring beam, the ***Fossa alterna*** two ring beams. The same slab can be used on the urine diverting ***Skyloo.***

The latrine parts are:

The ring beam/s (or pit linings)
The above ground vaults
The concrete slab
The superstructure
The pedestal
The vent pipe (with fly screen)
The hand washing facility

For the constructions an area is set aside to make the parts. This requires a flat piece of land, cement, river sand, wire for reinforcing, wire for handles (for slab), moulds for squat hole or pedestal hole, mould for vent pipe hole, vent pipe (normally 2 - 3m of 110mm PVC). The pedestal requires a plastic seat cover and a 20 litre bucket. Bricks can be used to make the mould for the ring beams and slab. For the hand washing facility there are various options, using plastic containers. It is also important to show how the superstructures can be made. A carpenter can help with this part of the demonstration.

THE CONSTRUCTIONS

Ring beams and simple slabs are used on the simpler toilets like the ***Arborloo*** and the ***Fossa alterna.*** If the soil is soft and sandy and may collapse a full pit lining is required for the ***Fossa alterna.*** Where above the ground vaults are used, these are built on an area of concrete laid on the ground.

The construction of demonstration ring beams and slabs now follows. This can be followed by construction of a working ***Arborloo*** and ***Fossa alterna*** and also simple pedestals (in two stages a day or two apart). Also the construction of the hand washing facility can be made. The carpenter can show the various ways of making the superstructure from various materials (gum poles, bamboo, grass, reeds etc).

For the urine diverting systems, a single or double vault will be built and also either a commercial urine diverting pedestal or squat plate or even a home made unit constructed from cement and a plastic bucket.

Follow instruction material in field manual if available.

Shallow pits can successfully be protected by a concrete "ring beam" where the soil is moderately firm. This is laid on slightly raised level ground and the hole is dug down inside it to about one metre depth. The soil from the hole is laid around the beam and rammed in place. This method is being tested in a wide variety of sites. Since the superstructure is portable and therefore light in weight, there may be little need to fully line the pit with bricks. In any case the ***Arborloo*** moves to a new site every year - it would be a waste of money to line the pit with bricks. Humus formation takes place more efficiently in pits with an earth lining. Ring beams and slabs made of concrete last a very long time and are a very good investment in time, money and materials.

The concrete ring beam

This is made of a mix of 3 parts river sand to one part cement or 3 parts river sand, 2 parts small stone and 1 pat cement. A 5 litre bucket can be used as a measure. Thus where stone is used 6 X 5 litre buckets of sand are mixed with 4 buckets stone and 2 buckets cement. In practice 3 X 5 litre buckets sand are mixed with 2 buckets stone and 1 of sand first. This mix is added to the mould. Wire reinforcing is added and the same mix is made up and added again.

The mould can be of bricks or wooden planks. The outer dimensions of the ring beam are 1m X 1.3m. The inner dimensions are 0.7m X 1m. 3mm wire is used as reinforcing - two lengths along each side. The concrete is cast in the late afternoon, covered with plastic, watered the following morning and kept wet for a week before moving.

Casting ring beams at a primary school in Mombasa, Kenya

The concrete slab.

This is made with the same mix as each ring beam and takes the same amount of materials. The slab is 1.2m long and 0.9m wide. The same amount of steel reinforcing wire is also used. It has hole made in it for the squat hole (about 250mm X 150mm) or the pedestal hole (300mm round) and also for a vent pipe. The curing instructions are the same. The squat hole is made about 35cm from the rear and if a vent pipe is required a hole is made about 150mm in from the rear side.

Recruits building a concrete slab at Kafunda, Ruwa

Above ground vaults

These are used with urine diverting systems (e.g. double vault or single vault such as the ***Skyloo***). There is some variation in design. Most are built in brick over a base made of concrete. The vault is between 0.5 to 1m deep (often 0.75m) and has a rear entrance door, which permits the vault contents (whether in a bucket or vault itself) to be extracted. The vault door should be near airtight. The capacity of these vaults varies but is about 1 cu.m. In the ***Skyloo*** the vault is only 0.5m deep, and 1.5m long and 0.9m wide allowing for a sloped back door.

Building a single vault for the *Skyloo* in Mombasa, Kenya.

Skyloo **built in Mombasa, Kenya, with external secondary composting pit chambers.**
This unit is fitted with a commercially made urine diverting squat plate made of tough plastic.

The home made pedestal (non urine diverting)

Pedestals are becoming more popular in Zimbabwe. Commercial pedestals are expensive and they can be made at home more cheaply. A neat pedestal can be made with a home made seat of concrete or using a mass produced plastic seat with lid. This seat together with a 20 litre bucket is required together with cement, river sand and reinforcing wire.

First small holes are made with the heated wire in the plastic reinforcing struts under the seat and a loop of wire is passed through these. The bottom is cut out of a 20 litre plastic bucket. The mix of cement one part and river sand 3 parts is used. A small amount is mixed up and laid under the toilet seat through the wire and levelled off. Next the plastic bucket is laid centrally over the seat. About 8 small wire bend in an L shape are inserted in the concrete so far laid around the bucket. This can be left to set for some hours. Then the side walls of the pedestal are built up with the same mix of sand and cement up the side walls of the bucket. This can be done in stages. Thin wire is wrapped around the bucket within the cement for reinforcing. The cement is built up to the top of the upturned bucket and left to cure. It is kept wet and covered once hardened.

After a few days the seat, bucket and cement side walls of the pedestal are turned over and placed on a plastic sheet. A mould of bricks or wooden planks is made about 40cm X 40xm. A further mix of the cement/sand is lais in this together with some more reinforcing wires. This forms the base of the pedestal. This is kept wet and covered after hardening for some days. It can then be used on the latrine.

Making a low cost pedestal at Kafunda

Home made urine diverting squat plate and pedestal

Most urine diverting pedestals and squat plates are made commercially. However it is possible to make them at home using plastic buckets and concrete. People who weld plastic (plastic surgeons) can do this job if shown how. A smaller bucket is cut to shape and fitted inside the larger bucket to make a urine diverter. The urine drains down the area contained by the cut smaller bucket into an outlet pipe. The outer shell of the pedestal is formed in concrete. The seat itself can be made in concrete or by using a commercially made toilet seat.

The superstructure.

There are many ways of making this part of the latrine. The best is to make a frame of some convenient material - steel, gum poles, bamboo, wooden planks etc. These are made up into a frame. A door is added connected to the frame through hinges which can be made of car tyres. A roof is made in the same frame materials, chicken wire is laid over this and then a plastic sheet. This can be lid over with grass first and then upgraded later with thin corrugated roofing sheet.

The frame, in what ever material it had been made, can be covered with any suitable material - plastic sheet, tin sheet, shade cloth, grass, reeds, thin wooden planks etc. Handles can be added if necessary to make lifting easier. Very often a carpenter is hired to assist in the construction of the superstructures during training. Traditional methods of using locally available materials can be used very effectively in making the "toilet house."

Vent pipes.

The vent pipe serves a very useful purpose. It draws out odours from the latrine pit and also traps flies if fitted with a fly screen. Air passing over the top of the pipe draws air up the pipe, and if this is fitted though a concrete slab which is sealed over the pit, any air that goes up the pipe is replaced in the pit by air drawn down the squat or pedestal hole. This means that odour from the pit cannot pass into the structure. Also if a roof is fitted and the pipe is fitted with a fly screen, the vent can act as a fly trap as well. Flies are attracted to the latrine by odour and are attracted by light when they leave it.

Whilst vent pipes fitted to ecological toilets are less vital as a means of controlling flies and odours (because liberal quantities of wood ash and soil added to the pit will also do this), they do serve an important function by removing excess moisture from the pit or vault.

FLIP CHART DIAGRAM - how the vent works.

Hand washing facilities

Hand washing is very important if the health aspects of sanitation are to be achieved. There are various ways of making a hand washing facility from discarded plastic containers. A simple end effective hand washing devise can be made from a discarded plastic oil container and a discarded plastic pill bottle. The construction of this useful hand washer can be shown. It is hung next to each toilet and is economical in its use of water. The water runs for a short while and stops itself. A small bar of soap can be attached with a short piece of string from the hand washer.

An even simpler hand washing device can be made from a plastic bottle with a screw cap and a section cut from a discarded ball point ink cartridge. Cut a part of the old ink cartridge about 30mm long with one end cut at an angle. Using a hot wire, make a small hole near the base of the bottle on one side. Then push the section of ink cartridge through the hole, fill up the bottle with water and close of the cap. Water will flow out of the "spout" when the cap top is opened up and will stop flowing when the cap is closed. Very little water is required for hand washing. A piece of soap can be hung from near the bottle on a string.

A simple hand washing device should always form a part of any improved toilet.

Part 5. Site visits - inspection of used latrine. Movement of *arborloo* and *Fossa alterna*

A tour of sites where people are using ecological toilets forms an important part of any training course in ecological sanitation, so this must have been set up some time before. After some time it will be possible to demonstrate, not only the planting of young trees on filled ***Arborloo*** pits but also the alternating nature of pit use in the ***Fossa alterna***.

Garden tours


Garden tour of eco-san demonstrations at Woodhall Road, Harare. Sniffing the humus formed in a 30 litre jar from converted faeces taken from the *Skyloo*. On the right trainees are told about changing pits in the *Fossa alterna.* The structure and two pits can be seen in this photo.


First, the structure and slab are removed from the pit which has been in use for one year. The pit contents are then covered with a good later of soil and leaves (right).


Next a thick layer of leaves is added to the base of the new pit. A layer of very weak cement mortar is added to the ring beam and the slab (in this case fitted with a plush pedestal) is lowered on to the ring beam. Finally the structure is fitted back over the slab. Good for another year.

Part 6. Inspection of gardens, orchards other facilities linked with ecological sanitation.


Demonstrations of food growing on eco-humus or soil fertilised with human excreta including urine is always convincing. These covo and tomatoes are fertilised with urine diluted with water.


"Sanitary Orchard" at the Friend Foundation, Harare. On the left a fine gum tree grows on a pit of organic waste (in this case dog manure) and soil. On the right an *Arborloo* with banana growing on pit of human excreta and soil. Below, a variety of tree species grow well on the mix of "manure" and soil. These include a variety of citrus, avocado, mulberry, paw paw, Leucaena, Acacia, and other indigenous trees.



Good implementation practice

Once the initial training has been completed and a number of facilities have been installed, there needs to be a period when the various facilities can be used, examined and tested by the users. If the outcome of this period is satisfactory, in other words the sanitary facilities are found acceptable, it is possible a demand may be created for more units. This manual does not intend to go into detail about the various tried and tested methods of implementing programmes, as these will vary from one organisation to another and from one country and area to another, Whilst there may be several examples in the sub-region of successful methods of implementing eco-san programmes, two deserve a brief mention here. These are examples of work being carried out in Mozambique and Malawi, mainly under the support of WaterAid, UK.

The Mozambique programme

This implementation programme is being performed in Niassa Province, Mozambique, by a local NGO, ESTAMOS and the English NGO WaterAid. Ecosan was originally introduced into Niassa during a workshop held in March 2002 (Edward Breslin (2001), Introducing Ecological Sanitation: Some lessons from a small town pilot project in Mozambique. Paper presented at Stockholm Water Symposium, 2001). Many participants found the concepts interesting, but wondered how to actually initiate a programme that offered households EcoSan options. Initially a series of meetings was held with key leaders and activist residing in various bairros in Lichinga. Leaders were asked if they would be willing to test EcoSan in their homes, and to identify others in their bairros who may also be interested. The response was considerable, because at that time the state of existing sanitation was poor. ESTAMOS constructed the first 35 ***Fossa alterna's*** and 6 ***Arborloo's*** in these bairros, after which considerable interest grew. Households with new latrines spoke with their neighbours about these odourless, shallow latrines. The latrines were aesthetically pleasing as well, as the two shallow pits (in the ***Fossa alterna***) were housed in one superstructure linked to a washing area. Walls were made of traditional materials and a roof covering to prevent rainwater from entering the latrine. In this case the slab was the only part of the system that needed to be moved (from one pit to the other at yearly intervals).

Interest in EcoSan was further enhanced through a series of radio interviews with a woman who has received a ***Fossa alterna*** and who spoke eloquently about the numerous advantages of the system over her previous "Improved Latrine." She spoke about her toilet no longer smelling and was fly less. She spoke with pride about how her neighbours admired her new latrine, and how she was able to transform her yard with the compost produced by the latrine.

In addition some ***Arborloo's*** were constructed at a weekend festival that drew hundreds of people. This system also drew interest and currently trees planted in used ***Arborloo*** pits in Niassa include guava, mango, orange, avocado as well as a range of local fruit trees.

ESTAMOS responded by initiating pilot projects in other areas using a range of participatory methods and social marketing techniques with communities involved in water and sanitation initiatives. Communities are taken through a Participatory Hygiene and Sanitation Transformation (PHAST) process that helps communities decide what key water and sanitation problems they would like to address.

ESTAMOS has made great use of demonstration latrines. Model ***Fossa alternas*** have been built throughout Lichinga and Mandimba and also Arborloo's. Communities interested in solving sanitation problems send representatives to these demonstrations and are given the opportunity to talk to owners about their new systems. This has led to considerable demand for EcoSan latrines in both Lichinga and Mandimba. ESTAMOS also made use of an agricultural demonstration plot by planting a guava in an ***Arborloo*** pit. The results were impressive as the guava outgrew older guava plants on the farm within a period of six months. Interest in EcoSan has also increased considerably in Maua and Nipepe in Niassa, where local teams of community activists support by DAS (Provincial Department of Water and sanitation) and DDOPH (District Directorate of Public Works and Housing) with the support of ESTAMOS and WATERAID are introducing sanitation through the PHAST methodology (*Introducing Ecological Sanitation in Northern Mozambique*. Field report of WaterAid. Edward D. Breslin and Feliciano dos Santos, 2002). Sanitation ladders covering health and hygiene issues are also used. Families are given a range of technical choices to consider (improved traditional latrine, SanPlat, VIP, ***Arborloo, Fossa alterna***, Urine diversion etc). The advantages and disadvantages of each system are explored with residents listing which are best and worst. Local drama has also been used as a promotional tool.

By December 2002 over 330 ***Fossa alterna*** had been built, 11 improved latrines and 6 traditional improved latrines, reflecting the choice. In addition, formal applications for latrines in Maua, as of December 2002 were 432 ***Fossa alterna***, 179 Improved latrines and 121 improved traditional latrines, once again reflecting preferences.

Why EcoSan over other alternatives?

The high interest in eco-sanitation options is of great interest and this aspect is discussed by Breslin and dos Santos in their papers. Monitoring and Evaluation (M&E) exercises reveal that families using the ***Fossa alterna*** consistently suggest that the absence of flies and odour are considerable advantages of EcoSan systems over improved latrines (SanPlat) and improved traditional latrines. Most conventional pit latrines in Niassa have offensive odours, are full of flies, and, because there is moisture evident in many improved latrines, they can also house mosquitoes in the superstructure. This according to surveys, has not been the case with the ***Fossa alterna***, even during the rains when management of EcoSan becomes more important and somewhat more complicated. (*Introducing Ecological Sanitation in Northern Mozambique.* Field report of WaterAid. Edward D. Breslin and Feliciano dos Santos, 2002).

Second, families do not have a great deal of space in their yards for toilets. But Ecosan provides people with an alternative that addresses this problem too. People see the ***Fossa alterna*** as a permanent solution, in sharp contrast to pit latrines that eventually fill up and need to be relocated. New sites for latrines inside small yards will not have to be found with the ***Fossa alterna***. It is this incentive which has made most people choose the ***Fossa alterna*** system (Edward D. Breslin and Feliciano dos Santos, 2002).

Third, EcoSan offers people the potential for added economic value, as compost from the eco-toilets can be used for small vegetable plots within a family's yard and some also use the ***Arborloo*** in their fields. Staff of the Department of Agriculture have shown interest in this compost which comes from pit excavation. Interest in EcoSan has grown more as more people have seen for themselves that the contents of the pit do transform into humus and fears about excavating unprocessed faeces have diminished.

Fourth, the basic concepts behind EcoSan make sense to people as they are simple and easy to understand, especially with demonstration models in place. Over time, as people see the value of introducing the soil/ash mix, when their toilets do not smell, do not attract flies and lack the humidity to entice mosquitoes, the management practices continue to improve. Moreover, few have said they think the use of excreta is culturally unacceptable – instead many families insist that it is simply logical.

Fifth, there is a growing sense that the shallower pit depths of EcoSan latrines will ensure that groundwater is not contaminated. This is an important issue among residents of Lichinga and Maua Sede, especially as people link poor health with poor drinking water from their household wells.

Sixth, latrines in general and EcoSan latrines in particular, are proving to be a source of some status and prestige in project sites. Invariably, families are not primarily interested in sanitation for health reasons, but rather for reasons of status and convenience. Also many traditional latrines have a reputation for collapsing during the rains. Latrine stability is an important issue – ***Fossa alterna*** have shallower pits and the first 30 cms are lined with brick and thus are far more stable than 3 – 5 metre deep conventional pit latrines which may be unlined.

Material assistance to householders

The programme uses the concept of a material incentive in the form of a single latrine slab, a small extra contribution of cement to help make the upper pit lining and a plastic sheet to line the roof. The family contributes by excavating the pits, buying the bricks and providing the materials for making the superstructure, sand, and labour for construction and also proving a cover for the second pit. The total cost of the ***Fossa alterna*** lies between US$18 – 27.

Lessons learned

The monitoring and Evaluation (M&E) programme has proved to be most valuable and information of relevance can be reintroduced back in to the programme. At first a considerable number of households had odour problems because they were afraid to fill their pits too quickly and therefore were not including enough soil/ash after each use. This never properly covered the excreta. This was overcome by the realisation larger quantities of soil and ash overcame the fly and odour problem and did not necessarily fill the pits at a fast rate. Also to allay fears that the pit will fill up more quickly, pits are being dug between 1.3 and 1.5 metres deep. Pits do fill up more quickly if overloaded, and used by large families or more than a single family.

EcoSan latrines are more difficult to manage in the wet season, partly because it is difficult to find dry soil and ash. However some forward planning by collecting dry soil and ash ands storing in bags under cover can over come this problem. In using soil and ash to add to the pit, often with the hands, it has been found that hand washing is more frequently undertaken and simple hand washing facilities are normally built as part of the latrine/bathing complex. As time passes it will be easier to assess the acceptance of excavating the pits once they are full of humus. Will people excavate the full depth of the pit or just part of it? These questions remain unanswered at the present time. Our knowledge of the use and acceptance of the ***Fossa alterna*** and other eco-san systems increases with time. Only time will tell.

A nice example of the Mozambican *Fossa alterna* in Niassa Province

On the left - building an *Arborloo* near Lichinga. An *Arborloo* **pit is just been topped up with soil and a tree planted near the foreground. On the right – the two pits of the *Fossa alterna*, one is partly excavated.**

The Malawi Programme

WateraAid and the CCAP have also been active in Malawi, promoting EcoSan. WaterAid has an excellent programme in Salima, and another programme conducted by the CCAP in the catchment area of Embangweni hospital in Northern Malawi, has strong sanitation promoters network. Here a sanitation team has an ambitious goal of constructing at least 500 latrines by the end of 2003. In this programme masons are trained to build the various eco-latrine types, the emphasis being on the *Arborloo***,** although more recently there has been a shift towards the *Fossa alterna* **.** Planting trees on filled latrine pits has been practiced in Malawi for generations, and thus is not a new concept in Malawi. Embangweni's sanitation co-ordinator is involved in intensive community mobilisation, involving promoters, agents and masons. Sanitation clubs also promote the concept of ecological sanitation. Meetings with local leaders and households are considered very important to this programme and demonstration latrines are built in the areas intended for local promotion.

This programme is paralleled by the propagation of young fruit trees for use in the programme, particularly mango, oranges and tangerines. Grafting techniques are also used. Paw paw and banana are also widely promoted as being suitable for use on Arborloo pits as they grow very fast. Schools are being used as distribution points for cement.

As of November 2003 nearly 400 eco toilets had been built. In July 2003, a total of 303 eco-latrines had been built in this project (183 ***Arborloo***, 15 ***Fossa alterna***, 57 children's latrine (a type of small ***Arborloo*** for children), 7 ***Skyloo*** and 41 improved traditional latrines. The number of trees planted is as follows: orange 68, Paw paw 51, guava 23, tangerine 15, bananas 13, granadillas 8, pears 3, mangoes 2, sweet apple 1 (Report of the CCAP Eco-sanitation Project at Embangweni, Malawi by Twitty Munkhondia).

More recently a programme initiated by COMWASH in the districts of Phalombe and Thyolo has started, using the methods developed in Salima and Embangweni. Here again local masons become skilled in making slabs and there are distribution centres for cement. Strong links are being made with the Ministry of Health and other government departments. All these projects show great promise for future expansion of eco-san in Malawi. They have been described by Morgan 2003a and 2003b).

Portable structures designed for use with the *Arborloo* in Malawi

Trainees lining *Fossa alterna* pits in Malawi

Summary of training and extension

In ecological sanitation the recycling of human excreta is made as simple and convenient as possible. Natural processes are involved in a way that retains a simplicity of method and flexibility of design. Health issues have always been considered. For instance the ***arborloo*** is designed to minimise human contact with faecal matter, and urine diversion systems attempt to sanitise faecal material more quickly and make it easier to handle. These aspects of design help to reduce the health risks associated with the practice of ecological sanitation. Also the provision of a reliable hand washing facility is essential if a latrine system is to be associated with an improvement in health.

The need for improved soils in a world which lacks food and where soils are often leached out and infertile is also an important consideration. Ecological sanitation attends to this matter. The humus resulting from composted human faeces makes an excellent soil conditioner. The aim is to mix it with infertile and worked out soil together with garden compost and leaf litters which are also produced in the garden. Thus those practising ecological sanitation should also be familiar with the methods of making garden compost and leaf mould so that all these fertile soils can be mixed to form a living and fertile humus. Such humus when properly used in agriculture helps to improve food yields and also food quality and hence provides more food security and improves the nutritional status of the beneficiaries. The fact that excreta can change into a nice smelling soil is one of Nature's marvels. Without this natural process of "building up" and "breaking down" no animal or plant life could exist on Earth.

Practical hands on training is vital – making a slab in Kenya

20. Summing up

This book has described the fundamental principles of ecological sanitation and provided a detailed description of how to build and manage a small range of lower cost eco-toilets where the recycled products can be put to good use. Ample evidence has been provided for the value of both humus derived from human excreta and also the urine for enhancing the production of a range of food crops. The greatest effect is normally achieved by combining the use of both humus and urine. Methods of growing vegetables using recycled human excreta have also been described. The importance of combining the use of recycled human excreta and other recycled organic materials like garden compost has also been emphasised. A number of gardening and constructional techniques which assist eco-san based projects have also been described. The health implications of using processed human excreta, has also been summarised.

The techniques described here cover only a very small, and as yet little known range of on-site options for lower cost sanitation. Many large scale projects based on ecological sanitation are being undertaken around the world and these are receiving much attention. The techniques and methods described here are less well known and intended for use by poorer members of the community, who may in the past have used only the pit toilet or no toilet at all. However it is this proportion of the world's population which is perhaps the largest, the least served and the most in need of improved facilities. It is hoped that this extended range of lower cost options will help to increase the coverage of this underprivileged segment of the population.

Ecological sanitation can also assist where people have used conventional water born systems like the flush toilet before, but where these systems are failing due to a lack of water or lack of maintenance of sewage processing systems. Overburdened or poorly maintained conventional sanitation systems can also pollute the environment considerably. These conditions apply mostly in the cities and peri-urban areas surrounding these cities. Where there is space, the systems described in this book may be useful. There are many projects currently being undertaken all over the world, where these same basic problems are being addressed by the application of ecological sanitation. GTZ and Sida/EcoSanRes are at the forefront of such work internationally.

There are a few central themes on which this particular approach to low cost sanitation, described in this book, has been built.

* The toilet system itself must be thought of, not so much as a disposal system, but as a processing unit.

* Soil can provide the all-important link between the toilet system and agriculture. In the toilet systems described in this book, soil is added to the toilet in quantity – approximately equal to the volume of solid excreta added. And for best results, the added soil should be combined with wood ash and leaves.

* The added soil, together with its companion ash and leaves, converts, purifies and otherwise hastens the conversion of the foul and dangerous mass of excreta into humus, which becomes pleasant to handle, relatively safe and is rich in nutrients. The process is entirely biological, with beneficial organisms of all kinds tending to thrive and pathogenic organisms tending to die out. The inventor of the process is Nature itself.

*The end result of this natural process is a valuable humus-like soil, which can be used to enhance the growth of both trees and vegetables. Excreta, soil, ash and leaves are abundant and cost nothing. In combination and when processed they have great value.

* The processing of human excreta (both humus and urine) is best integrated into a broader scheme of recycling all organic products in both the home and the garden.

Ironically this method of using soil to process excreta was first used in the form of the "earth closet" over 100 years ago. This technique preceded the use of water born sanitation as we know it today. The concept of using earth, rather than water, quickly went out of fashion however, after the invention of the flush toilet. As we have seen the "earth closet" and its variants still have considerable merit and greatly deserve revival.

All organic material can be composted. Thus leaves are recycled by making leaf compost. Organic vegetable matter, derived from both kitchen and garden are recycled to make garden compost. Manure derived from animals is recycled to enter the compost heap. The composted materials from all sources, of both animal and plant origin, are applied back into the soil, which becomes enriched. Thus it is the combination of recycled leaves, manure, vegetable matter, kitchen scraps together with recycled human excreta which are used to form a medium which is mixed with topsoil to enhance the growth of food crops.

Put simply, eco-toilets form part of an ecological approach to managing the garden and home in a holistic way. Even used water (grey water) can be recycled in such a way that it can enhance the production of food. The home and garden becomes part of an eco-home and eco-garden. Recycling in all its forms is encouraged. That is how Nature works!

The question then remains, what if I am not a gardener and have no interest or time to produce my own vegetables? Many may have no garden, but this will rarely apply to those for whom this book has been written. If this is the case, these eco–toilets will at least save water if the alternative is a flush toilet. If the alternative is a deep pit toilet, this new approach will provide an alternative facility which is safe, relatively cheap and pleasant to use. The fact remains that all pit toilets will eventually fill up and must be replaced sooner or later. For those millions who use pit toilets, low cost eco-toilets may provide a good answer for the future. For many, it will be the low cost of the simpler toilet systems described in this book which will have the greatest appeal. For others, it will be the ease of construction and the possibility of self sufficiency which will appeal. For others, the selling point may be that for the first time a toilet can do more than just dispose of excreta.

There is also the possibility that once put to use, the production of humus from the eco- toilet, together with the re-use of urine, may encourage the home owner to consider growing vegetables or enriching flower beds or growing more fruit trees. My own interest in gardening and the organic approach was much encouraged when I started to use an ecological toilet and reused the humus formed and the urine.

In this study I have been constantly amazed by the conversion process - how all these materials which in their prime state could never be classified as soil, easily turn into a product which can only be described as soil. Thus leaves turn into soil, organic wastes from the kitchen turn into soil, vegetable and manure turns into soil and even human excreta turns into soil. Soil is surely the beginning and the end of it all. In this discipline, the answer does indeed lie in the soil.

But even the richest soils need rejuvenation when they have yielded their nutrients up to the growing plants and a method of constantly re-introducing the nutrients derived from urine and humus into the soil is required. Thus compost or processed manure should constantly be introduced into the vegetable garden. Where jars, basins or other containers are used, once the vegetables have been harvested, the used soil can be tipped out into a pile, sieved and introduced into a fresh pile of soil to which fresh compost or eco-humus is added. So there is constant rejuvenation of the soil which is used.

I subscribe to the view held by Louis Bromfield, that there is nothing wrong with carefully combining different techniques in the garden, provided that the soil is enriched, biologically, and plant life is helped to flourish. And careful use of organic and even inorganic plant foods, even those available on the market can also be used carefully in combination with the methods described.

Conclusions

This book attempts to provide practical information which will allow those living in rural, peri-urban and even some urban areas of Africa to build and practice the art of recycling nutrients from their own excreta in order to gain better crops and vegetables in their own back gardens. The work is primarily intended for use in East and Southern Africa, where there is space, where back yard gardening is practiced and where the climate is warm and wet seasons are interspersed with dry.

The basic principles outlined in this book are the most important. These principles can be adapted to suit local conditions in various countries in the sub-region. The method chosen will depend on several factors, not least the amount of money available to build a facility and the willingness of the user to engage in the practice of recycling.

Eco-toilet in an African setting. Ruwa, Zimbabwe

It should be remembered that all these eco-toilet systems require a degree of management which is far more demanding than required by users of the normal deep pit latrine or even the flush toilet. This may not always be clearly understood at first. Thus practical hands-on training and demonstration are vitally important. Often judgements about final design and processing methods may be taken only on-site where soil type, ground stability and drainage have been assessed.

The methods described in this work represent new ventures into the world of low cost sanitation, and there is still much to learn. This work has been written by a researcher, who dabbles at the fringe of understanding. There is an ocean more still to learn. The methods described are intended to add on to the sanitary range of options already available and not compete with them. The pit latrine, currently the commonly used excreta disposal system in the world, has survived over the centuries because, along side its potential deficiencies, it has great merit. It is simple and easily managed. A pit dug 3m deep may take 10 years to fill and thus requires limited management. When full however, the pit is usually difficult to empty and a new toilet must be built. The pit toilet can also be upgraded with a screened vent pipe to make it almost odourless and fly free. In the great majority of cases pit toilets do not seriously pollute ground water, especially if the toilets are well placed in relation to the water source (30m distant). However in high density settlements where pit toilets are built close together and shallow wells provide a source of domestic water, contamination of the water source is possible. This is where shallower pit or urine diversion eco-toilets can play a useful role.

The flush toilet and related waterborne systems have brought with them the possibility of people living together in cities, and of greatly reduced incidents of disease which has made modern life possible. Thus the application of waterborne systems made possible a huge rise in living standards for countless millions of people around the world. And this continues to be the case. All sanitary systems have their place. Both the pit and flush toilet systems will remain as major excreta processing systems for as long as we live. They will be joined by urine diverting systems and variants of both the flush and pit toilets which make recycling possible. There is room for all these systems to be used in the most appropriate setting.

This new ecological approach to sanitation has come just in time to add a new perspective and dimension to sanitation itself. The low cost alternatives described in this work, offer really practical solutions for providing acceptable sanitation on a small budget. Very often it is the simplicity, low cost and ease of construction which may appeal at first to the beneficiary. And upgrading from one system to another is always possible over time. The direct link to agriculture and forestry is also an important element in this new initiative. The additional benefits of recycling the compost and urine to enhance food production and tree growth are clear to see. These various practical benefits may convince the householders to take up the eco-san route.

ONLY TIME WILL TELL!

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