Sandec: Department of Water and Sanitation in Developing Countries

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Sandec Training Tool 1.0 – Module 6

Solid Waste Management

Summary

With progressing urbanisation, solid waste management is becoming a major public health and environmental concern in urban areas of many developing countries. The overall goal of urban solid waste management is to collect, treat and dispose of solid waste generated by all urban population groups in an environmentally and socially satisfactory manner using the most economical means available.

However, a typical solid waste management system in a developing country displays an array of problems, including low collection coverage, irregular collection services, indiscriminate open dumping and burning without air and water pollution control, breeding of flies and vermin, as well as handling and lack of control of informal waste picking or scavenging. These public health, as well as environmental and management problems are caused by various factors constraining the development of effective solid waste management systems. (The World Bank, 2008)

This document provides an overview of the present state-of-the-art of solid waste production and management. It contains the characteristics of municipal solid waste and describes current waste treatment systems and technologies, as well as non-technical aspects like private sector involvement and financial arrangements.

Figure 1: Solid waste management in the context of environmental sanitation.

Not included in Module 6

- Industrial hazardous waste
- Technical details for recycling and disposal
- Transboundary waste movements

Impressum

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Cover photo: Pammal collection vehicle in India. (Source: Eawag/Sandec)

Content

1.1 How is municipal solid waste (MSW) characterised?

▸ **The characteristics of MSW are dependent on local culture, standard of living and natural resources.**

The main goal of municipal solid waste management (MSWM) is to reduce the waste volumes and to protect the health of the urban population, particularly that of low-income groups who suffer most from poor waste management. In urban areas, solid waste is generated by households, commercial and industrial enterprises, as well as healthcare facilities and institutions. With the exception of industrial, construction and debris waste, the aforementioned waste generated in cities is referred to as municipal solid waste. (Zurbrügg, 2003a)

Semisolid waste, such as sludge or nightsoil, is dealt with by liquid waste management systems; whereas hazardous industrial or medical waste is, by definition, not a component of municipal solid waste. It is normally quite difficult to separate from municipal solid waste, particularly when its sources are small and scattered. (Schüberler et al., 1996, p. 17)

Regional solid waste characteristics and quantity are dependent on the standard of living and lifestyle of the inhabitants of a region, but also on volume and type of available natural resources. Urban waste can be subdivided into two major components – organic and inorganic.

Waste generated in countries located in humid, tropical and semitropical areas is usually characterised by a high concentration of plant debris; whereas the waste, generated in areas subject to significant seasonal temperature variations or where coal or wood are used for cooking and heating, may contain an abundance of ash. The amount of ash may be substantially higher in winter. Waste is usually more or less contaminated by nightsoil, irrespective of climatic conditions. (UNEP, 2005, p. 2)

What is waste?
The term 'waste' has a different meaning for different people. In general, waste is 'unwanted' for the person who discards it; a product or material which is no longer valued by the first user and therefore thrown away. However, 'unwanted' is subjective, as it could be of value for another person under different circumstances or even in a different culture. There are many large industries using primarily or exclusively waste materials as their industrial feedstock – paper and metals are the most common. (Van de Klundert et al., 2001, p. 9)

Further questions
- ▸ What is the purpose of segregating waste at its point of generation, i. e. household level?
- ▸ Are there any major differences in household waste composition in different countries or regions?

Additional info
▸ UNEP (2005). Solid Waste Management, CalRecovery Inc. www.unep.or.jp/Ietc/Publications/spc/Solid_Waste_Management/Vol_I/Binder1.pdf (last accessed 28.04.08)

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1.2 What are the objectives and main elements of an integrated solid waste management?

▶ **Integrated solid waste management includes all activities, which seek to minimise the health, environmental and aesthetic impacts of solid waste.**

The main goal of municipal solid waste management (MSWM) is to protect the health of the urban population, particularly that of low-income groups who suffer most from poor waste management. Secondly, MSWM aims to promote environmental conditions by controlling pollution (including water, air, soil, and cross-media pollution) and to ensure the sustainability of ecosystems in the urban region. Thirdly, MSWM supports urban economic development by providing the required waste management services and guaranteeing the efficient use and conservation of valuable materials and resources. Fourthly, MSWM aims to generate employment and income in the sector itself. The goals of MSWM are therefore:

1. To protect environmental health
2. To promote the quality of the urban environment
3. To support the efficiency and productivity of the economy
4. To generate employment and income

To achieve these goals, it is necessary to establish integrated and sustainable systems of solid waste management that meet the needs of the entire urban population, including the poor. The essential condition of sustainability implies that waste management systems must be ab-

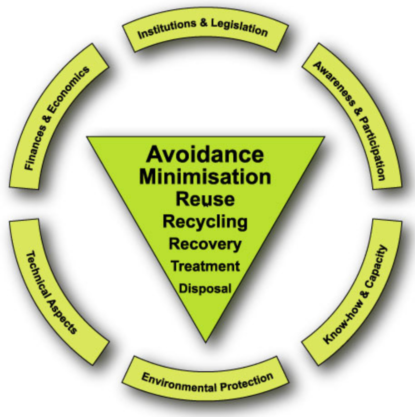

Figure 2: National and local factors (circular boxes) influencing the core concepts of the waste management hierarchy (triangle), in which solid waste elements diminish in priority from top to bottom. (Eawag/Sandec).

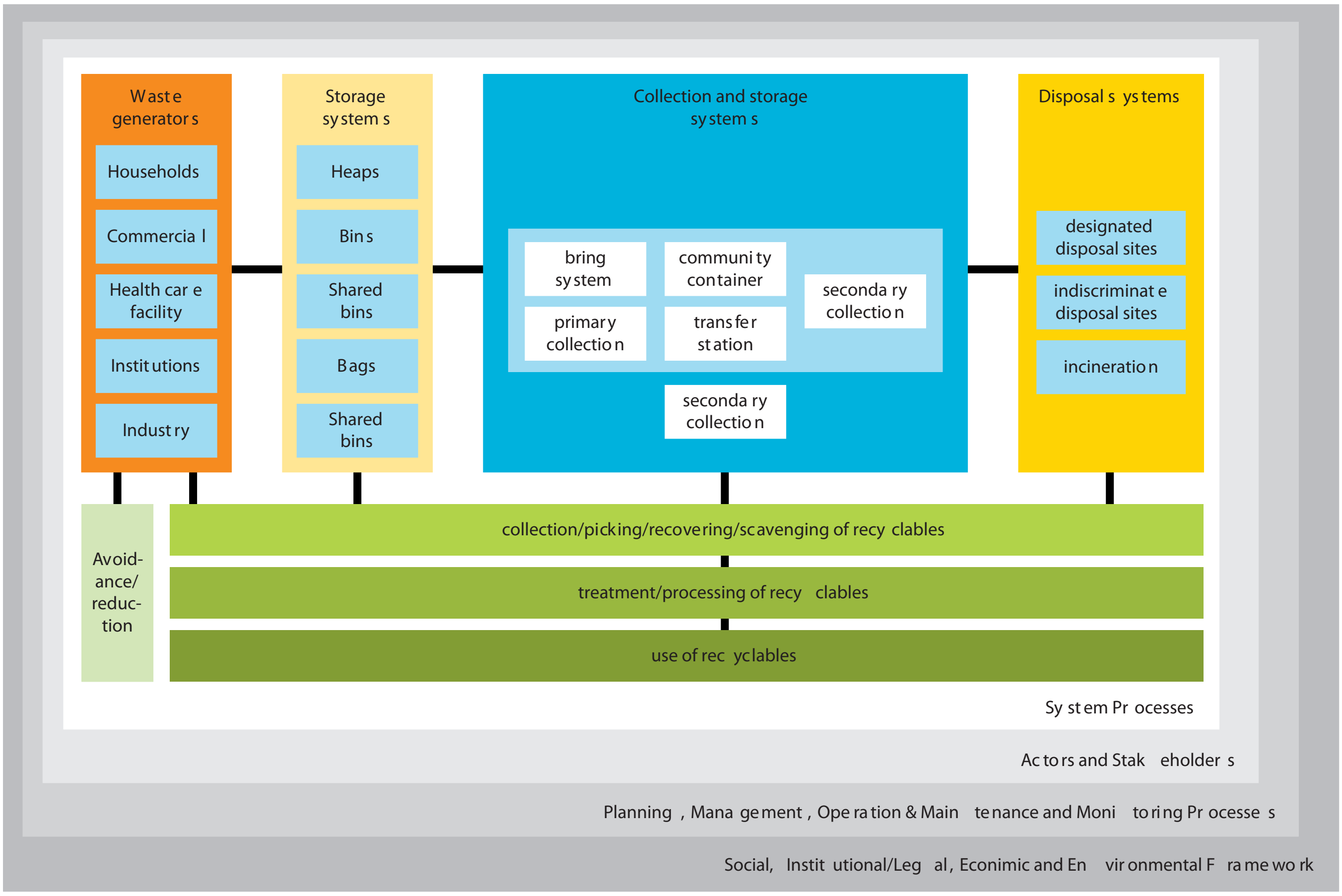

Figure 3: Elements of an integrated solid waste management. (Eawag/Sandec)

sorbed and carried by the society and its local communities. In other words, these systems must be adapted to the particular urban and area-specific circumstances and problems. They must employ and develop the capacities of all stakeholders, including the households and communities requiring the service, private sector enterprises and workers (both formal and informal), as well as government agencies at the local, regional and national level. (Schübeler et al., 1996)

Key to integrated solid waste management is the development of a waste management hierarchy, integrating widespread elements of national and regional policy – often considered as the most fundamental basis of modern MSWM practice. The hierarchy classifies waste management operations according to their environmental or energy benefits (UNEP, 2005, p. 8 – 9):

1. Prevent the production of waste or reduce the amount generated.
2. Reduce toxicity or negative impacts of the waste generated.
3. Reuse the materials recovered from the waste stream in their current forms.
4. Recycle, compost or recover materials for use as direct or indirect inputs for new products.
5. Recover energy by incineration, anaerobic digestion or similar processes.
6. Reduce the volume of waste prior to disposal.
7. Dispose of residual solid waste in an environmentally sound manner, generally in landfills.

In practically all countries, the hierarchy is similar to that described above, with higher priority given to the first points. (UNEP, 2005, p. 9)

Figure 2 illustrates this hierarchy embedded in a set of factors related to SWM. The main elements of an integrated solid waste management system are depicted in Figure 3. These elements can be divided into technical and non-technical aspects, as shown in Table 1.

Integrated waste management is based on the concept that all aspects (technical and non-technical) should be analysed together, since they are in fact interrelated, i. e. developments in one area frequently affect practices or activities in another area. (UNEP, 2005, p. 7 – 8)

An integrated approach is an important element of sound practice as:

- Certain problems are more easily resolved in conjunction with other aspects of the waste system than on their own. Also, development of new or improved waste handling in one area can disrupt existing activities in another area, unless changes are handled in a coordinated manner.
- Integration allows for capacity or resources to be optimised and, thus, fully utilised. Economies of scale for equipment or management infrastructure can be frequently reached only if all the waste in a region is managed as part of a single system.
- An integrated approach allows for public, private and informal sector participation with roles adapted to each.
- Since some waste management practices are more costly than others, integrated approaches facilitate identification and selection of low-cost solutions. Some waste management activities cannot bear any charges; some will always be net expenses, while others may produce an income. An integrated system can result in a range of practices that complement each other in this regard.
- Failure to have an integrated system may mean that the revenue-producing activities are "skimmed off" and treated as profitable, while activities related to maintaining public health and safety fail to secure adequate funding and are operated at low or insufficient levels.

(UNEP, 2005, p. 8)

Non-technical aspects	Technical aspects
• Setting policies • Developing and enforcing regulations • Planning and evaluating municipal SWM activities by system designers, users and other stakeholders • Marketing recovered materials to brokers or to end-users for industrial, commercial or small-scale manufacturing purposes • Establishing training programmes for MSWM workers • Carrying out public information and education programmes • Identifying financial mechanisms and cost recovery systems • Establishing prices for services and creating incentives • Managing public sector administrative and operation units • Incorporating private sector businesses, including informal sector collectors, processors and entrepreneurs	• Generation and storage of household waste (household is regarded here as the "source" of waste generation. It also includes commercial entities or institutional bodies generating waste) • Reuse and recycling at household level (including animal feed and composting) • Primary waste collection and transport to transfer station or community bin • Management of the transfer station or community bin • Secondary collection and transport to the waste disposal site • Waste disposal in landfills • Using waste characterisation studies to adapt the system to the types of waste generated

Table 1: Technical and non-technical aspects associated with integrated solid waste management. (UNEP, 2005; Zurbrügg, 2003a)

Further questions

▸ Is waste avoidance and reduction generally given first priority by municipalities?

Additional info

▸ UNEP (2005). Solid Waste Management, CalRecovery Inc. www.unep.or.jp/Ietc/Publications/spc/Solid_Waste_Management/Vol_I/Binder1.pdf (last accessed 28.04.08)

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2.1 What are the problems related to insufficient solid waste management?

▶ **Uncontrolled dumping of solid waste can lead to severe health hazards for local inhabitants, and pollute natural resources like water, soil or air.**

According to a survey by the United Nations Development Programme (UNDP) of 151 mayors of cities around the world, the second most serious problem (after unemployment) faced by city dwellers is insufficient solid waste disposal. (UNDP, 1997, Draft Interim Report, Part 3)

The risks posed to the environment and public health arise from the way this waste, generated by human activities, is handled, stored, collected, and disposed of. Where intense human activities concentrate, such as in urban centres, appropriate and safe solid waste management (SWM) is of utmost importance to allow healthy living conditions for the population. Although most governments have acknowledged this fact, many municipalities are struggling to provide even the most basic services. (Zurbrügg, 2003b, p. 1)

The main problems and issues related to unsatisfactory SWM in most developing countries are:

a) inadequate coverage of the population to be served;
b) operational inefficiencies of municipal SW services and management;
c) limited use of the recycling activities by the formal and informal sectors;
d) problems related to the disposal of solid waste; and
e) problems concerning the management of non-industrial hazardous waste.

All these problems have common social, institutional, financial, and technical denominators. (Schertenleib et al., 1992, p. 3)

Typically, one to two thirds of the solid waste generated are not collected (World Resources Institute et al., 1996, p. 1). As a result, the uncollected waste, which is often also mixed with human and animal excreta, is dumped indiscriminately on streets and in drains, thus contributing to flooding, breeding of insect and rodent vectors and to the resulting spread of diseases. (UNEP-IETC et al., 1996)

In low-income countries, most of the collected municipal solid waste is dumped on land in a more or less uncontrolled manner. Such inadequate waste disposal practices create serious environmental problems affecting not only the health of humans and animals, but also giving rise to serious economic and other welfare losses. The environmental degradation caused by inadequate waste disposal can be measured by the contamination of surface and groundwater through leachate, soil contamination through direct waste contact or leachate, air pollution by waste burning, spreading of diseases by different vectors like birds, insects and rodents, or the uncontrolled release of methane by anaerobic waste decomposition.

In cities of developing countries, the urban poor suffer most from the life-threatening conditions of deficient SWM (Kungskulniti, 1990; Lohani, 1984), as municipal authorities tend to allocate their limited financial resources to the richer areas with higher tax yields from citizens with more political power. Usually, wealthy residents use part of their income to avoid direct exposure to the environmental problems close to home by shifting them away from their neighbourhood. Thus, though environmental problems at the household or neighbourhood level may decrease in higher-income areas, citywide and regional environmental degradation remains the same or increases due to a deficient SWM. (Zurbrügg, 2003b, p. 1)

Photo 1: Polluted open sewer in Togo. (Source: Eawag/Sandec)

In an attempt to accelerate its industrial development, an economically developing nation may fail to pay adequate attention to solid waste management. Such a failure results in severe penal-

Photo 2: Open street site dump in India. (Source: Eawag/Sandec)

ties at a later time in the form of resources needlessly lost and a staggering adverse impact on the environment, public health and safety. The penalty is neither avoided nor lessened by a resolve to do something about the waste in the future, when the country may be in a better position to take appropriate measures. This is true because the rate of waste generation generally increases in direct proportion to that of a nation's advance in development. The greater the degradation of the environment, the greater is the effort required to restore its good quality. In summary, the effort to preserve or enhance environmental quality should at least be commensurate with that afforded to the attainment of advance in development. (UNEP, 2005)

Environmental and health impacts

The organic fraction of MSW is an important component, as it constitutes a sizable fraction of the solid waste stream in a developing country, but also because of its potentially adverse impact upon public health and environmental quality. A major adverse effect is the attraction of rodents and vector insects for which it provides food and breeding grounds. Reduction of environmental quality takes the form of foul odours and unsightliness. These impacts are not confined merely to the disposal site. On the contrary, they pervade the areas surrounding the sites wherever the waste is generated, spread or accumulated. Unless organic waste is appropriately managed, its adverse impact will continue until it has fully decomposed or otherwise stabilised. Uncontrolled or poorly managed intermediate decomposition products can contaminate air, water and soil resources.

Studies have shown that a high percentage of workers handling refuse, and individuals residing near or on disposal sites, are infected by gastrointestinal parasites, worms and related organisms. Contamination of this kind is likely at all points where waste is handled. Although it is certain that vector insects and rodents can transmit various pathogenic diseases (amoebic and bacillary dysentery, typhoid fever, salmonellosis, various parasitoses, cholera, yellow fever, plague, and others), it is often difficult to trace the effects of such transmission to a specific population. Both public health and environmental quality benefit directly and substantially from the implementation of modern solid waste management practices. (UNEP, 2005, p. 3)

Further questions

▸ Are social, political, technical or rather financial constraints the reasons for the general lack of solid waste management and services?

Additional info

▸ Zurbrügg, C. (2003). Urban Solid Waste Management in Low-Income Countries of Asia – How to Cope with the Garbage Crisis. SCOPE. Durban, South Africa. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_swm/downloads_swm/USWM-Asia.pdf (last accessed 28.04.08)

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2.2 What are the municipal solid waste categories and how much waste is produced?

▸ **MSW generally consists of organic waste, paper, plastics, glass, metal, textiles, and other inert materials.**

According to Key Note, 2.02 billion tons of MSW were generated worldwide in 2006. The average quantity of municipal solid waste generated throughout Latin America, Asia, and some countries in Africa is in the order of 400 g/cap/day. This equals approximately 30 – 40 % of the daily per capita waste generated in the United States and in Western European countries. (UNEP, 2005, p. 53)

Growth in wealth and increase in waste are interlinked – the more affluent a society, the more waste it generates (compare Figure 4). As less wealthy nations develop, they too create more wealth, thus adding to the world's waste output.

Key Note forecasts that total global MSW will increase by 37.3 % between 2007 and 2011. (Key Note, 2007, p. 16)

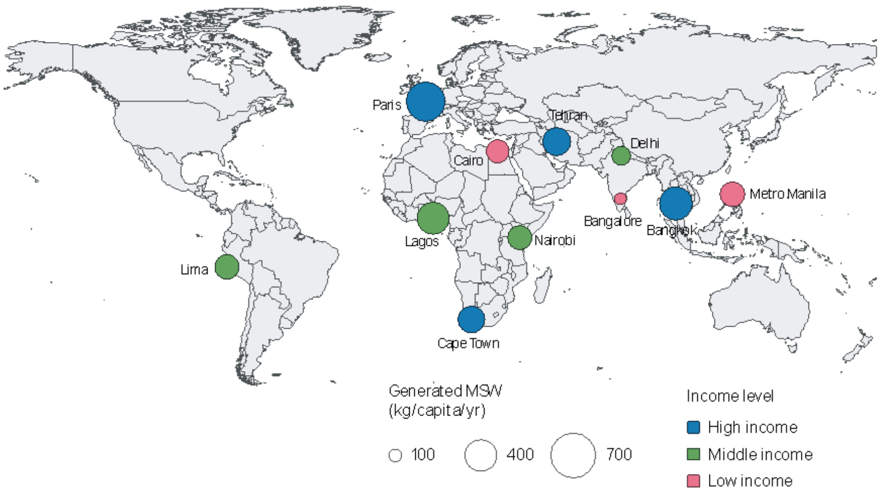

Figure 4: Generation of MSW (kg/capita/yr) in 11 cities and their GDP in 2005 (in US$, using purchasing power parity exchange rates) per capita according to the World Bank's income classification of 2006 (low income: US$ 905 or less; middle income: US$ 906 to 11,115; and high income: US$ 11,116 or more). (Eawag/Sandec, 2008)

The influence of income level on waste generation is also revealed by studies looking at different urban income levels of neighbourhoods. Table 2 shows the example of Durban, South Africa.

Income level	Waste generation (kg/cap/day)
High income	1.48
Middle income	0.41
Low income (formal)	0.13
Low income (informal)	0.11

Table 2: Waste generation rates in Durban, South Africa as a function of average income level of neighbourhoods. (Zurbrügg, 2003a, p. 4)

Although economic standing is a key determinant of how much solid waste a city produces (World Resources Institute et al., 1996), this generalisation may not always be valid, but may vary according to the socio-cultural consumption habits. The example of high variability in relation to the income level of neighbourhoods in Durban also depicts the problem of data reliability when operating with city averages or worse even, when using country average waste generation rates. Not only income but also urbanisation level of a city indicated by its population size is interrelated with the waste generation rates. Rural villages and small towns have significantly lower values of generated waste per capita. Table 3 shows waste generation in relation to relative city size for Nepal, Egypt and Sri Lanka (Akolkar, 2001; Saber, 1998; UNEP, 1999 in Zurbrügg, 2003a). Thus, average countrywide solid waste data can be very misleading if used in a specific city context.

Solid waste generation not only differs in relation to the local context, but also to its waste composition. In industrialised countries, domestic waste consists mainly of packaging materials, such as paper and plastics, whereas waste from low and middle-income countries contains high biodegradable organic waste fractions (cf. Figure 5).

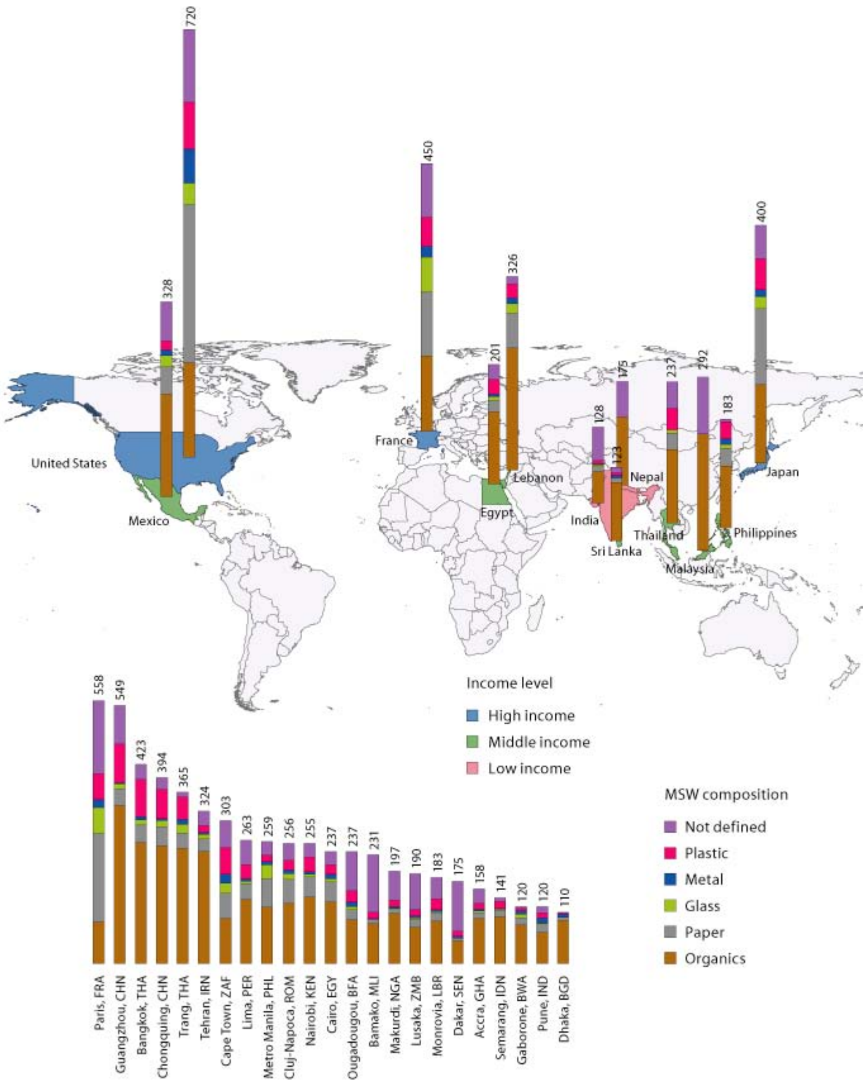

Figure 5: Top: MSW composition (kg/capita/yr) in 12 countries grouped according to their gross national income (GNI). Bottom: MSW composition (kg/capita/yr) in 23 cities. (Eawag/Sandec, 2008)

Country-specific studies reveal that the physical characterisation of solid waste differs in categories. Most waste characterisation studies have established the following categories:

- Biodegradable
- Paper
- Plastic
- Glass
- Metal
- Textiles and leather
- Inerts (ash, earth and others)

(Zurbrügg, 2003b, p. 4)

Further questions

- How much waste do I produce every year?
- How much waste do people in other countries produce?
- How much waste is recycled, burned and dumped?

Additional info

- Eawag/Sandec (2008). Global Waste Challenge - Situation in Developing Countries. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_swm/index_EN (last accessed 30.07.08)

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Country	Large cities	Middle cities	Small cities
Nepal	0.5	0.35	0.25
Egypt	1.0 – 1.3	0.5 – 0.8	0.25
Sri Lanka	0.65 – 0.85	0.45 – 0.65	0.2 – 0.45

Table 3: Waste generations rates (kg/cap day) of different sized cities

2.3 How is solid waste management related to rapid urbanisation?

▶ **Development of solid waste systems generally lags behind urbanisation rates.**

Rapid urbanisation is taking place especially in low-income countries. In 1985, globally 41 % of the world's population lived in urban areas: by 2015 the urban proportion is projected to rise to 60 % (Schertenleib et al., 1992). Of this population, 68 % will be living in cities of low-income and lower middle-income countries (cf. Figure 6). (Zurbrügg, 2003b, p. 2)

The situation is acute, as slums are growing at an alarming rate and the municipal solid waste management services are lagging behind the needs of the inhabitants, especially in urban poor areas. (UNEP, 1999)

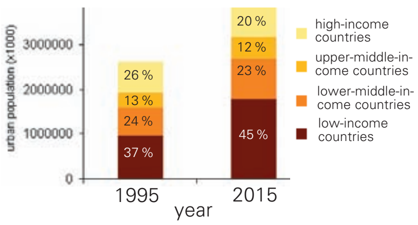

Figure 6: Global urban population categorised by the different economies. The economies are divided according to 1996 GNP per capita: low income US$ < 785; low middle income: US$ 786 – 3115; upper middle income: US$ 3116 – 9635; and high income: US$ > 9636. (www.worldbank.org/data/databytopic/class.htm). (Zurbrügg, 2003b)

Further questions

▶ How should authorities deal with the problem of equity of service access in areas where the population is too poor to pay the full cost of waste management?

▶ How should municipal waste management systems be adapted to specific demands and requirements of residential populations, including, in particular those of women and low-income households?

Additional info

▶ UNEP (1999): Global Environment Outlook, Geo-2000. UNEP. www.grid.unep.ch/geo2000/english/0070.htm. (last accessed 28.04.08)

Available from the Internet.

UN News, 26 February 2008

"By the end of this year, half of the world's 6.7 billion people will live in urban areas, according to a report unveiled by the United Nations today, which also predicts that future growth of the world's urban population will be concentrated in Asia and Africa." (UN, 2008)

2.4 What is the present state in SWM?

▶ **Most cities in the developing world collect only part of the overall waste, and only a tiny fraction of the collected waste is treated or properly disposed of.**

Even though municipal solid waste management is a major responsibility of local governments, typically consuming between 20 % and 50 % of municipal budgets, it has been estimated that about 30 – 50 % of the waste generated in developing countries is never collected (Schüberler et al., 1996; UNEP, 2005). Uncollected waste accumulates in vacant lots or is simply discharged into bodies of water. As a result of inadequate disposal and excessive littering, the burden of waste collection is, in many instances, transferred from the collection system to the street cleaning system.

Typical productivity of a refuse collection worker in developing countries (defined as total weight of waste collected by the entire system, divided by the number of collection workers) is approximately 250 kg/day. Average expendi-

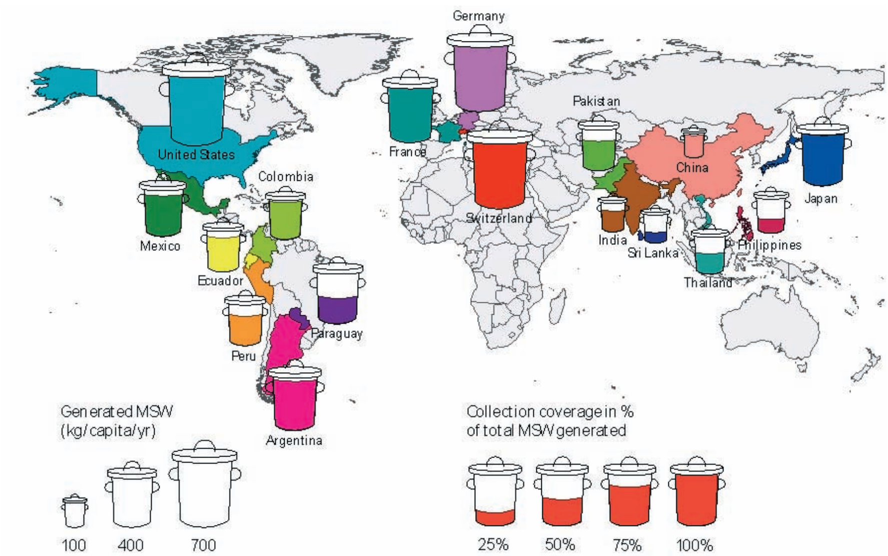

Figure 7: Total MSW generated (kg/capita/yr) and collection coverage in % in 17 countries. (Eawag/Sandec, 2008)

ture (at 2002 price level) on solid waste management, including street cleaning and final disposal, ranges from about US$ 1/cap/yr to nearly US$ 5/cap/yr. (UNEP, 2005, p. 53 – 54)

With the mounting urgency of urban environmental problems identified (for example in Agenda 21, Chapters 7 and 21) and growing concern for capacity building at municipal management level in recent years, MSWM has attracted increasing attention from bilateral and multilateral development agencies. With its broad organisational implications and close links to other sectors, MSWM constitutes an important entry point for integrated urban management support. (Schüberler et al., 1996, p. 15)

A word on the significance of collection, transfer and street sweeping. Collection is by far the largest cost element in most MSWM systems, accounting for 60 – 70 % of costs in industrialised countries, and 70 – 90 % of costs in developing and transition countries. Collection and street sweeping comprise the single largest category of expenditure in many municipal budgets. Failure or inadequacy of collection, especially in developing countries, where there is frequently considerable human faecal waste in the municipal solid waste, can lead to public health hazards. Given its high visibility and importance, one would expect collection to receive a high degree of scrutiny and analysis and, as a consequence, to be a highly efficient municipal or private operation. In fact, particularly in developing countries, the opposite is quite often true. Waste collection and street sweeping are often highly inefficient. Workers are frequently poorly motivated, untrained, undercompensated, and disregarded. Further obstacles to efficiency are obsolete or non-functional equipment and inaccessible routes, which have not kept pace with urban growth. Up to half of the poorer sections of developing cities are underserved or completely unserved. In some industrialised countries, waste collection has recently received more attention, due partly to the introduction of source-separated collection of recyclables and organics. Testing and analysis, which has accompanied the development, introduction and monitoring of separate collection, has often had positive spin-off effects on collection of the rest of the waste. In developing countries, an influx of loans and grants for infrastructure development is just beginning to affect collection systems, sometimes for the better, sometimes for the worse. A further problem is that waste collection is often in jurisdictional no man's land, where fiscal, operational and administrative responsibility is fragmented between public health, public works and public cleansing departments, with budgetary and operational responsibility in conflict. The association with waste often means that waste collection functions have low status, and managers and supervisors do not receive training, support or recognition. (UNEP-IETC et al., 1996, Chapter 1.3.1)

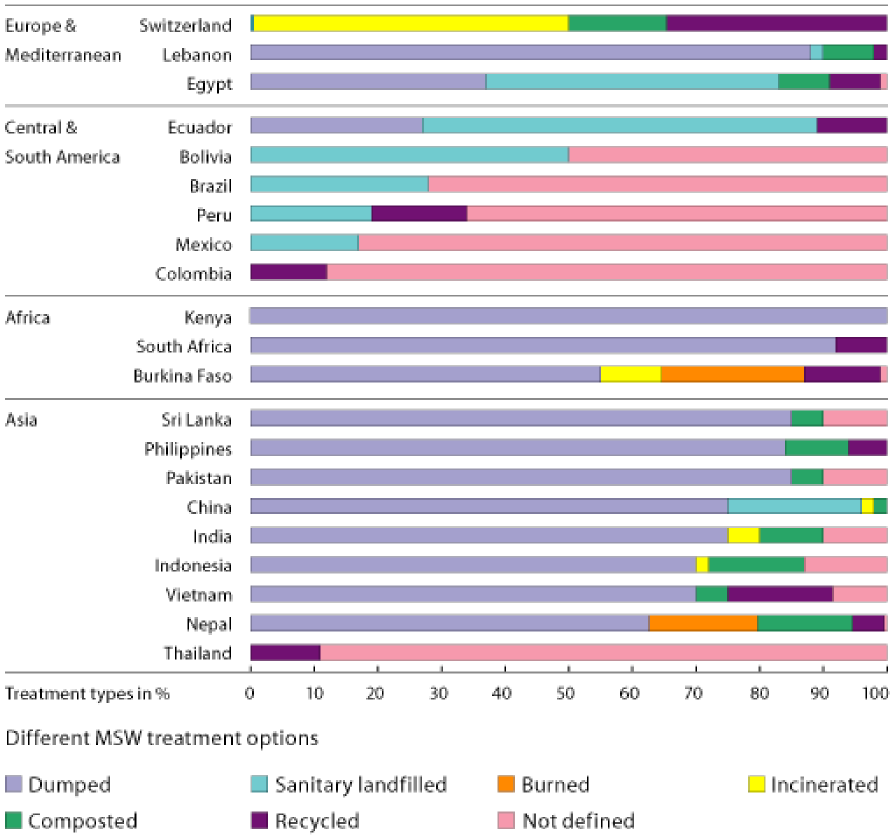

Figure 8: Percentage of the commonly used MSW treatment and disposal technologies in 21 countries. (Eawag/Sandec, 2008)

Further questions

- What priority should be given to waste minimisation and resource recovery in relation to waste treatment and disposal?
- How should authorities deal with the service needs of irregularly illegal settlements?

Additional info

- Eawag/Sandec (2008). Global Waste Challenge - Situation in Developing Countries. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_swm/index_EN (last accessed 30.07.08)

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2.5 What role does organic waste play in the context of SWM?

▸ **The high moisture content of organic waste (which makes up the main component in MSW, especially in low-income countries), influences the feasibility of collection and treatment options.**

A high biodegradable matter and inert material content in solid waste leads to a high density (weight to volume ratio) and high moisture content (compare Table 4). These physical characteristics significantly influence the feasibility of certain treatment options. Vehicles and systems operating well with low-density waste, prevalent in industrialised countries, will not be suitable or reliable under conditions where high organic content and density are common. The extra weight, abrasiveness of the inert material, such as sand and stones, and corrosiveness due to the high water content, may cause rapid deterioration of equipment. Waste with a high biodegradable, water or inert content will also have low calorific value and, thus, be unsuitable for incineration. (Zurbrügg, 2003b, p. 5)

In general, the organic components of urban solid waste can be classified into three broad categories: putrescible, fermentable and non-fermentable. Putrescible waste tends to decompose rapidly and, unless carefully controlled, its decomposition produces malodours and visual unpleasantness. Fermentable waste tends to decompose rapidly, but without the unpleasant accompaniments of putrefaction. Non-fermentable waste tends to resist decomposition and to break down very slowly. A major source of putrescible waste is food preparation and consumption. Its nature varies with lifestyle, standard of living and seasonality of foods. Fermentable waste is typified by crop and market debris. (UNEP, 2005, p. 1)

	Low-Income Countries *	Middle-Income Countries+	High-Income Countries
Waste generated (kg/cap. and day)	**0.4 – 0.6**	0.5 – 0.9	0.7 – 1.8 (CH: 1.1)
Waste density (kg/m^3)	**250 – 500**	170 – 330	100 – 170
Water content (%)	**40 – 80**	40 – 60	20 – 30
Composition			
Organic	**40 – 85**	20 – 65	20 – 50 (CH: 22)
Paper, cardboard	**1 – 10**	15 – 40	15 – 40 (21)
Glass and ceramics	**1 – 10**	1 – 10	4 – 10 (3)
Metal	**1 – 5**	1 – 5	3 – 13 (6)
Plastics	**1 – 5**	2 – 6	2 – 13 (13)
Dust and ash	**1 – 40**	1 – 30	1 – 20 (5)

Table 4: Waste characteristics
* Countries with GDP < US$ 360 per year per capita; + countries with GDP > US$ 360, < US$ 3500 per year and capita. (Cointreau, 1982 and SAEFL, 1994 in Zurbrügg, 2003a)

Moisture content
Moisture content is determined as follows: The sample is weighed as received ("wet weight") and then allowed to stand until it is air-dried, i. e. until its moisture content is equal to that of the ambient air. The moisture content is then obtained by the following formula:

$$Mc = \frac{W_w - W_d}{W_w} \times 100$$

where:
Mc = moisture content (in %)
W_w = wet weight of sample
W_d = dry weight of sample
(UNEP, 2005, p. 39)

Further questions
▸ What are the main processing methods of segregated organic wastes?

Additional info
▸ UNEP (2005). Solid Waste Management, CalRecovery Inc. www.unep.or.jp/Ietc/Publications/spc/Solid_Waste_Management/Vol_I/Binder1.pdf (last accessed 28.04.08):
Download available on the CD of Sandec's Training Tool and from the Internet.

3.1 What are the main storage, collection and transport options?

▶ **In developing countries, muscle-powered carts are feasible in most cases for primary transport and non-compactor trucks for secondary transport.**

Solid waste management facilities and equipment should be evaluated and appropriate technical solutions designed and selected, with careful attention to their operating characteristics, performance, maintenance requirements and expected life cycle costs. Technical evaluation requires data on waste composition and volumes, indications of important area-specific variations of waste generation and its expected changes over time, an understanding of the disposal habits and requirements of different user groups, as well as an assessment of the technical capability of public and/or private sector organisations responsible for operating and maintaining the systems.

The technical systems established for primary collection, storage, transport, treatment, and final disposal are often poorly suited to the operational requirements of the city. In many instances, the provision of imported equipment by international donors leads to the use of inappropriate technology and/or a diversity of equipment types, thus undermining the efficiency of operation and maintenance functions. (Schüberler et al., 1996, p. 47)

Some of the typical elements of a solid waste management system in developing countries (depicted in Figure 9) will be described in detail in the following subchapters.

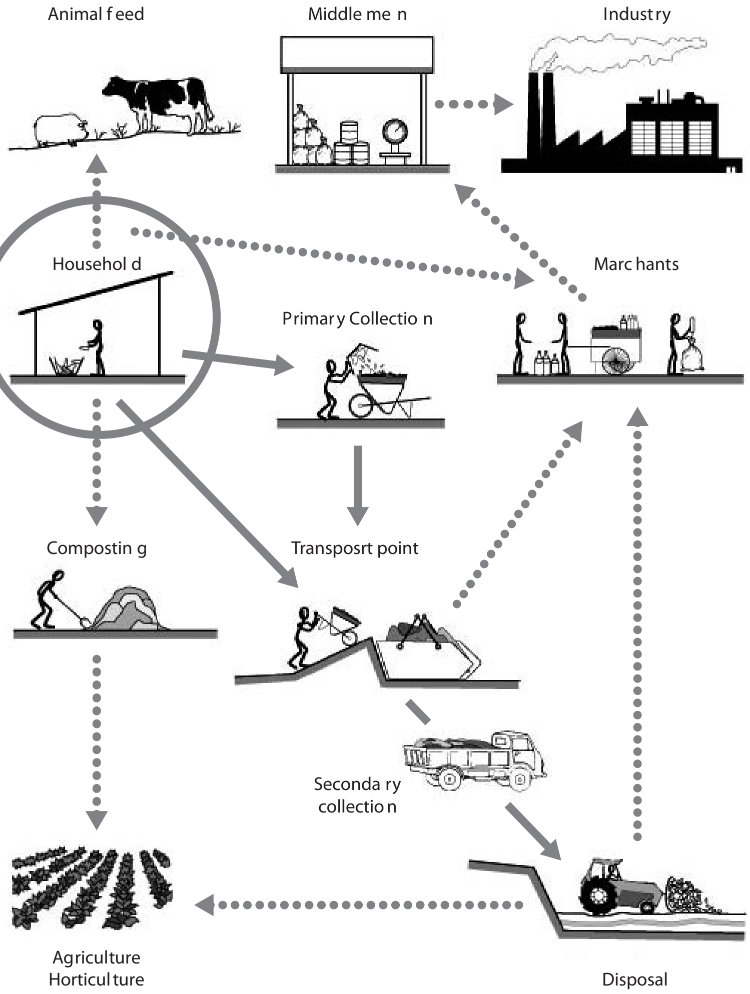

Figure 9: Typical main elements of a solid waste management system in low or middle-income countries, where recovery and recycling elements and processes are indicated by the dotted arrows. (Eawag/Sandec)

Primary storage and transport

Every MSWM system (except backyard composting or burying of the waste in one's own back yard) includes collection in some form or another.

Primary storage

Most collection systems depend on some kind of set-out container. In industrialised countries, this is usually a paper or plastic bag, or a metal or plastic garbage can. In developing countries or rural areas, set-out containers include bags, pots, plastic or paper bags, cane or reed baskets, concrete or brick vats, urns, boxes, clay jars, or any other kind of container available.

In some places, waste is stored in a pit in front of the house while awaiting collection. In other places, any type of container can be used to store or organise waste. Storage containers are often insufficient and waste is simply piled up or heaped in the street or on the ground to await collection. In places with community transfer, residents use bags or baskets for carrying waste to the containers. The increasingly available non-biodegradable plastic bags are becoming a problem for composting. Industrialised countries have developed special containers for certain recyclable materials.

The choice of set-out container has an important effect on collection effectiveness. Containers like baskets or paper bags allow waste to have contact with air, thus promoting decomposition while discouraging the formation of anaerobic odours. (UNEP-IETC et al., 1996, Chapter 1.3.2)

Communal collection

In communal collection – very common in developing countries – individuals bring their waste directly to the collection point, usually a container that can be accessed on foot. In a somewhat similar vein, some European cities require residents to take their wheeled containers to a specific location on the day of collection and retrieve them when emptied. Industrialised countries also use communal collection in rural areas, where most waste is brought by car, or separate collection of recyclables, household hazardous waste or specific materials such as leaves.

Communal collection is a particularly appropriate means of organising collection, where household collection is impossible or marginally feasible, where inadequate resources are allocated to poor areas, or where local customs promote it. The solid waste authority may choose to set up containers on street corners, at various spots along a densely populated road or at the edge of a neighbourhood accessible to both generators and collection vehicles.

An advantage of communal collection points for household waste drop-off is their more or less continuous access to disposal or materials recovery facilities. The disadvantages of communal collection are that such facilities may receive little attention from municipal authorities, and residents may deposit dangerous materials in or near the container.

Sound practice in communal collection design presupposes awareness of the inherent conflict between the physical demands imposed by public convenience in disposal and the strategies required to maintaining cleanliness and control waste pickers, odours, vectors, animals, flies, and other insects.

Sound practice also presupposes the availability of an adequate number of easy to use containers by the entire population, including the children. The responsible authority must carry out very frequent collection (often daily) and must be committed to cleaning up overflows. (UNEP-IETC et al., 1996, Chapter 1.3.2)

Primary transport

Muscle-powered carts, wagons and relatively small rickshaws pulled, pushed or foot-pedalled, bicycles or animals are important sound practice for MSW collection in many developing countries and rural hilly areas of transition countries. Compared to other means of transport, such vehicles are inexpensive and easy to build and maintain. In many cases, muscle-powered vehicles represent the soundest mix of capital, labour and available resources for waste or materials collection.

Small-scale collection can also be conducted by electric or propane-powered vehicles servicing a small or inaccessible area in combination with a larger "host" vehicle. Muscle-powered primary collection (or micro-collection) may be coupled with transfer into a larger "host" vehicle at the edge of the neighbourhood. This is sometimes done with street sweeping or materials recovery in industrialised countries. (UNEP-IETC et al., 1996, Chapter 1.3.2)

Muscle-powered or micro-mechanical vehicles work well:

- in densely populated areas of limited street access or unpaved roads;
- in squatter settlements;
- on hilly, wet or rough terrain; and
- with relatively small waste volumes from a relatively large number of densely populated housing units.

Muscle-powered vehicles exhibit the following disadvantages:

- use of animals or human power is perceived by some as old-fashioned or shameful;
- the vehicles have a limited travelling range and are generally slower than fuel-powered vehicles;
- animals pulling such vehicles leave waste, which must be cleaned up;
- weather exposure has a greater effect on humans and animals when they are not in motorised vehicles; and
- problems associated with animal characteristics, health etc.

Photo 3: Kerbside containers in Thailand. (Source: Eawag/Sandec)

Photo 4: Primary collection by wheelbarrow, Pakistan. (Source: Eawag/Sandec)

Secondary storage (transfer point) and collection

Transfer refers to the movement of waste or materials from the primary collection vehicle to a secondary, generally larger and more efficient, transport vehicle. While virtually all waste systems include collection, not all offer transfer.

The point of transfer is often referred to as "transfer station" or "transfer point". Primary collection vehicles bring their waste to a transfer station and dump it. It is then transferred, with or without compaction, to other vehicles for a longer haul to a disposal site. Transfer, which may include a short storage period, also provides a point of access to the waste or material stream and an opportunity to remove certain materials or perform processing, such as shredding, compacting, screening, wetting or drying.

Transfer stations are sound practice where i) vehicles servicing a collection route are required to travel a shorter distance, unload and quickly return to their primary task of collecting the waste; ii) in industrialised countries, and where waste from large urban areas in developing countries is disposed of in large, new landfills, incinerators and composting facilities, increasingly designed to serve a number of communities or an entire region and thus sited a considerable distance from the collection service areas. In theses circumstance, transfer stations can be very attractive, since transporting waste from the route to the facility takes longer and uses more fuel.

Transfer tractor-trailers or compacting trucks can carry larger MSW volumes than regular collection vehicles, thus allowing them to travel longer distances and carry more waste. This lowers fuel costs, increases labour productivity and saves on vehicle wear. Drawbacks of transfer stations include the additional capital costs of purchasing vehicles and building transfer stations, and the extra time, labour and energy needed to transfer waste from collection vehicles to transfer trailers.

Some developing countries have transfer stations similar to the type described above, including non-mechanised, local transfer points serving the special needs of particular collection service areas. A micro-collection vehicle, designed to service a hilly or a densely populated area with narrow or congested streets, can transfer its load to a larger vehicle or a stationary container at such a transfer point. This even allows to service collection areas that are inaccessible to a truck. Such transfer points may also degenerate into unregulated dumps in the absence of institutional commitment and managerial capacity to ensure their efficient operation. (UNEP-IETC et al., 1996, Chapter 1.3.3)

Photo 5: Transfer point in Indonesia. (Source: Eawag/Sandec)

Compactor trucks

In industrialised countries and cities, use of some type of compacting vehicle has become the standard sound practice of waste collection. A compactor truck:

- allows waste containers to be emptied into the vehicle from the rear, the front or the side;
- densely compacts the waste by hydraulic or mechanical pressure;
- quickly removes the waste from public view; and
- inhibits vectors and insects from accessing the waste during collection and transport.

The characteristics of compactor trucks include:

- high capital costs;
- sensitive hydraulic mechanisms, which must be well maintained in order to function; i.e. they can break down if an attempt is made to compact already dense waste;
- high fuel and operating costs;
- moderate operating skills; and
- at least two persons to operate the truck under most conditions.

(UNEP-IETC et al., 1996, Chapter 1.3.2)

Compactor trucks work well where:

- paved roads are wide enough to allow passage and turning;
- waste is set out in containers or bags for the crews to pick them up quickly; and
- density and moisture content of the waste is low.

Compactors work poorly where:

- the waste stream is either very dense or very wet, such as mixed waste in developing countries or newspapers in developed countries;
- the materials collected are source-separated organics or materials with a septic content; compaction tends to squeeze out the moisture and discharge it as leachate;
- collected materials are gritty or abrasive; and
- roads are very dusty.

Photo 6: Compactor truck in Vietnam. (Source: Eawag/Sandec)

Non-compactor trucks

Non-compactor trucks are more efficient and cost-effective than compactor vehicles in small cities and areas where waste tends to be very dense and has a limited potential for compaction. Use of lighter, more energy-efficient box-trucks, vans and dump trucks can be appropriate for sparsely populated areas, where distance is the main constraint to collection efficiency.

Non-compactor trucks used for waste collection usually require a dumping system to easily discharge the waste. Nevertheless, dump trucks with a high loading capacity may not offer the best choice for a non-compactor truck. Non-compactor trucks generally need to be covered to prevent residues from flying off the truck and/or rain from soaking the waste. (UNEP-IETC et al., 1996, Chapter 1.3.2)

Advantages of non-compactor trucks

Non-compactor trucks are a sound technical practice for solid waste collection where:

- the waste is generally very wet or dense;
- labour is relatively inexpensive compared to capital;
- highly skilled maintenance is scarce;
- collection routes are long and relatively sparsely populated;
- capital and operating costs are limited; and
- downtime for maintenance must be minimised.

Disadvantages of non-compactor trucks

The main problem associated with the use of non-compactor trucks is of political rather than technical nature:

- government officials, who attach a low status to non-compactor trucks, tend to see compactors as a means to modernise their waste collection system;
- salesmen recommend compactor trucks as the only means of appropriate waste transport. This may be true for industrialised countries, but certainly not for most developing countries; and
- donor agencies from industrialised countries tend to recommend collection equipment considered efficient in their own countries, and thus assume that compactor trucks make adequate use of the funds provided.

Further questions

▸ How can operational integration and reliability of technical systems be achieved despite diverse local collection needs, large number of different actors and decision-makers, as well as incremental development of facilities and equipment?

Additional info

▸ UNEP-IETC and HIID (1996): International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management. UNEP, International Environmental Technology Centre. www.unep.or.jp/ietc/ESTdir/pub/MSW/index.asp (last accessed 28.04.08)

Available from the Internet.

3.2 What are the major organic waste treatment options?

- **Composting is the main treatment option for organic waste.**
- **Biogasification and vermicomposting are gaining increasing recognition.**

Composting

Solid waste composting for use as a soil amendment, fertiliser or growth medium is of prime importance in many countries. Asian countries in particular have a long-standing tradition of making and using compost. In Western Europe, a range of modern technologies is applied to produce compost.

Nonetheless, composting is the waste management system with the highest failure rate worldwide. In cities of developing countries, most large mixed-waste composting plants, often designed and funded by foreign consultants, have failed or operate at less than 30 % capacity.

The most frequent problems cited for composting failures are: high operation and management costs, high transport costs, poor quality product as a result of poor pre-sorting (especially plastic and glass fragments), poor understanding of the composting process, and competition from chemical fertilisers (which are often subsidised). In many urban areas, collection systems are too unreliable for urban authorities to ever consider running composting facilities efficiently.

While many bio-waste composting facilities have failed, the majority of source-separated composting systems have succeeded. Yard, garden, restaurant, and market waste composting projects quietly thrive in every corner of the globe. The biological composting process is so basic that it is very likely to succeed if there is an appropriate input stream and proper handling. (UNEP-IETC et al., 1996, Chapter 1.4.1)

Although the composting process is similar in all areas of the world, industrialised, transition and developing countries reveal some practical differences. The main differences relate to the waste stream to be composted, the agricultural traditions associated with production and use of compost and the physical infrastructure of the built and natural environment. As regards composting, transition countries exhibit similar infrastructures as industrialised countries, however, their waste streams are comparable to those of developing countries. (UNEP-IETC et al., 1996, Chapter 1.4.2)

Composting Technologies

There are two fundamental types of composting techniques: open or windrow composting, a slower process conducted outdoors with simple equipment, and the enclosed system composting, where composting is performed in a building, tank, box, container or vessel. (Chapter adapted from: Dulac, 2001, p. 13 – 14)

In-vessel or enclosed systems. In-vessel systems, such as drum and agitated bed technologies or any technical system enclosed in a building, require complex equipment. These systems are highly engineered, capital-intensive and have to be managed on a daily basis, since their automated systems and design have to prevent potential health risks to workers and the environment. Their energy consumption is also substantial. Ongoing operation and maintenance is critical and less forgiving than more passive approaches, as they require access to specialised pieces of equipment, which generally have to be manufactured and delivered at a high price. The equipment may have been designed for specific climatic conditions and may not be applicable universally. They require less land and produce compost in a shorter time than open systems. Automated in-vessel systems cannot always meet the socio-economic conditions prevailing in different areas of the developing world (e. g. limited education and available institutional infrastructure support, labour rich/capital-poor economies). Their operating costs usually start at US$ 40 per ton, for the least expensive variant; more expensive systems can cost up to US$ 100 per ton.

Open or windrow systems. Open composting processes are simpler and require less capital and energy. They generally rely more on land and labour and less on machinery. They require far more land and longer periods to produce compost than enclosed systems. In the labour-rich and capital-poor cities of Eastern Europe and the South (where enclosed systems have a long history of failure), they are usually more reliable and adapted to local needs, and the local authorities are capable of sustaining operations over a longer time period. Operating costs range from US$ 5 to US$ 20 per ton, depending primarily on accessibility of the site and turning frequency.

Duration of composting

Composting is completed when the compostable materials have entirely turned into humus. Compost stability can be tested by re-wetting the material to see whether it heats up again, thus revealing still uncomposted materials in the pile. Most aerobic composting systems include a period of active composting, generally from 21 to 60 days, and a period of curing, generally from 6 to 24 months.

Composting can be accelerated by intensive aeration and inoculation of the piles with suitable bacteria. More land is required when the period of composting is longer, as the throughput of waste is slower. In places where land for siting is scarce, sound practice may entail selection of more intensive management practices instead of more extensive land use.

(UNEP-IETC et al., 1996, Chapter 1.4.2)

Kitchen waste composting versus animal feeding in a waste management system

There are many viable systems to feed kitchen waste to animals or to collect it for livestock feeding. In terms of the waste management hierarchy, this represents a higher use of kitchen waste than composting, as more nutrient value is productively used. (There are, however, considerable health risks in feeding waste to animals).

Whenever a compost system is being planned, it is important to evaluate the extent to which compostables are already being diverted to animal feed. Municipal authorities are sometimes unaware of these processes. If people need their kitchen waste for animals they are unlikely to cooperate with centralised composting systems. In developing countries, disruption or replacement of animal feeding systems with composting is generally not sound practice. (UNEP-IETC et al., 1996, Chapter 1.4.2)

Composting of mixed solid waste

Composting of mixed solid waste is a controversial issue. In industrialised and transition countries, the waste stream is generally too diverse and contains too many metals and plastics to allow mixed-waste composting to be considered sound practice. Technical approaches to mixed-waste composting have relied heavily on mechanical pre-processing and separation systems. These have generally failed to operate or to produce either a clean stream of compostables or marketable recyclables. In developing countries, the waste stream contains high levels of organic waste, as the main non-compostables are not thrown away but picked out prior to final disposal, thus resulting in a highly compostable waste stream. Composting it by low-cost technology can be considered sound practice, especially where urban and peri-urban agriculture provides a strong demand for the resulting compost. (UNEP-IETC et al., 1996, Chapter 1.4.2) However, waste separation at source (household level) is still preferable.

Siting and composting scale

Most compost systems require open land for establishing and handling compost piles. In many ways, the type of land and sites available dictate the choice of composting system. Sound practice in siting for facilities other than backyard bins includes:

- selection of a site with access adapted to the type of transportation;
- availability of a buffer area between the site and nearby land users to minimise waste nuisance and compost odours;
- appropriate soil for absorption or collection of leachate; and
- the possibility to place the compost indoors to protect it from unfavourable weather conditions or to buffer the surrounding environment.

(UNEP-IETC et al., 1996, Chapter 1.4.2)

Heat treatment

Heat is one of the most effective ways of killing pathogens and the parameter used to achieve inactivation in some of the most widely applied processes, such as sewage sludge treatment. In Figure 10, inactivation of pathogens is plotted as a function of temperature and time. This creates a defined "safety zone" margin. If the corresponding temperature-time relationship is achieved throughout the exposed material, it can be considered microbiologically safe for handling and use. For example, efficient microbial inactivation occurs if a temperature of > 55 °C is maintained for one to a few days. The time and temperature relationship for various pathogens have been widely accepted, though "new" pathogens have been identified and slight variations in the results have been observed.

To treat excreta, thermophilic digestion (50 °C for 14 days) or composting in aerated piles for one month at 55 – 60 °C (+ 2 – 4 months further maturation) are recommended and a generally accepted procedure. Recommendations for treatment of e. g. sewage sludge and organic household waste (food waste) also rely on such temperatures (Danish EPA, 1996; EC, 2000; Swedish EPA, 2002).

Haug (1993) states that composting at 55 – 60 °C for a day or two should be sufficient to kill essentially all pathogens. The cited regulations above rely on longer periods in order to provide a handling margin. It is common that cold zones are formed within the digested or compost material, resulting in local areas with less inactivation and possible regrowth of pathogenic bacteria. Digestion and composting also aim at degrading and stabilising organic material. For faeces, inactivation of pathogens is of key importance. A composting process will also decompose toilet paper, making the material more aesthetical and suitable for agricultural use.

(Schönning et al., 2004, p. 21 – 22)

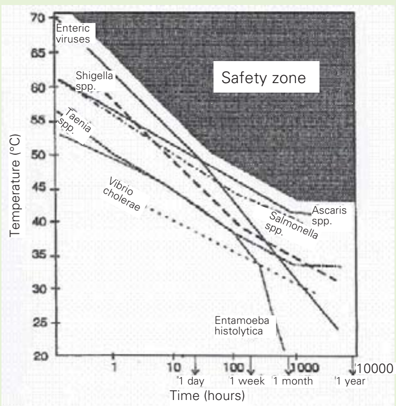

Figure 10: The "safety zone diagram". (Feachem et al., 1983)

Backyard composting

Backyard composting can be both an individual strategy for managing household kitchen and garden waste and a formal strategy for managing the organic waste stream in a region. Backyard composting is the smallest composting scale and offers a sound approach if:

- a significant number of households have individual or collective yards or gardens, and enough available space for a compost pile;
- composting is culturally accepted by most people; and
- the waste stream to be composted contains primarily vegetable matter, as rodents and insects are easier to control if animal matter is scarce.

(UNEP-IETC et al., 1996, Chapter 1.4.2)

Decentralised neighbourhood, block or business-scale composing

The next larger composting scale is the neighbourhood, block or business-scale composting site. Such facilities can provide a waste management opportunity to a small group of people at relatively low cost. Small-scale composting uses the waste of a number of households, shops or institutions. Sound practice for siting neighbourhood composting sites requires that they:

- be accessible to all who want to use them;
- be clearly designated with signs that all users and non-users can read or interpret;
- be sited with the agreement of the surrounding land users;
- have adequate fencing or control to prevent their becoming an open dump; and
- have appropriate soil to absorb leachate.

A compost monitor or supervisor should be elected from within the user community to maintain order and cleanliness. Sound practice generally requires the municipal authority to provide technical and logistical support for removal of undesired items or turning of the piles. (UNEP-IETC et al., 1996, Chapter 1.4.2)

Decentralised composting at village and community-scale

Composting is clearly sound practice for management of compostable waste streams at village or community-scale. Centralised composting of this type, whether privately or publicly developed, must fall under the jurisdiction of the municipal or community authorities, which accept responsibility for its operation. These facilities will generally be in the range of 2 to 50 tons per day, depending on the size of the community and volume of compostable materials in the waste stream.

Siting is important, and sound practice requires neighbourhood composting operations to follow the siting guidelines listed above. At this scale, the site may have to accommodate more compost turning, processing, screening, and storage than at smaller scales. (UNEP-IETC et al., 1996, Chapter 1.4.2)

Example of sound practice: The Jakarta composting experiments

Development of community-based composting in Jakarta is a good example of a sound composting practice in a developing country. Aid from Australia, Germany, the Netherlands, and New Zealand helped to initiate pilot projects in Jakarta in the 1980s. Later, the Harvard Institute for International Development (HIID) and the Centre for Policy Implementation Studies, supported by the Government of Indonesia and the Jakarta City government, worked on a model for operating small-scale, neighbourhood composting in Jakarta. Starting around 1992, several small composting enterprises were set up in Jakarta. The Jakarta experiments incorporated sound practice in small-scale composting in similar cities, while enhancing the role of the informal sector. The project trained individuals already involved in materials processing and taught them the basics of composting. A second element was compost market stimulation through training the intermediate buyers of recyclables to understand the physical and commercial properties of the compost. In the pilot project, measures were taken to protect the workers' health, however, it is uncertain if these precautions will be observed when and if private entrepreneurs take over the model and operate it as a business. Sound practice would be a follow-up of the pilot projects by creating the necessary urban infrastructure to facilitate more enterprises and monitor the labour conditions.

The Jakarta research project provides a good example of how cities can begin to examine possible sound practices in municipal solid waste composting. An assessment of small-scale, multi-source composting projects in Jakarta and Bandung in 1994, suggested that such composting can achieve important waste reductions and contribute to improving the neighbourhood environment. Good management and market research as well as a consistent institutional support system are essential for the lasting success of such projects.

(UNEP-IETC et al., 1996, Chapter 1.4.4)

Centralised composting at the municipal scale

In centralised composting of waste from multiple sources, the waste is transported from several points to a facility capable of receiving 10 to 200 tons per day.

Municipal-scale composting plants receive waste from a single jurisdiction, usually a city, including occasionally associated suburbs or squatter settlements. Differences in scale, management, financing, and siting distinguish municipal-scale, centralised plants from regional facilities. At this scale, sound practice for siting the compost facility in industrialised countries must usually be a formal process that includes:

- a technical assessment of the area, soil and geographic attributes of potential sites;
- the involvement of engineering and design professionals in site selection and design;
- an environmental assessment of potential sites, a formal evaluation and selection process to involve all stakeholders;
- a formal remediation or compensation programme to minimise and/or compensate for nuisance from traffic, odour, leachate, and noise at the composting site;
- a separate collection and/or preprocessing system to ensure that only desired materials actually enter the composting system, and appropriate attention to the role of waste pickers or the informal sector in pre-processing and recovery of non-compostables; and
- a formal system for using and/or marketing the finished compost.

In addition to the siting and design requirements cited above, sound practice for regional-scale composting includes:

- a siting process that takes into account the equity effects of siting a compost plant for several jurisdictions within the boundaries of one of them. A frequent strategy here is to distribute the sites for landfill, compost plant and incinerator (if part of the system) among the different municipalities.
- agreements between the participating municipalities or jurisdictions for siting, design, financing, operations, maintenance, environmental compliance, and billing for services;
- enforceable protocols for the quality and composition of the compostable materials delivered to the facility, since failure of separation from any one source can contaminate the compost for all participating jurisdictions;
- agreements between the jurisdictions for use, take-back and marketing of the finished compost;
- waste delivery agreements and commitments from the various participating jurisdictions; and
- designated routes for delivery of compostables.

(UNEP-IETC et al., 1996, Chapter 1.4.2)

Composting at landfill and incineration sites

Composting facilities may be located at landfill sites, particularly in developing countries, but increasingly also in industrialised countries. This allows separate collection of organics or yard waste to be processed at the landfill. Siting is simplified or rolled into the landfill siting process. Here, sound practice differs in industrialised and developing countries. In industrialised countries, sound practice will usually require the composting operations to be separate from the landfill, have their own scale or separate entrance, and resulting compost to be split between a low-quality product used in landfill operations as daily and final cover, and a high-quality used for other purposes.

In developing countries, where the waste stream has a sufficiently high organic fraction, waste may be left to decompose at the landfill or dump. In cases of natural composting, sound practice requires clear decisions about the role of decomposition processes in landfill management, whether or not remove the top layers of material once partially decomposed, for further composting or use in agriculture, and whether farmers should be allowed to remove compost from the landfill or dump. (UNEP-IETC et al., 1996, Chapter 1.4.2)

Major composting factors to be considered

- Siting: Compost facilities must be reasonably close to the input stream and potential users should meet the needs of the nearby community.
- Input stream: Source-separated organics are best. However, in most developing countries, this is not always possible. Mixed waste can be processed to yield acceptable compost.
- Selection of appropriate technology: The technology chosen must be adequate for the input stream and level of economic development of the country.
- Scale: A smaller-scale facility often facilitates careful composting and formation of a good product.
- Market development: Governments generally need to stimulate the compost market. Quality standards are an important marketing element.
- Existing compost practices using compost from dumps and garbage dump farming: These traditional activities, while often dangerous could, in some instances, be safe if they include an adequate testing programme.

Vermicomposting

Vermicomposting, also called vermiculture or worm composting, is a relatively cool but aerobic composting process in which certain varieties of redworms and earthworms can be used to break down organic materials. Worms mechanically break down compostables and partially decomposed materials by eating them, and biochemical decomposition occurs via bacteria and chemicals in the worms' digestive system.

Vermiculture requires considerable labour and carefully controlled composting conditions, including temperature, moisture and the mix of ingredients. Its success to date is limited to relatively small-scale or pilot programmes. The use of vermicomposting in centralised or village-scale composting systems is currently being explored in pilot projects. Considerable work was conducted in Manila in the 1970s; however, the markets for the resulting worm castings did not develop.

Vermiculture can be carried out by small-scale enterprises in a cottage--industry manner. Since worms are easily affected by impurities, the organic waste should be source-separated domestic or market waste.

Vermiculture produces a superior fertiliser-type product. However, the available information is not enough to indicate whether sufficient markets exist to absorb worm castings on a scale that would significantly contribute to municipal waste reduction. Since vermiculture does not necessarily kill all pathogens, some viruses and parasites may survive the process. Therefore, if the input materials present a high pathogen risk, the finished product could still contain pathogens. This may be of particular concern in developing countries, where waste used in vermicomposting may not be source-separated. (UNEP-IETC et al., 1996, Chapter 1.4.2)

Black Soldier Flies

Sandec is evaluating a new technology in a simple facility promising to combine waste treatment and the generation of a valuable (by-)product, i.e. an organism feeding on waste itself. The life cycle (cf. Fig. 11) of the non-pest Black Soldier Fly, *Hermetia illucens* fits this purpose extremely well.

The larvae voraciously feed on organic material and reduce its dry mass by 40 – 50 %. This figure is similar to the reduction achieved by composting or biogas digestion units. However, it is not only the ability to reduce waste that makes the Black Soldier Fly a promising waste manager. After the larvae have fed extensively on waste, the last larval stage or so-called prepupae crawl out of the waste in search of a dry pupation site. This migration stage may be used to harvest the prepupae by simply channelling their migratory paths into a collection vessel.

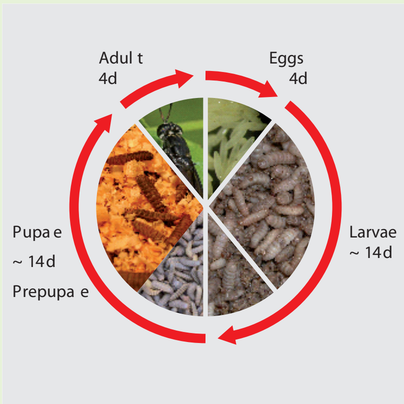

Figure 11: Life cycle of the Black Soldier Fly, *Hermetia illucens* at 25 °C

In this prepupae life stage, their bodies are rich in protein and fat, thus making them an excellent component of animal feed for aquaculture or poultry production. Feeding experiments in aquaculture that replace fishmeal by larvae meal revealed highly promising results (Bondari and Sheppard, 1981; St-Hilaire et al., 2007). Such feedstuff of animal origin also becomes a very attractive and urgently needed alternative to the rapid and increasing global role of aquaculture and its ecologically and economically questionable demand for fishmeal, currently reflected by a steady increase in market prices. Given this situation, waste management processes using the Black Soldier Fly larvae may not only become a self-sustained waste treatment option, but also a profitable and flourishing business.

(Diener et al., 2008)

Biogasification

Biogas is produced by bacteria biodegrading organic matter under anaerobic conditions. The natural generation of biogas is a key component of the biogeochemical carbon cycle. Methanogens (methane producing bacteria) are the last link in a chain of microorganisms degrading organic material and returning the decomposition products to the environment. Biogas – a source of renewable energy – is generated in this process.

Biogas is a mixture of gases mainly composed of:
- Methane (CH_4): 40 – 70 vol.%
- Carbon dioxide (CO_2): 30 – 60 vol.%
- Other gases: 1 – 5 vol.%

The calorific value of biogas is approximately 6 kWh/m³ and equivalent to about half a litre of diesel oil. The net calorific value depends on the efficiency of the burners or appliances. Methane is the valuable component of biogas when used as a fuel. (ISAT et al., p. 4 – 5)

"Methane fermentation", "methane production" and "anaerobic digestion" are among the terms frequently used to designate biogasification. Here, biogasification is defined as the decomposition of organic matter of biological origin under anaerobic conditions with an accompanying production primarily of methane (CH_4) and secondarily of other gases, mainly carbon dioxide (CO_2). (UNEP, 2005, p. 259)

Every year, some 590 – 880 million tons of methane are released worldwide into the atmosphere by microbial activity. About 90 % of the emitted methane are derived from biogenic sources, i.e. from the decomposition of biomass. The remainder is of fossil origin, such as petrochemical processes. (ISAT et al., p. 4). As indicated in Table 5, methane acts as a strong greenhouse gas.

Anaerobic digestion (AD) or biomethanation of organic solid waste is considered a promising treatment option to digest waste. This process is already widespread in industrialised countries and is gaining increased importance given the growing demand for renewable energy and high market prices for fuel. In low and middle-income countries, AD is currently common mainly in rural areas, with livestock manure as major feedstock. However, accessible knowledge and information on technical and operational feasibility, challenges and opportunities are limited as regards urban or peri-urban settings where predominantly organic solid waste is available as feedstock. Nevertheless, in South India, numerous biogas plants treating kitchen and market waste have already been in operation for a few years. (Vögeli et al., 2008)

ARTI

The ARTI compact biogas plant, developed in India, is a small, household system designed to treat 1 – 2 kg of food waste per day. This already widespread system in South India is now also being promoted in Tanzania and Uganda.

Photo 7: ARTI biogas plant in Dar es Salaam. (Source: Eawag/Sandec)

Although it is considered a successful approach, data on its performance in Africa is rather scarce yet. More information will be needed to acquire a better assessment of this treatment option. Monitoring of an ARTI biogas plant at household level and experiments at the Ardhi University of Dar es Salaam shall provide reliable data on daily gas production, gas composition, effluent quality, suitability of this technology for different feedstock, and operating convenience. This project was launched in July 2008 in collaboration with the Ardhi University of Dar es Salaam and the University of Applied Sciences in Zurich. (Vögeli et al., 2008)

	Global Warming Potential (GWP) for Given Time Horizons		
	20-yr	100-yr	500-yr
Carbon dioxide	1	1	1
Methane	72	25	7.6

Table 5: Comparison of global warming potentials of CH_4 and CO_2 (GWP of CH_4 includes indirect effects caused by enhanced ozone and stratospheric water vapour). (IPCC, 2007)

Advantages of the biogas technology

Well-functioning biogas systems can yield a wide range of benefits for their users, society and the environment in general:
- production of energy (heat, light, electricity);
- transformation of organic waste into a high quality fertiliser;
- improvement of hygienic conditions through reduction of pathogens, worm eggs and flies;
- reduction of workload, mainly for women, in firewood collection and cooking;
- environmental advantages through protection of soil, water, air, and woody vegetation;
- micro-economical benefits through energy and fertiliser substitution, additional sources of income and increasing yields from animal husbandry and agriculture;
- macro-economical benefits through decentralised energy generation, import substitution and environmental protection.

(ISAT et al., p. 5)

Biogasification process

The process of biogasification can be divided into three steps. The overall process rests on the maintenance of a relatively critical balance between the respective activities of the three stages. An imbalance reduces the efficiency of the overall process and may lead to the complete standstill of all microbial activity when no methane production occurs. Immediately after its initiation, the sequence of readily observable reactions in a continuous culture is a gradual decline in pH level (the acid stage), followed by a similarly gradual rise in pH level, and eventually by the production of a methane-rich gas (the methane production stage). (UNEP, 2005, p. 260 – 261)

Parameters and process optimisation

The metabolic activity involved in microbiological methanation is dependent on the following factors:

- Substrate temperature
- Available nutrients
- Retention time (flow-through time)
- pH level
- Nitrogen inhibition and C:N ratio
- Substrate solid content and agitation
- Inhibitory factors

Each of the various types of bacteria responsible for the three stages of methanogenesis is affected differently by the above parameters. Due to the interactive effects between the various determining factors, accurate quantitative data on gas production as a function of the above factors is not available. (ISAT et al., p. 11)

Substrate temperature. Anaerobic fermentation is in principle possible between 3 °C and approximately 70 °C. Differentiation is generally made between three temperature ranges:

- the psychrophilic temperature lies below 20 °C,
- the mesophilic temperature ranges between 20 °C and 40 °C and
- the thermophilic temperature lies above 40 °C.

The rate of bacteriological methane production increases with temperature. In general, unheated biogas plants perform satisfactorily only where mean annual temperatures are around 20 °C or above, or where the average daily temperature is at least 18 °C. Within the range of 20 – 28 °C mean temperatures, gas production increases over-proportionally. If the temperature of the biomass is below 15 °C, gas production will be so low that biogas production is no longer economical.

The process of biomethanation is very sensitive to temperature fluctuations. The degree of sensitivity is, in turn, dependent on the temperature range. Brief fluctuations not exceeding the following limits may be regarded as still un-inhibitory with respect to the process of fermentation:

- psychrophilic range: ± 2 °C/h
- mesophilic range: ± 1 °C/h
- thermophilic range: ± 0.5 °C/h

Temperature fluctuations between day and night are no great problem for plants built underground, since the temperature of the earth below a depth of one meter is practically constant. (ISAT et al., p. 11)

Retention time. For continuous systems, the mean retention time is approximated by dividing the digester volume with the daily influent rate. Effective retention time may vary widely for the individual substrate constituents, depending on vessel geometry, type of mixing procedure etc. Selection of a suitable retention time thus depends not only on the process temperature, but also on the type of substrate used.

The following approximate values apply to liquid manure undergoing fermentation in the mesophilic temperature range:

- liquid cow manure: 20 – 30 days
- liquid pig manure: 15 – 25 days
- liquid chicken manure: 20 – 40 days
- animal manure mixed with plant material: 50 – 80 days

If retention time is too short, the bacteria in the digester are "washed out" faster than they can reproduce, and fermentation practically comes to a standstill. This problem rarely occurs in agricultural biogas systems. (ISAT et al., p. 12)

pH value. The methane-producing bacteria live best under neutral to slightly alkaline conditions. Once the process of fermentation has stabilised under anaerobic conditions, the pH will normally range between 7 and 8.5. Due to the buffer effect of carbon dioxide-bicarbonate (CO_2 - HCO_3^-) and ammonia-ammonium (NH_3 - NH_4^+), the pH level is rarely taken as a measure of substrate acids and/or potential biogas yield. A digester containing a high volatile-acid concentration requires a somewhat higher-than-normal pH value. If the pH value drops below 6.2, the medium will have a toxic effect on the methanogenic bacteria. (ISAT et al., p. 12)

Nitrogen inhibition and C:N ratio. All substrates contain nitrogen. For higher pH values, even a relatively low nitrogen concentration may inhibit the process of fermentation. Noticeable inhibition occurs at a nitrogen concentration of roughly 1700 mg ammonium-nitrogen (NH_4-N) per litre substrate. Nonetheless, given

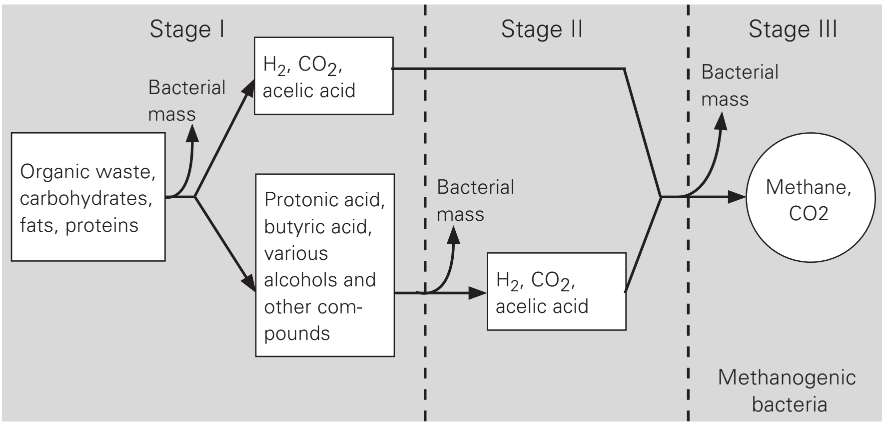

Figure 12: The three-stage anaerobic fermentation of biomass. (ISAT et al.)

enough time, the methanogens are capable of adapting to NH_4-N concentrations in the range of 5000 – 7000 mg/l substrate, the main prerequisite being that the ammonia level (NH_3) does not exceed 200 – 300 mg NH_3-N per litre substrate. The rate of ammonia dissociation in water depends on the process temperature and pH value of the substrate slurry.

Microorganisms need both nitrogen and carbon for assimilation into their cell structures. Various experiments have shown that the metabolic activity of methanogenic bacteria can be optimised at an approximately 8 – 20 C:N ratio, whereby the optimum point varies from case to case, depending on the nature of the substrate. (ISAT et al., p. 12 – 14)

Substrate solids agitation. Many substrates and various modes of fermentation require some sort of substrate agitation or mixing in order to maintain process stability within the digester. The most important objectives of agitation are:

- removal of the metabolites produced by the methanogens (gas)
- mixing of fresh substrate and bacterial population (inoculation)
- preclusion of scum formation and sedimentation
- avoidance of pronounced temperature gradients within the digester
- provision of a uniform bacterial population density
- prevention of the formation of dead spaces that would reduce the effective digester volume.

(ISAT et al., p. 14)

Inhibitory factors. The presence of heavy metals, antibiotics (Bacitracin, Flavomycin, Lasalocid, Monensin, Spiramycin etc.) and detergents used in livestock husbandry can have an inhibitory effect on the process of biomethanation. (ISAT et al., p. 14)

Further questions

▸ What are the consequences of land-spreading untreated organic waste?

Additional info

▸ UNEP-IETC and HIID (1996): International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management. UNEP, International Environmental Technology Centre. www.unep.or.jp/ietc/ESTdir/pub/MSW/index.asp (last accessed 28.04.08)

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▸ Rothenberger, S., Zurbrügg, C., Sinha, M., Enayetullah, I.(2006): Decentralised Composting for Cities of Low and Middle-Income Countries. A Users' Manual. Eawag/Sandec. www.eawag.ch/organisation/abteilungen/sandec/publikationen/publications_swm/downloads_swm/decomp_Handbook_loRes.pdf (last accessed 28.04.08)

▸ ISAT and GTZ: Biogas Digest. www.gtz.de/de/dokumente/en-biogas-volume1.pdf (last accessed 28.04.08)

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3.3 What are the recycling options for non-organic waste?

▸ **While sophisticated waste processing units reclaim large amounts of MSW in industrialised countries, it is the informal sector in the DCs that sorts out waste and sells the recovered materials to vendors and specialised recycling units.**

Using recycled plastics in road construction

Reusing plastic waste to pave roads is an experiment that has been successfully conducted in many places, such as Kalamassery in Kerala, in Kolkata and Bangalore. The first technology approach, developed by Bangalore-based K K Plastic Waste Management Limited, entails the use of plastic waste along with bitumen - the conventional ingredient to pave roads. Not only does the road become a receptacle for plastic waste, but it also has a better grip.

The process

The plastic waste products (bags, cups and so forth) made out of polyethylene, polypropylene and polystyrene are separated, cleaned if necessary, and shredded into small pieces to allow their passage through a 4.35-millimetre sieve. The aggregate (granite) is heated to 170 °C in the mini hot-mix plant; the shredded plastic waste subsequently added softens and coats the aggregate. The hot bitumen (160 °C) is directly added and mixed well. As the polymer and bitumen are molten, they mix and the blend coats the surface of the aggregate. The mixture is transferred to the road for paving.

(Zhu et al., 2007)

Public interest in recycling has increased dramatically over the last 15 years throughout the industrialised world, and is presently gaining ground in developing countries. This interest has been driven in the developed economies by a variety of factors, including concerns about increasing waste generation, dwindling landfill capacity, air pollution from incineration, and a general appreciation of the need for environmental protection. In response, a wide array of policies, regulations and programmes have been implemented. These include changing the requirements for recycling in households and businesses, banning recyclables from being landfilled, creating deposit-refund programmes and financial incentives for source separation and waste reduction. Other policies have been designed to stimulate the demand for recycled materials. These include guidelines for buying recycled products, requirements for a minimum recycled content and tax incentives for products with recycled content.

In some countries, comprehensive extended producer responsibility (EPR) frameworks have been introduced to target both supply and demand. EPR policies shift the responsibility for meeting government-specified recycling targets to the industries that produce the recyclables. Governments are also increasingly encouraging industries to adopt environmental management systems (EMS). These holistically address waste generation through source reduction, reuse and recycling. (Abubakar et al., 2006, p. 6)

In developing countries, recycling inorganic materials from municipal solid waste is often a well-developed activity performed by the informal sector, although such activities are seldom recognised, supported or promoted by the municipal authorities. Some of the key factors affecting the potential for resource recovery comprise the cost of the separated materials, their purity, quantity, and location. Storage and transport costs are major factors governing the economic potential of resource recovery.

In many low-income countries, the fraction of materials extracted for resource recovery is extremely high, the work very labour-intensive and the income very low. In such situations, creation of employment is the main economic benefit of resource recovery. The conditions in industrialised countries are totally different, as resource recovery is conducted by the formal sector within a legal framework and with a general public concern for the environment and generally high costs. (Zurbrügg, 2002, p. 23)

Solid waste recycling is an ancient practice. In prehistoric times, the metal fraction was melted and recast. Recyclable materials are currently recovered from municipal refuse by various methods, including shredding, magnetic separation of metals, air classification that separates light from heavy fractions, screening, and washing. Another method of recovery in industrialised countries is the wet pulping process: Incoming refuse is mixed with water and ground into slurry in the wet pulper resembling a large kitchen disposal unit. Large pieces of metal and other non-pulpable materials are pulled out by a magnetic device before loading the slurry from the pulper into a centrifuge, the so-called liquid cyclone. Here, the heavier non-combustibles, such as glass, metals and ceramics are separated out and sent on to a glass and metal-recovery system; other, lighter materials go to a paper fibre recovery system. The final residue is either incinerated or used as landfill. (Abubakar et al., 2006, p. 6)

Further questions

▸ Is full cost-recovery of solid waste management possible through recycling?

Additional info

▸ Abubakar, E. and Bello, M. (2006): Municipal Solid Waste Management: Options for Developing Countries, IPAC Technical Meeting. EEMS Limited, Kaduna, Nigeria. www.eemslimited.com/issues/msw_options.pdf (last accessed 28.04.08)

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3.4 What are the final disposal options and how are they characterised?

▶ **Landfilling is the most common option for final disposal worldwide. In ICs, a significant fraction of MSW is incinerated and part of its energetic value thus reclaimed in the form of heat and electricity.**

Incineration

The primary benefit of MSW incineration is a significant reduction in weight (up to 75 %) and volume (up to 90 %), which can be valuable if landfill space is limited. Generation of revenues from energy production, known as waste-to-energy incineration, can also partially offset the cost of incineration; although typically less expensive forms of energy production are available. Incineration breaks down some hazardous, non-metallic organic waste and destroys bacteria and viruses, which is the main benefit of medical waste incineration. If the MSW incineration option is considered, decision-makers must weigh the benefits of incineration against the significant capital and operating costs, potential environmental impacts and technical difficulties of operating an incinerator. (UNEP-IETC et al., 1996, Chapter 1.5.1)

MSW incineration is typically only cost-effective in regions where suitable landfill space is scarce. Such landfill scarcity can arise due to geographic constraints, as with a highly urbanised region or island, or due to environmental conditions, as in regions with a high water table. Jurisdictional and political boundaries can also constrain the size and number of sites available for landfilling, thereby increasing the attractiveness of incineration.

Some factors currently make incineration difficult or not advisable in many developing countries, i.e. high capital and operating costs in relation to national income levels and the comparatively low cost of sanitary landfilling. Due to its high moisture and low energy content, it is difficult to incinerate waste in many developing countries. Moreover, the technical infrastructure required to maintaining incineration facilities, including their pollution control equipment, is generally not yet available in developing countries. The frequently lacking infrastructural elements include highly trained personnel, regular availability of technologically advanced testing and repair facilities and a well-functioning system to ensure the readily available spare parts. (UNEP-IETC et al., 1996, Chapter 1.5.1)

For environmentally sound incineration, air pollution control equipment must be serviced regularly by highly specialised personnel. Monitoring equipment is costly and requires thorough maintenance and servicing by trained technicians. In summary, incineration is expensive if conducted in a sustainable manner with low adverse health and environmental risks. If poorly conducted (with low financial costs), it can become expensive in terms of human health and environmental impacts.

Some countries, which have emerged from developing country status, are definitely able to incinerate their waste. Singapore operates three MSW incinerators handling about 90 % of the MSW generated. South Korea also operates numerous incinerators. MSW incineration is also being considered in Bangkok, where three incineration plants located at landfills are already in operation, primarily to incinerate hazardous waste.

Pilot projects, supported by bilateral or international aid or joint ventures with foreign companies, may make such initiatives more feasible as they can make foreign capital and technology training available in developing countries. (UNEP-IETC et al., 1996, Chapter 1.5.1)

Factors influencing technology choice
MSW incineration may offer a sound practice only in situations where most or all of the following conditions apply:

- suitable landfill space is scarce, making incineration a cost-effective alternative;
- the necessary environmental protection measures are properly installed and maintained;
- the facility is adequately sized and sited to fit the other components of the MSWM system;
- the materials to be burned are combustible and have sufficient energy content; and
- energy markets are available nearby.

(UNEP-IETC et al., 1996, Chapter 1.5.1)

Use of energy

In waste-to-energy plants, heat from the burning waste is absorbed by water in the wall of the furnace chamber or in separate boilers. Water is heated to the boiling point and is converted to steam. At that point, either the steam is used for heating or to turn turbines to generate electricity. The amount of energy recovered from waste is calculated as a function of the amount of waste combusted, of the energy value of the waste stream and efficiency of the combustion process. About one-fifth of the electricity produced in incineration facilities is used at the facilities for general operations. The remaining electricity is sold to public and private utilities or nearby industries. In many countries, utilities provide a stable market for electricity generated from incinerators. The availability of purchasing electricity and its sales rates will, however, vary according to region. (UNEP-IETC et al., 1996, Chapter 1.5.3)

Environmental impacts

Potential pollution emissions into the air through exhaust stacks and into water through ash leachate are the main environmental risks of MSW incinerators. Proper planning to minimise environmental damage, as well as public education and involvement directly addressing these issues, are essential to successful incineration programmes. The combustion of any substance will generate by-product emissions likely to be released into the air. The following air emissions are usually associated with incinerators: metals, especially mercury, lead and cadmium; organics, such as dioxins and furans; acid gases, such as sulphur dioxide and hydrogen chloride; particulate matter, such as dust and grit; nitrogen oxides (which are ozone precursors); and other substances, such as carbon monoxide.

People can be exposed to emissions directly by inhaling contaminated air or through skin contact with contaminated soil and dust. Exposure can also occur indirectly by eating foods contaminated by these substances. Aside from human health risks, plants and animals may also be adversely affected by emissions from incinerators. The ultimate effects are dependent on contaminant concentrations of the emissions, type of environmental control measures adopted, height of the emission stack, location of the facility, and prevailing weather and geographic conditions.

A related contamination concern is associated with the area close to the incinerator, i. e. below its emission plume. All pollutants likely to escape will reach the ground closest to the incinerator. It is therefore particularly important to site an incinerator in an area as isolated as possible. In general, industrial areas make more sense than other areas as their contamination levels may already have induced the taking of precautions.

However, adequate control of air emissions requires further pollution control measures. MSW incinerators must be well-operated and well-maintained to ensure the lowest possible emissions. Good combustion practice, such as ensuring optimal levels of temperature in the combustion chamber and residence time of the MSW remaining in the combustion chamber, can lower emission levels. Major variations in these or other incineration operations could lead to a limited but significant output of contaminated air emissions.

Major technical requirements are among the obstacles to incineration in most developing countries.

Incinerator ash may contain concentrations of heavy metals, such as lead, cadmium, mercury, arsenic, copper, and zinc released by plastics; coloured printing inks, batteries, certain rubber products, and hazardous waste from households and small industrial generators. Organic compounds such as dioxins and furans have also been detected in incinerator ash.

Since incinerator ash is generally disposed of in an MSW landfill, the environmental pollution control measures typically adapted for sustainable sanitary landfill operations (e. g. liners and leachate collection/treatment) become all the more important.

Ash can be stabilised and solidified by encasing it in concrete prior to disposal, thereby reducing significantly the migrating potential of the contaminant. Some also advocate managing fly ash and bottom ash separately, with additional stabilisation of the fly ash through vitrification or pyrolysis, as fly ash can contain higher metal concentrations. In addition to landfilling, incinerator ash has been used in the production of road bedding, concrete, brick, cinder block, and curbing. These uses are controversial as leachates may contain toxic constituents of these materials.

Most heavy metals (e. g. mercury, cadmium and lead) originate from items commonly found in MSW, such as household batteries, thermostats, fluorescent lamps, plastics, and solder-bearing items (e. g. consumer electronics, light bulb sockets and plated metals). Removing these items from the waste stream, at household, commercial and industrial levels, may therefore lead to a significant reduction in the metals found in incinerator ash. (UNEP-IETC et al., 1996, Chapter 1.5.4)

Landfills

All definitions of "sanitary landfill" call for the isolation of the landfilled waste from the environment until it is rendered innocuous through natural biological, chemical and physical processes. The major differences between the various definitions reside in the degree of isolation, means of accomplishing it, monitoring prerequisites, and closing or maintaining the landfill after its active life. In industrialised nations, a far greater degree of isolation is usually required than actually needed in developing nations. This is not surprising as the means to attain a high degree of isolation in developing nations are complex and expensive.

A disposal site must meet the following three general but basic conditions to qualify as a sanitary landfill:

1. waste compaction;
2. daily covering of the waste (with soil or other material) to protect it from environmental influences; and
3. control and prevention of negative impacts on public health and the environment (e. g. odours, contaminated water supplies etc.).

However, the meeting of all the specific conditions may be technologically and economically impractical in many developing countries. Therefore, the short-term goal should be to comply as far as possible with the more important conditions under the existing set of technical and financial circumstances. The long-term goal is to eventually meet all the specific requirements related to design and operating conditions. Only then can all the benefits associated with a sanitary landfill be yielded. Prevention of negative impacts on public health and the environment is the most important prerequisite. (UNEP, 2005, p. 323 – 324)

A landfill is a vital component of any well-designed MSWM system. It is the ultimate repository of a city's MSW after all other MSWM options have been exhausted. In many cases, the landfill is the only option available after MSW is collected. Safe and effective landfill operation depends on the sound planning, administration and management of the entire MSWM system. This begins with an institutional and environmental policy that views MSWM as an important component in the sustainable development plans of a city and country. It continues with the implementation of MSWM regulations designed to protect human health and the environment, and with the funding driven by the needs of the system rather than by political expediency. It ends with the coordination of MSWM programmes to consolidate waste reduction and resource recovery through collection, transfer and ultimate disposal into an integrated system. This system must provide a vital public service without compromising human health or the environment.

Landfill types range from uncontrolled open dumps to sound sanitary landfills. (UNEP-IETC et al., 1996, Chapter 6.1)

Left unmanaged and uncontrolled, solid waste openly dumped on land:

1. generates liquid and gaseous emissions (leachate and landfill gas) likely to pollute the environment; and
2. presents a breeding ground for disease-carrying animals and micro-organisms.

Uncontrolled land disposal of solid waste also leads to other public health, safety and environmental risks. (UNEP, 2005, p. 323)

Landfills: Land and volume requirements

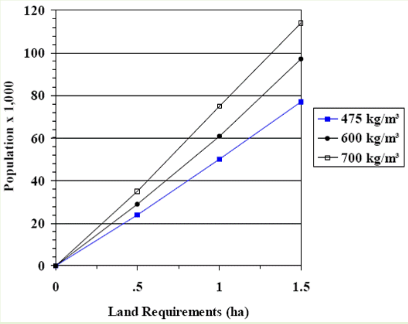

Figure 13: Land requirements for a landfill as a function of waste compaction.

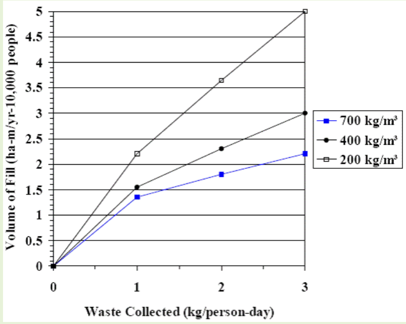

Figure 14: Relationship between bulk waste density and required landfill volume.

(UNEP, 2005, p. 332)

Open dumps and the need to upgrade them

Open dumps are common in developing countries as their initial costs are low and they do not require expertise or equipment. However, remediation costs of these sites can easily exceed their total lifetime capital and operating costs. Contaminated groundwater may never be returned to its usable condition, and other environmental impacts may take several decades to be restored. The numerous birds that feed on the waste in open dumps could represent more serious disease vectors than flies or rodents.

The practice of open dumping is a dilemma for the poorer and smaller cities and towns of developing countries, and is certainly not sound practice. (Note however, in very poor countries, where cities are located near deserts (e. g. North Africa and the Middle East), unimproved open dumps may conceivably be considered sound if the savings from not upgrading dumps are used to improve the collection service.) Managers are often told to close open dumps and construct controlled landfills. As a consequence of inadequate technical and managerial resources, solid waste managers attempt in many places to improve open dumping practices and gradually upgrade the sites.

A number of countries have acquired considerable experience with such low-cost upgrading methods. Solid waste departments can rent the heavy equipment necessary to improve the infrastructure and grading of the dump or can subcontract this work to a private engineering firm. The initial upgrading step consists in constructing perimeter drains to collect the run-off and leachates, the site should then be graded to minimise leaching through the waste. Machines can be rented about every two months to regularly adjust the grading, construct trenches for the deposit of waste (if necessary) and dig up cover material. Maintaining the grading and applying cover material can subsequently be conducted manually by municipal workers. In some cases, a provincial ministry acquires the necessary earthmoving equipment, which is then rotated among the dumps of the jurisdiction. In places where equipment is acquired by the authority operating the dump, such equipment should be kept as simple as possible to make operation and maintenance feasible. It is important to prove to municipal engineers that improvements can be made to open dumps with little capital outlay and additional costs. (UNEP-IETC et al., 1996, Chapter 6.3)

Non-landfill disposal

Some countries, including China, have a long-standing tradition of disposing garbage directly onto farmland. Farmers seek the nutrient value of the organic portion of the waste as long as it contains little plastic, glass or metal. This is a hazardous practice, since uncomposted organic waste contains pathogens. Regulations in China require farmers to compost the waste first, however, these regulations are often not complied with.

Finally, some municipalities dispose their MSW at sea, on land near the ocean or on riverbanks, though many industrialised and developing countries have banned these practices. In general, these practices cannot be considered environmentally sustainable. (UNEP-IETC et al., 1996, Chapter 6.5)

Further questions

▸ To what extent should public subsidies be used to promote environmentally safe waste disposal in landfills?

Additional info

▸ UNEP-IETC and HIID (1996): International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management. UNEP, International Environmental Technology Centre. www.unep.or.jp/ietc/ESTdir/pub/MSW/index.asp (last accessed 28.04.08)

Available from the Internet.

4.1 What is hazardous household waste?

Households generate small quantities of hazardous waste, such as oil-based paints, paint thinners, wood preservatives, pesticides, household cleaners, used motor oil, antifreeze, and batteries. Hazardous household waste (HHW) in industrialised countries, such as the US, accounts for totally 0.5 % of all the waste generated at home. In developing countries, the percentage is even lower.

No specific cost-effective sound practices can be recommended for hazardous household waste management in developing countries. Since concentrated waste tends to create more of a risk, hazardous household waste is best jointly landfilled with the MSW stream, where biological reactions tend to have a fixing effect on small amounts of toxic metals, while other toxic substances are diluted within the MSW.

Where financial resources are available (typically in industrialised countries), specific sound practices are in place for separating hazardous household waste from the regular MSW stream. (UNEP-IETC et al., 1996, Chapter 1.7.3)

What makes a waste hazardous?

Hazardous waste come in many shapes and forms. It can be liquid, solid, contain gas or sludge. It can be the by-product of manufacturing processes or simply discarded commercial products, like cleaning fluid or pesticide. Four defining characteristics of hazardous waste are:

- **Ignitability.** Ignitable waste can create fires under certain conditions or is spontaneously combustible. Examples include waste oils and used solvents.
- **Corrosivity.** Corrosive waste includes acids or bases capable of corroding metal, like storage tanks, containers, drums, and barrels. Battery acid is a good example.
- **Reactivity.** Reactive waste is unstable under "normal" conditions. It can cause explosions, toxic fumes, gases or vapours when mixed with water. Examples include lithium-sulphur batteries and explosives.
- **Toxicity.** Toxic waste is harmful or fatal when ingested or absorbed. When toxic waste is disposed on land, contaminated liquid may drain (leach) from the waste and pollute groundwater. Certain chemical waste and heavy metals are examples of potential toxic waste.

(UNEP, 2004, p. 34)

4.2 What are the dangers of hazardous waste?

▸ **Inappropriate storage, collection and treatment of hazardous waste pose a high risk to natural resources and public health.**

Surface Water Contamination

Changes in the water chemistry due to surface water contamination can affect all levels of an ecosystem. It can impact the health of lower food chain organisms and, consequently, the availability of food up through the food chain. It can damage the health of wetlands and impair their ability to support healthy ecosystems, control flooding and filter pollutants from storm water runoff. The health of animals and humans are affected when they drink or bathe in contaminated water. Moreover, aquatic organisms, like fish and shellfish, can accumulate and concentrate contaminants in their bodies. When other animals or humans ingest these organisms, the dose of contaminants is much higher than when directly exposed to the original contamination.

Groundwater Contamination

Contaminated groundwater can adversely affect animals, plants and humans if it is removed from the ground by man-made or natural processes. Depending on the geology of the area, groundwater may rise to the surface via springs or seeps, flow laterally into nearby rivers, streams or ponds, or sink deeper into the earth. In many parts of the world, groundwater is pumped out of the ground to be used for drinking, bathing, other household uses, agriculture, and industry.

Air Contamination

Air pollution can cause respiratory problems and other adverse health effects, since contaminants are absorbed by the lungs and reach other parts of the body. Certain air contaminants can also harm animals and humans when they contact the skin. Plants rely on respiration for their growth and can also be affected by exposure to contaminants transported in the air.

Leachate

Leachate is the liquid that forms as water trickles through contaminated areas leaching out the chemicals. For example, the leaching of landfill can result in a leachate containing a cocktail of chemicals. In agricultural areas, leaching may concentrate pesticides or fertilisers, and in feedlots, bacteria may be leached from the soil. The movement of contaminated leachate may result in hazardous substances entering surface water, groundwater or soil.

Soil Contamination

Contaminants in the soil can harm plants when they take up the contamination through their roots. Ingesting, inhaling or touching contaminated soil, as well as eating plants or animals that have accumulated soil contaminants can adversely impact the health of humans and animals.

(Chapter adapted from: UNEP, 2004)

Further questions

▸ What technical equipment and procedures are required for optimal source-separation of hazardous waste?

Additional info

▸ UNEP (2004): Vital Waste Graphics, The Seventh Meeting of the Conference of the Parties to the Basel Convention, Geneva. www.grida.no/publications/vg/ (last accessed 28.04.08)

Download available on the CD of Sandec's Training Tool and from the Internet.

▸ <www> www.ewasteguide.info

4.3 What is e-waste?

▸ **E-waste is any refuse created by discarded electronic devices and components as well as substances involved in their manufacture or use.**

The high tech boom has brought with it a new type of waste – electronic waste, a category that barely existed 20 years ago. Now e-waste represents the largest and fastest growing manufacturing waste. The black and white TV turned to colour, the basic mobile phone needed a camera, a personal organiser and music, and who wants last year's computer when it can't handle the latest software? As we continually update and invent new products, the life of the old ones becomes shorter and shorter. Like ship breaking, e-waste recycling involves the major producers and users, shipping the obsolete products to Asia, Eastern Europe and Africa. But instead of being "green", we are exporting a load of problems to people who have to choose between poverty or poison.

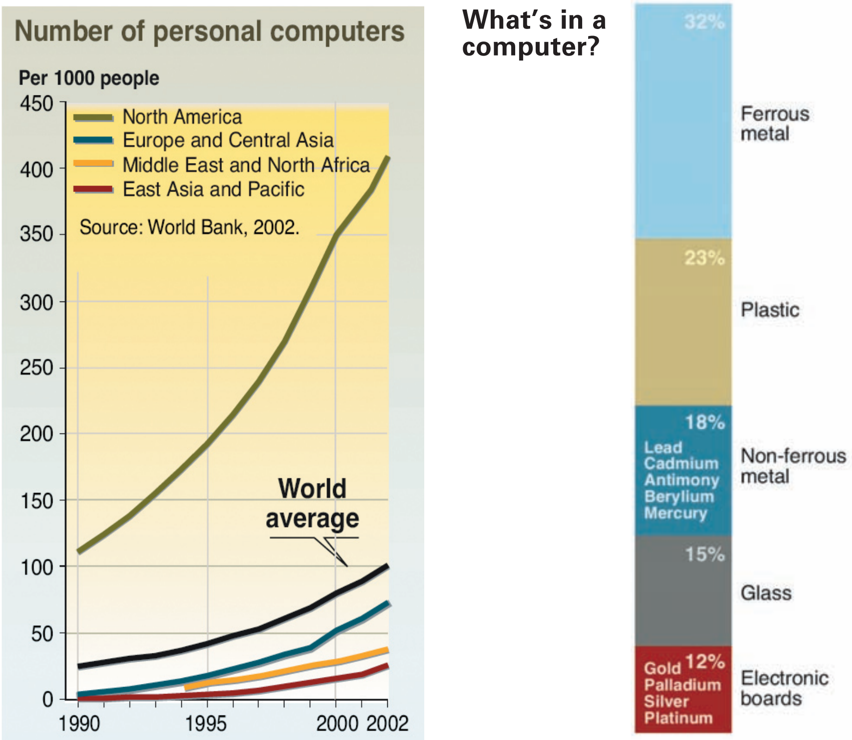

Figure 15: Number of computers worldwide and their components. (UNEP, 2004)

E-waste from computers

On average, a computer is made up of 23 % plastic, 32 % ferrous metals, 18 % non-ferrous metals (lead, cadmium, antimony, beryllium, chromium, and mercury), 12 % electronic boards (gold, palladium, silver, and platinum), and 15 % glass. Only about 50 % of the computer is recycled, the rest is dumped. The toxicity of the waste is mostly due to the lead, mercury and cadmium – non-recyclable components of a single computer may contain almost 2 kg of lead. Much of the plastic used contains flame-retardants, which makes it difficult to recycle.

In many countries, entire communities, including children, earn their livelihood by scavenging metals, glass and plastic from old computers. To extract the small quantity of gold, capacitors are melted down over a charcoal fire. The plastic on the electrical cords is burned in barrels to expose the copper wires. All in all, each computer yields about US$ 6 worth of material. Not very much when you consider that burning the plastic sends dioxin and other toxic gases into the air. And the large volume of worthless parts is dumped nearby, allowing the remaining heavy metals to contaminate the area. (UNEP, 2004)

Let me give you a computer
Communities in West Africa receive used computers from donors in developed countries. However, what was intended as a useful gift quickly becomes a waste product. When things go wrong, as they often do with computers (especially old ones), the lack of technical support means they end up on the scrap heap. It is estimated that the current number of personal computers worldwide amounts to over one billion. In developed countries, these have an average service life of only two years. In the United States alone there are over 300 million obsolete computers. After its amendment, the Basel Convention banned the export of hazardous waste disposal to developing countries. Some countries (for example those in the European Union) have already implemented this proposed amendment. Moreover, countries like China have banned the import of e-waste, although significant volumes are still entering the country illegally.

Further questions
- How much e-waste is in the waste stream?
- How much e-waste is recycled?
- How do I recycle my cell phone?

Additional info
- UNEP (2004): Vital Waste Graphics, The Seventh Meeting of the Conference of the Parties to the Basel Convention, Geneva. www.grida.no/publications/vg/ (last accessed 28.04.08)

Download available on the CD of Sandec's Training Tool and from the Internet.

5.1 Who are the stakeholders to consider within SWM?

▶ **Stakeholders include households and communities requiring service, private sector enterprises and workers (formal and informal), and government agencies at the local, regional and national level.**

SWM cannot be solved with innovative technology or engineering alone. It is an urban problem that is closely related to a number of issues, such as urban lifestyle, resource consumption pattern, employment and income, and other socio-economic and cultural aspects. All these factors have to be consolidated in a common platform to ensure long-term solutions to urban waste disposal.

A large number of stakeholders are essential for the success of a solid waste management system. They influence activities on different spatial levels, such as household, neighbourhood, city, region, and nation.

Activities related to solid waste management at the household level are predominantly driven by socio-economic factors. Social responsibility and environmental awareness are driving forces for:

- Central/provincial government
- City council
- NGOs and CBOs
- Private informal sector
- Private formal sector
- Internal and external support agencies

(Zurbrügg, 2003a, p. 7)

Similarly, actions to be taken at the state and national level are predominantly economic, political and administrative. Measures at the neighbourhood and city level cut across all themes.

Decisions and actions are embedded in a technological, environmental, social, financial and economic, organisational, administrative, institutional and political framework.

Experience in several countries has shown that cooperation and coordination between the different stakeholder groups will ultimately lead to increased sustainability of a waste management system. (Klundert et al., 2000 in; Zurbrügg, 2003a)

As an alternative to the large (often international) companies providing most or all of the solid waste services to a city, the involvement of micro-- enterprises or small enterprises (MSEs) should be considered. Since they often use simple equipment and labour-intensive methods, they can collect waste in places where the conventional trucks of large companies have no access. These MSEs may be started as a business to create income and employment, or they may be initiated by community members wishing to improve the immediate environment of their homes.

Appropriate practice in waste management systems requires a clear definition of jurisdiction and accountability, with all stakeholders participating in system design, including those affected at every level being made aware of their areas of responsibility.

Governments will generally have final jurisdiction and responsibility for overall MSWM policy and management, irrespective of whether or not they are directly involved in waste management. The following participants have some important relation to waste management and, in some cases, significant levels of responsibility for policies or operation.

- **Residential waste generators.** Preferences of local residents for particular types of waste services, their willingness to source separate recyclable materials, their willingness to pay for the service, and their capacity to move waste to communal collection points, all have an impact on the overall waste system. Incentives can affect residents' preferences and behaviour.
- **Business waste generators.** Since businesses also produce waste, the business sector can become a significant player in the waste management system, particularly since businesses are increasingly charged directly for the waste services. As with residents, incentives can play an important role in shaping behaviour.
- **Public health and sanitation departments.** Maintenance of public health and sanitation is an important public responsibility, especially in developing and transition countries, where it generally falls under the jurisdiction of the municipal public health department. In an integrated system, this department often has inspection and enforcement responsibilities, but is not directly involved in collection or disposal operations.
- **Public works departments.** These local government units often have operational responsibility for waste collection, transfer, treatment, and final disposal. Frequently, however, different department are responsible for collection of recoverable materials or management of private contractors, thus often creating conflicting goals and activities.
- **Natural resource management agencies.** Since these agencies are often responsible for activities relating to materials recovery or composting at the local or regional level, they are therefore separated from waste management functions. This results in poor integration as sound practice often places all the functions under the same agency or department.
- **National or state/provincial environmental ministries.** Overall, waste management policy is generally established at these levels. With respect to materials recovery policies, there is less policy-making at this level in developing countries. Sound practice includes not only the establishment of policies, but putting programmes in place, implement them and establish integration consistent with the policies.
- **Municipal governments.** In most countries, city or town governments assume the overall responsibility for waste management operations. They ensure regular collection services and delivery of the collected materials to processors, markets or disposal facilities. The municipal government, which is ultimately responsible for the entire process, usually finances vehicles, crews and other equipment.

- **Regional governments.** Regional bodies or large city governments are often responsible for landfills, incinerators, composting facilities or the like, particularly in countries where there is a shortage of disposal space at the local level. Regional governments in charge of these facilities generally have access to sources of revenue from fees paid by waste collection companies for disposal.
- **Private sector companies.** Private sector companies tend to act as concessionaires or contractors of the responsible government authority in waste collection, street sweeping, materials recovery, and, increasingly, in construction and operation of landfills, incinerators and composting plants. Unlike governments, private companies do not have any direct responsibility for maintaining public sanitation or health, so their involvement is limited to profit making functions. If there is no source of revenue, it is not reasonable to expect private sector involvement. The necessary revenue can, however, come from direct charges or government allocations.
- **Informal sector workers and enterprises.** In developing countries, but also increasingly in industrialised and transition countries, individual workers and unregistered, small enterprises recover materials from the waste stream, either by segregated or specialised collection, by buying recyclable materials, or by picking through waste. These workers and enterprises clean and/or upgrade and sell the recovered materials, either to an intermediate processor, a broker or a manufacturer. Informal sector workers sometimes manufacture new items from recovered materials, such as gaskets and shoe soles from discarded tires. These workers are often referred to as waste pickers or scavengers.
- **Non-governmental organisations.** Non-governmental organisations (NGOs) are yet another set of participants in waste management operations. NGOs are often commissioned to improve the environment or the quality of life of poor or marginalised populations, and may stimulate small-scale enterprises and other projects. Since waste materials often represent the only growing resource stream, these organisations frequently base their efforts in extracting certain materials, currently not recovered, and in processing them to increase their value and produce revenue. This is how a number of composting projects were launched in Latin America.
- **Community-based organisations.** In some locations with insufficient collection or where neighbourhoods are underserved, community-based organisations play an active role in waste management operations. These smaller-scale organisations or

Importance of scavengers/waste pickers

In developing countries, informal waste pickers or scavengers play an important role in solid waste management systems, acting in parallel with formal waste collection and disposal agents. Scavengers collect reusable and recyclable materials from streets, dumpsites or landfills that can be reintegrated into the economy's production process. Despite the benefits generated for society, waste pickers are ignored when waste management policies are formulated. (Moreno-Sánchez et al., 2006, p. 371)

In many developing countries, the socio-economic status of scavengers is usually very low. The general population and the authorities often view and treat them as 'part of the rubbish they work with' (ASMARE Street Scavenger's Association, 1998). Low education levels and unhealthy working conditions combined with their popular status lead to a negative self-perception and lack of self-confidence. (UNESCO, 2001)

Medina states that even though scavengers are not always the poorest of the poor, their occupation is generally assigned the lowest status in society. Historically, outcasts and marginal groups, such as slaves, gypsies and migrants have performed waste collection and recycling activities in developing countries. In Muslim countries, non-Muslims usually perform refuse collection and recycling activities, since contact with waste materials is considered impure. (Medina, 2000).

Photo 8: Waste pickers at a transfer station, Nepal. (Source: Eawag/Sandec)

In India, scavengers are mostly Dalits, or 'untouchables', not simply the lowest in the caste system but essentially outside it. The daily contact with garbage and sometimes even human excreta reinforces their 'untouchable' status. In other countries, such as Egypt, scavenger communities are groups of rural migrants who adopt scavenging as a way to survive in the city and end up specialising in this sector. In many countries, gypsies were the ethnic group involved in scavenging activities (cf. Fonseca, 1996). Aside from the day-to-day bad treatment that waste pickers experience, their low status can deter them from climbing the social ladder. NGOs and sometimes even governments strive for recognition of scavengers' humanity and value. One way of tackling the ascribed and self-replicated low status of scavengers, whether or not related to ethnicity, is through the creation of co-operatives.

Besides raising income, this form of grassroots development can potentially provide scavengers with a certain status; they are recognised and accepted as part of the waste management system, which is beneficial to the entire population and increases both their self-esteem and self-reliance. (Nas et al., 2004, p. 345 – 346) local NGOs are formed primarily as self-help or self-reliance units, which may, over time, evolve into service organisations that collect fees from their collection clients and from the sale of recovered materials. NGOs working with informal workers and community-based entrepreneurs often seek recognition for these organisations as part of the waste management system.

- **Poor and marginal populations in squatter areas.** The waste service, much like other public services, frequently follows political power and clout, leaving the residents of poor and marginalised areas with inadequate service (or no service at all), dirty streets and regular accumulation of refuse and faecal matter on streets and in other public areas. Very often, these people have the greatest need for improved or expanded waste service.
- **Women.** Waste handling disproportionately touches the lives of women, particularly in some developing and transition countries. Women often collect the waste, set it out or move it to community transfer areas. Women are far more likely to be involved in materials recovery than in other comparable types of physical work. This is possible due to their daily contact with the waste in their homes, and probably because women tend to be among the most marginalised groups in some societies.

(UNEP, 2005, p. 9 – 11)

Further questions

▸ Which MSWM functions, responsibilities and powers should be assumed by which level of government?

▸ What institutional arrangements and approaches would foster more demand-oriented solid waste services?

▸ On what basis should authorities decide which waste management functions should be contracted out to private sector enterprises?

▸ What is the potential role of community in local waste management, and what inputs are required to promote community-based waste management?

▸ What instruments of awareness building and incentives should be employed to mobilise peoples' contribution to waste minimisation and recovery?

▸ What forms of collaboration between informal sector waste workers and municipal authorities may be established to improve the productivity and working conditions of informal sector workers?

Additional info

▸ Klundert, A.v.d. and Anschütz, J. (2000): The Sustainability of Alliances between Stakeholders in Waste Management. UWEP/CWG. www.gdrc.org/uem/waste/ISWM.pdf (last accessed 28.04.08):

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5.2 What are the characteristics of private sector involvement?

▸ **Three key factors are decisive for the success of private sector involvement: Competition, accountability and transparency. Private sector participation can increase service quality and reduce costs through introduction of commercial principles.**

Provision of municipal solid waste services is a costly and vexing problem for local authorities everywhere. In cities of developing countries, service coverage is low, resources are insufficient and uncontrolled dumping is widespread with resulting environmental problems. Moreover, substantial inefficiencies are typically observed. One solution commonly proposed is to contract service provision out to the private sector in the belief that service efficiency and coverage can be improved and environmental protection enhanced. The private sector assumes three important roles in solid waste management. First, where existing public service delivery is either too costly or inadequate, private sector participation offers a means of enhancing efficiency and lowering costs through the introduction of commercial principles and greater attention to customer satisfaction. Second, in situations where local public funds for investment are in chronically short supply, the private sector may be able to mobilise needed investment funds. Third, the private sector is well situated to draw on local and international experience in the waste management field and introduce proven and cost-effective technologies along with management expertise. (Cointreau-Levine et al., 2000, p. 3)

However, opinion leaders, familiar with private sector participation, have urged that private enterprises involved in the provision of solid waste management services should not be seen as a panacea – a cure for all problems – even though their involvement has often resulted in very significant improvements in many situations. Experience has led some experts to believe that if a local government body has not been able to provide a satisfactory solid waste management service using its own resources, it will not be able to engage a private enterprise to provide a satisfactory service. Some assert that involving the private sector always results in increased corruption and misappropriation of public funds. However, most voices are in favour of private sector participation – some because of positive experience, some because of their political standpoint, and some out of a desperation nurtured by the failure of the public sector.

But opposition to the involvement of the private sector in the provision of public services can be expected in most situations. This may result from:

- political views;
- general resistance to change;
- opposition from labour unions;
- fears about corruption;
- fears of officials that they will lose power, influence or income;
- previous experience of private sector participation; and
- a belief that private companies take huge profits or other factors.

In general, a wide variety of arrangements can be implemented to take advantage of the benefits of private sector participation. To be successful, however, cooperation with the public sector is crucial. Both sides should have rights that are upheld by the courts and duties that are backed up by the threat of sanctions. Such an equal partnership is much more likely to result in effective and economical services that continue for a long period. Unfortunately, the public sector often dominates, with little concern for the rights of the private sector, and the result can be the bankruptcy of the company or the reluctance of companies to bid for future work. (Coad, 2005, p.3, 8, 25)

Key factors for successful private sector participation

Competition. There should be competition between different private sector companies and, if possible, also between the private and public sectors. Competition provides motivation to maintain effort. It sets a standard against which performance is compared or assessed. Furthermore, it provides a continual reminder that there are others engaged in the same activity who could take the place of a competitor who is performing poorly.

Accountability. Private sector service providers should sense that they are accountable to the people whose waste they collect and to the local government agency that has engaged or licensed them. The companies know that if they fail to provide the required service in the required way, there will be consequences. They are not free to do as they please. Such accountability results from a well-prepared contractual agreement, from effective enforcement of the terms of the agreement, and from the understanding that there will be financial penalties if expectations are not met. Microenterprises, which draw their workforces from the communities that are served, benefit from the accountability that the laborers feel towards their neighbours who expect a fair and satisfactory service. The public sector agency (whether municipal or regional government) responsible for the service should also feel accountable to both the public and the elected representatives for the way it oversees the service. Often capacity development will be required if government is to effectively discharge its responsibilities.

Transparency. There is growing concern about the crippling effects of corruption and favouritism or "cronyism". More and more emphasis is being placed on "good governance" at city, regional and national levels. Financial dealings and decision-making should be transparent. The reasons for decisions – especially the selection of private sector service providers – and the management of public funds should be open before the public. In this way the service can enjoy the support of the public and competition is encouraged, since the competitors are reassured that they will have the opportunity of competing on fair and equitable terms. Public support can be expected to result in more widespread payment of charges or taxes, and fair competition to result in lower costs and better services.
(Cointreau-Levine et al., 2000, p.8 – 9)

Further questions

- What are the reasons leading to the involvement of private enterprises?
- Why do some oppose the participation of the private sector?
- What are the steps to be taken and the questions to be answered when developing a strategy for involving the private sector?
- Why is it so important to work closely with the general public as recipients of the service?
- What are the common shortcomings in the tendering process and in contractual documents?
- What the most successful ways of implementing private sector participation?
- Why is the monitoring of private sector service providers often ineffective and the cause of conflict?

Additional info

- Cointreau-Levine, S. and Coad, A. (2000): Private sector participation in municipal solid waste management - Guidance Pack. SKAT, St. Gallen, Switzerland. http://rru.worldbank.org/Documents/Toolkits/waste_fulltoolkit.pdf (last accessed 28.04.08)

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5.3 How do legal frameworks and international treaties influence MSW management?

▸ **Government enactments vary greatly in different countries. Action plans and guidelines, like the Agenda 21 or the Basel Convention, have been established at an international level.**

Currently, no convention or other measure exists for the comprehensive management of waste. Efforts to deal with waste on an international scale have been largely confined to managing the problems associated with the trans-boundary transport of waste. Although some technical guidelines for the management of certain specific types of waste have been drafted under the Basel Convention (1989), the effectiveness and impact of these guidelines on waste minimisation are yet to be determined. The environmental, economic and social implications of a rapidly increasing 'waste problem' have gained recognition over recent decades, and the need for a response to the waste management problem on an international scale has long been accepted. At the 1992 UN Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, the international community adopted the Rio Declaration on Environment and Development and Agenda 21, an action plan designed to guide the Earth's development in a sustainable manner (United Nations Conference on Environment and Development 1992. The same goals were reiterated ten years later at the World Summit on Sustainability Development. (Meyers et al., 2006, p. 505 – 506)

The prime driver behind improved waste management is legislation, but this does not fulfil its aims unless it is supported by effective enforcement. Indeed, a lack of enforcement gives rise to unscrupulous operators that appear to comply with the law, but in practice deal with waste incorrectly or even dump it illegally.

There is a legal international trade for reused or recycled materials, however, some of the world's wealthy nations are exporting mixed or even hazardous waste to poorer countries, where it is not properly treated.

Traditionally, municipalities have been responsible for municipal waste collection and disposal, but commercial companies are increasingly being used for waste management tasks. In some countries, commercial companies work with municipal organisations, while in others, the municipalities themselves have formed companies for waste-management work. The use of private waste management contractors is increasing. (Key Note, 2007)

MSW Rules 2000 (India)

In 1996, a public interest lawsuit was filed with the Supreme Court against the government of India, state governments and municipal authorities for their failure to perform their duty of managing MSW adequately. As a consequence, the Supreme Court appointed an expert committee to look into all aspects of MSW and make recommendations to improve the situation. On the basis of their report, the ministry issued in September 2000, the Municipal Solid Waste (Management and Handling) Rules 2000 under the Environment Protection Act 1986.

These rules lay down the steps to be taken by all municipal authorities to ensure management of solid waste according to best practice. The municipalities were mandated to implement the rules by December 2003, with punishment if authorities fail to meet the standards prescribed. Nevertheless, most municipalities did not meet the deadline. Some cities and towns have not even started to implement measures that could lead to compliance with these rules.

(Zhu et al., 2007)

Further questions

▸ How much importance should be attached to alternative instruments of waste management (regulations and controls, economic incentives, non-economic motivations and solidarity)?

Additional info

▸ Schüberler, P., Wehrle, K. and Christen, J. (1996): Conceptual framework for municipal solid waste management in low-income countries. In: Working Paper no. 9. World Bank. Report Nr. 40096. http://go.worldbank.org/3I0WRR9IF0 (last accessed 28.04.08)

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5.4 What are the financial arrangement options for SWM?

▸ **Options include government support, private sector financing, fees, and charges.**

Structuring financing for waste management systems

Sound practice in financing waste management systems usually entails differing treatment of fixed and variable costs. Fixed costs, which establish waste or materials collection, processing or disposal capacity, may be paid from general tax revenues. The rationale for this is that all members of society benefit from having the overall solid waste management system in place. Once societies reach a certain level of sophistication, they may be able to recover a certain portion of fixed costs from commercialised collection, processing and disposal operations, and not rely solely on general tax revenues to fund these activities. Direct or indirect fees can be allocated for payment of variable costs directly proportional to the same. One key to developing sound cost recovery systems is to accurately track down all costs. A surprising number of municipal governments do not actually know the total costs of collection or disposal, so they have no basis on which to set or defend fees. Establishing well-functioning and transparent full-cost accounting systems should be a high priority where they do not yet exist. (UNEP, 2005, p. 13)

Fees and charges

Until recently, waste management, financed by general revenues, was considered the responsibility of the government in most developing, transition and European socio-democratic countries. Partly as a result of austerity and structural adjustment policies and pressures from multilateral financial institutions, and partly as a result of pressures to limit taxes, governments have, in recent years, increasingly focused on identifying specific revenue sources for waste management. This has led to a series of innovations relating to fees and charges for waste collection and disposal:

Charging directly for waste services. One approach to the financing of waste systems is to obtain payment from those who benefit from the services. On the simplest level, waste generators benefit from collection service, and there have been some attempts, particularly in North America, to get households to pay directly for their own waste removal on the basis of how much waste they generate. The system of unit fees for waste removal works well and represents sound practice when individuals want to get rid of their waste and can afford the fees. It works poorly when people are too poor to pay fees, when the fees are simply too high or when there are ready alternatives and no controls for waste disposal, such as unregulated disposal in the countryside. Fees can be used to finance waste collection or other aspects of the waste system, and also as incentives to create less waste.

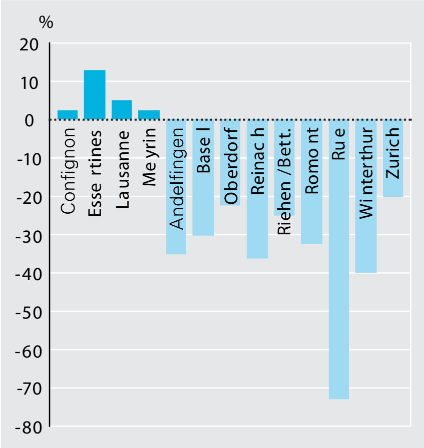

Figure 16: Development of collected combustible waste volumes. (Basis: kg/inhabitant index)

Indirect charges. In some locations, the waste charges are linked to other public services that people are willing to pay, such as water or electricity. In addition to the waste charges, water and (if present) sewer charges allow some cost recovery. Studies have revealed that consumption of water and electricity are rough indicators of waste generation.

Incentives and penalties. Charges and fees can also be used as incentives to encourage "good behaviour" or discourage "bad behaviour". For example, the price of disposal can be increased and the costs for materials recovery subsidised to provide incentives to source separate. In some instances, fines can be imposed to discourage illegal dumping.
(Adapted from UNEP, 2005, p. 12 – 13)

Polluter pays principle
A study by SAEFL (Swiss Agency for the Environment, Forests and Landscape), Switzerland, conducted between 2000 – 2003, examined the ecological and financial advantages and disadvantages of waste disposal charges based on the polluter pays principle. Case studies were conducted in 13 municipalities, where charges of this kind had mainly been introduced. Figure 16 shows changes in combustible refuse volumes between 1997 and 2001 for municipalities without waste bag charges (positive values) and for municipalities, which had adopted the new system (negative values), using data from one year prior to the system's inception until 2001.

Conclusions of the study: Introduction of the polluter pays principle led to a 30 % reduction in combustible waste collected by the municipalities. The amount of collected recyclables increased by 30 %.

(Bischof et al., 2003)

Further questions
- ▸ What steps should be taken to include financial and economic analysis into strategic planning functions?
- ▸ How can the use of appropriate cost accounting systems be promoted despite possible reluctance from municipal officials?
- ▸ How may local governments ensure that MWSM revenues are used for the intended purpose?
- ▸ How should incentives for cost reduction and increased operational efficiency be incorporated into municipal cost reduction and service effectiveness?
- ▸ In which task areas and under what conditions will private enterprises contribute most effectively to cost reduction and service effectiveness?
- ▸ What MSWM revenue collection system will attain adequate cost recovery while, at the same time, create real incentives for cost reduction and effectiveness?

Additional info
▸ **UNEP (2005). Solid Waste Management, CalRecovery Inc. www.unep.or.jp/letc/Publications/spc/Solid_Waste_Management/Vol_I/Binder1.pdf (last accessed 28.04.08):**

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