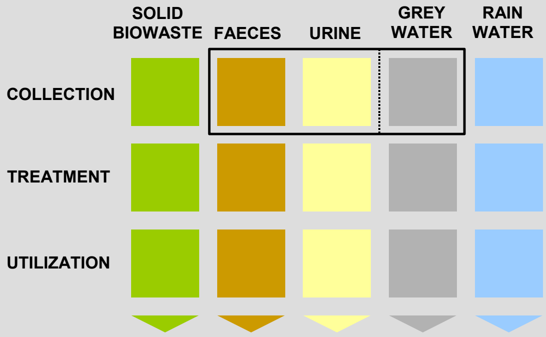
04 Vacuum Technology
(Low pressure systems)

B.1 Vacuum Sewer System

- Sewage transport in low pressure system
- Water savings up to 80 %
- Possibility to collect concentrated blackwater for further treatment (biogas production)
- High flexibility of the system



B.1 Vacuum Sewer Systems

B.1.1 Functional principles

Briefly explained, vacuum sewerage means that in a central vacuum station a low pressure of about –0.6 bar is created by at least two vacuum pumps. The wastewater from the houses is held

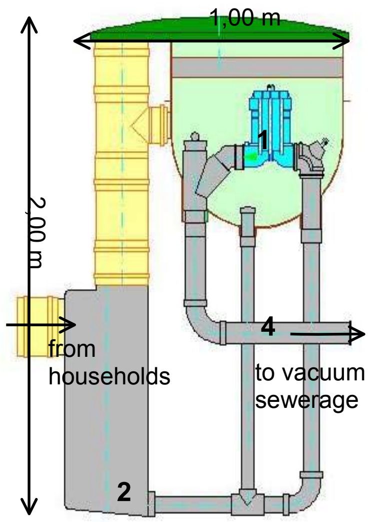


Figure 1: Cross section of Collection chamber with membrane valve *(ROEDIGER,2002)*

back in collection chambers (Figure 1), with pneumatic regulating valves (1), close to the houses. When a given volume of wastewater is collected in the chamber sump (2), a pneumatic controller (3) is activated by hydrostatic pressure. The controller opens an interface valve (1) for an adjustable time period. The wastewater (10 to 50 l) and a certain amount of air (20 to 60 l) are evacuated through the open valve into the vacuum sewer line (4). The pressure gradient between the vacuum station and atmospheric pressure at the collection pits is responsible for the movement of sewage to the vacuum tank. The vacuum mains discharge into a collection tank at the vacuum station. By use of sewage pumps, sewage will be transported to treatment facilities or into a conventional system afterwards. The exhaust air can be further treated in bio filters, consisting of bark and wood.

The sewers are passed in specific profiles, in saw-tooth-pocket or wave profile with significant high and low points. Wastewater comes to rest at the low points and forms plugs. The system works like a

Figure 2: Pneumatic diaphragm valve 65 mm (1) and controller (3) *(ROEDIGER;2002)*

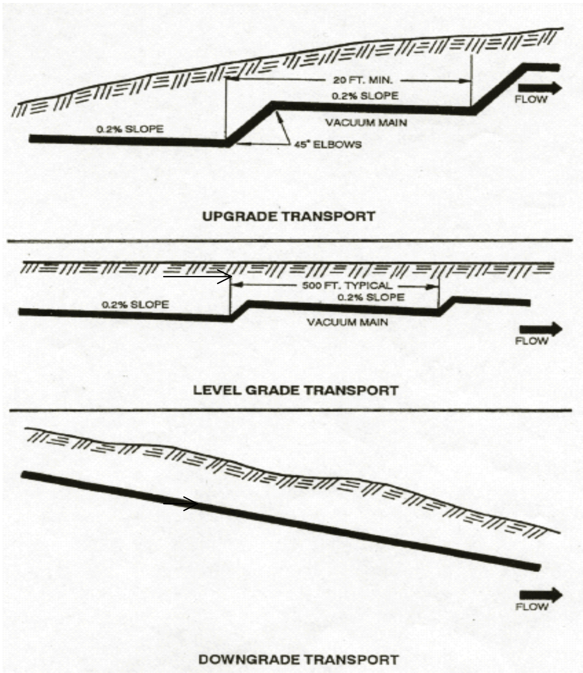


Figure 3: Passing procedure depending on surface conditions *(AIRVAC)*

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ecosan sector project

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

P.O. Box 5180
65726 Eschborn, Germany
fon: +49 6196 794220
fax: +49 6196 797458
e-mail: ecosan@gtz.de
internet: http://www.gtz.de/ecosan

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

commissioned by:
Federal Ministry for Economic Cooperation and Development

pneumatic tube conveyor: it's even possible to negotiate jumps. When air is admitted through an upstream interface valve, these plugs are accelerated and pushed over the high points towards the vacuum station.

The vacuum station is the heart of the vacuum sewer system. Wastewater and air enter the vessel from the vacuum sewer. The wastewater is collected in the vessel and if a certain volume is reached (mostly 25 % of the tanks volume) it is discharged to wastewater treatment plants or to conventional sewer by sewage pumps.

B.1.2 Operation and maintenance

The vacuum sewerage is a High Technology and requires of course correct construction, maintenance and damage control. If these conditions are

Box 2: Life expectancy of system components in years [10]

Vacuum vessel	25 to 40
Collection chambers	30 to 55
Vacuum pumps	20 to 30
Piping system	50 to 80
Sewage pumps	12
Pneumatical interfaces	30

guaranteed, the system is reliable and nearly maintenance-free. Due to the turbulent flow, blockages won't appear. Continuous aeration prevents deposits, odours and septicity. Thus flushing of the sewer is not necessary. Maintenance and electricity consumption are limited to the vacuum station, and thus concentrated in one location. Due to the low pressure inside the pipes, leakages won't occur. It's even possible to pass the pipes in the same trench as the drinking water main.

Due to the under-pressure in the reticulation pipe system, an extended pump run time, unlike in gravity systems where leakage can only be noticed by sewer monitoring will indicate every damage of pipes. Thus control and maintenance of the valves and the piping is not essential.

Access to pipes can be gained at each collection chamber. Division valves are installed on major branch connections and on the mains to allow for isolation of particular sections for troubleshooting or repairing. Inspection pipes, installed at distances of approx. 100 m permit insertion of inflatable balls and precise locating of leaks. Any person with basic technical knowledge can operate a vacuum system. High school education

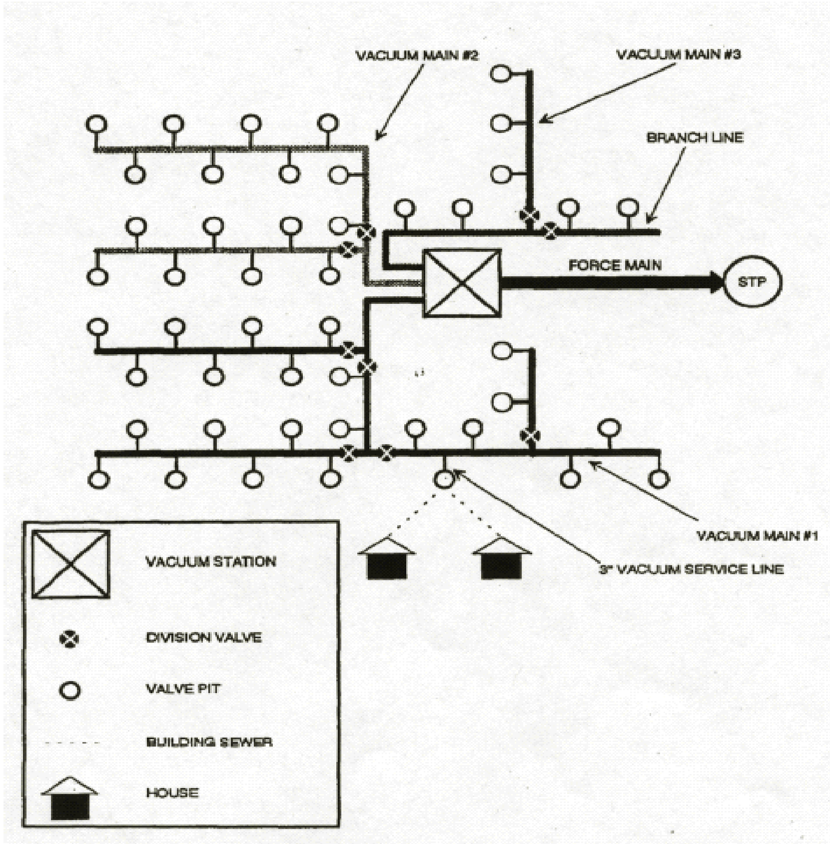

Figure 4: Vacuum Sewer System *(AIRVAC)*

is absolutely adequate [21].

Only the pumps in the vacuum station need electrical power (10 to 30 kWh per inhabitant per year) and maintenance ca. once a year, the vacuum station should be visited once a week carrying out a visual inspection, which lasts about one hour [20].

Material used in bio filters (wood, bark) should be changed every two to three years.

An emergency generator is necessary in case of frequent power cuts to prevent prolonged pump failure and breakdown of the vacuum system.

B.1.3 Extent of application

Vacuum sewerage is not a new technology; it's actually a state of the art. The beginnings of this today widespread special drainage procedure go back to the Dutch engineer Liernur, who used around the 1860`s for the first time such systems. In the sixties of the 20th Century the Swede Liljendahl took up the ideas by Liernur again and developed them further. The system was rapidly improved and its reliability was crucially increased. By the use of plastic pipelines in 1970 a new spreading wave was released worldwide. A further large thrust for the intensified application of the vacuum drainage took place in Germany with the entrance of further suppliers of

Box 3: Suitability of vacuum sewer systems [17]

- Low density population settlement
- Decentralised or semi-decentralized sanitation systems
- Insufficient natural slope, i.e. flat topography
- Poor subsoil conditions (i.e. unstable soil or rock, high groundwater table, complicate excavation)
- Obstacles to the sewer route
- Aquifer protection zones
- Seasonal operation (e.g. holiday resorts)
- Minimal space for infrastructure installations
- Water sensitive areas (lakes, rivers and coasts, or where flooding can occur)

evacuated system in the middle of the 90's. (In this period the main components interface valve and pumps were reduced in price around ca. 40 %.) Thereby the vacuum sewerage became also interesting for ranges that were reserved for the gravity sewerage so far [8,9]. Worldwide there are today five suppliers of vacuum sewer systems.

The system has been grown out of its infancy; vacuum sewerage can be applied all over the world in every elevation, if certain conditions are given. Vacuum sewerage lends itself ideally to rural areas, coastal areas, lakesides, flat terrain, briefly, anywhere where difficult terrain would make conventional gravity system with pumping stations too expensive.

It is especially suitable for areas with high groundwater table (lakes, rivers and coasts, where flooding can occur) or where water protection areas might be crossed. Vacuum technology is also interesting where the wastewater flow is low or varies in a wide range e.g. in resorts. Even when the flow is less wastewater is kept fresh due to aeration and relatively low periods of staying in the pipes. In densely populated areas, vacuum technology is not an economical substitute for gravity systems due to the high wastewater volumina and thus extended pump run times. Vacuum technology is not suitable where longer transport sessions over 4 km become necessary.

B.1.4 Economical data

Under difficult technical and topographical conditions vacuum sewerage systems are quite cheaper than conventional sewerage. If the costs for conventional systems would exceed 2000 €/P vacuum sewerage should be taken into account [9]. Experiences have also shown that a minimum of 75 – 100 customers is needed to be cost effective [21].

Vacuum sewers are 20 to 25 % less costly to construct than conventional sewers due to cost savings listed in the box 4.

A collection chamber costs about 1500 €, about 850 to 900 € without installation [20]. A Vacuum station is available from 20'000 to 100'000 € depending on size. The electricity consumption varies between 10 to 30 kWh/(P•a).

B.1.5 Design information

collection chamber

The collection chamber consists of polyethylene high density (PE-HD) or glass reinforced plastics (GRP) and it contains one membrane (see figure 2)

Box 5 Installation costs Shoshong, Botswana [14]

Component	Quantity	Price [€]
Vacuum station	1	88 480
Collection chambers	40	60 000
Sewer line	4 400 m	88 366

or piston interface valve (see figure 8), which are pneumatically regulated. Ventilation for the correct air/liquid ratio varies between 3:1 and 15:1 and is adjusted by the system supplier. The collection chambers are installed under driveways, paths, roads or even gardens.

sewer

The length of the sewer mains varies between 2 to 4 km, they should be declined at least with a slope of 0,2 % towards the vacuum station. The lifts are installed every 6m to 100m, depending on the laying procedure and topography (see figure 2). Pipes are

Figure 5: Collection chamber

Figure 6: Vacuum station with buried vessel

made of PE-HD or polyvinyl chloride (PVC); both can be glued and welded. Common diameters are 65 mm to 200 mm. The flow velocity of the plugs is

Figure 7: Prefabricated compact vacuum station *(Mosel)*

between 4 m/s and 6 m/s.

vacuum station

The vacuum station should be located next to a conventional sewer or wastewater treatment plant and if possible at a low point. The constructional design can be variable,

Box 4: Capital/Operational costs saving due to [7]:

- Narrow and shallow trenches (1,0m to 1,4m)
- Low diameter of sewer (65 mm to 250 mm)
- Efficient construction period
- No requirement for manholes
- No requirement to clean or remove sediments from within the vacuum sewers
- Pump sizes and subsequently electrical power consumption are significantly reduced concerning no groundwater infiltration.
- Elimination of infiltration allows a reduction of size and costs of the treatment plant

e.g. as monolithic or stonewalled construction up to blockhouses. The

Figure 8: Vacuum operating valve (QUAVAC)

most common type is a buried steel vessel due to water tightness, volumes range from 5 to 25 m³. The stations and collection chambers should be protected against lifting just as arrangements for noise and odour protection should be met. A bio filter lends itself to exhausted air deodorization. Futhermore the vacuum station consits of at least two vacuum- and sewage pumps, which are usually rotary vane or rotary piston pumps. The sewage pumps forward the wastewater automatically to the gravity sewer or directly to the wastewater treatment plant.

Detailed information on construction can be found in the ATV A 116, see B.1.7.

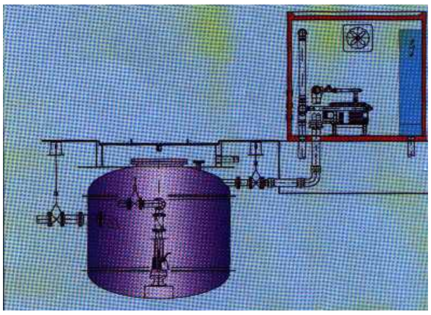

Figure 9: Vacuum station with an external buried steel tank. Vacuum pumps are in the house *(ROEDIGER,2002)*

B.1.6 Strenghts and weaknesses

Health impact

The probability of pathogen pollution of the groundwater is only small due to no wastewater leakage.

Environmental impact

There is almost no opportunity for nutrient leakage into the soil and the groundwater; therefore vacuum systems can be used in groundwater protection areas. Vacuum sewerage lends itself as a tool for integrated ecological concepts. Compared to conventional sewer system it does not depend on a minimum wastewater volume, in order to transport suspended solid. Water consumption may therefore be reduced and no water would be required for flushing the sewers.

Vacuum sewerage allows for the transport of a more concentrated wastewater than gravity systems do. A high potential for treatment and recycling of low-diluted flow streams exists. As an example, vacuum sewers may be especially useful in ecosan systems to collect low-diluted black or brown water only, which could be treated in an anaerobic digester producing biogas and fertilizing sludge.

Operating the systems requires energy input for the vacuum pumps.

Costs and benefits

Compared to gravity drainage there may be lower investment costs due to the facts mentioned under B.1.4. Furthermore vacuum technology is more flexible and more appropriate in areas with seasonal fluctuations. Repairs and cleansing are less costly than for conventional systems.

Socio-cultural suitability

The vacuum sewerage provides the same comfort for wastewater evacuation as gravity sewerage.

There are no differences in application for the user compared to conventional sewerage. If a breakdown occurs the storage capacity provided by the service pipe prevents overflowing into the basement. Initially there may be some concerns regarding the vacuum technology, but first experiences have shown that once the system is applied, the acceptance will increase. (see project data sheet Botswana, Shoshong)

Fewer accidents occur during the construction periods due to shallower trenches. The regional contractor can be easily involved in the installation of this system and all the civil work can be done without heavy excavation equipment and blasting.

Otherwise measures for noise protection and odours should be done.

Technical suitability

The vacuum sewerage is a High Tech solution and technically more challenging than gravity, on the other hand it is easy to construct due to the use of ductile and lightweight material and there is a high flexibility in the construction period according to obstacles granted. The complexity of operation and maintenance compared to gravity drainage is less, but the pumping energy is required, thus the system is vulnerable to power breakdowns and failure of technical or other assets.

B.1.7 Further reading

Complex literature about it hardly exists; designing concepts are mostly based on company internal empiric data.

ATV-DVWK-A 116 „Besondere Entwässerungsverfahren, Teil 1: Unterdruckentwässerungssysteme außerhalb von Gebäuden“
ATV-DVWK, D-53773 Hennef, 2004

Project work by Lars Späth “The Potential of Vacuum Sewerage as an Alternative in Communal Wastewater Collection Systems”
Lars Späth, D-76128 Karlsruhe, 1998

European Standard EN 1091 „Vacuum Sewerage outside buildings“ DIN Deutsches Institut für Normung e.V., Berlin, 1999

B.1.8 Manufacturers

ROEDIGER VAKUUM HAUSTECHNIK GmbH

Kinzigheimer Weg 104-106
D-63450 Hanau
Phone: +49-(0)-6181-309-275
fax: +49-(0)-6181-309-280
info@roevac.com
http://www.roevac.com/

Vacuum sewerage projects in Germany, some African and Asian countries, sanitary systems in Europe, China, and VAE.

SCHLUFF Kanalisationssysteme

Wasserwaage 5
D-24226 Heikendorf
Phone: +49-(0)-431-24405
schluff@schluff.com
http://www.schluff.com/

Some experience in vacuum sewerage, collection chamber require additional energy

Iseki Vacuum systems Ltd.

High March
DAVENTRY
Northamptonshire, NN11 4 QE
Phone: +44-(0)-1327-878777
Fax: +44-(0)-1327-315232
sales@iseki-vacuum.com
www.iseki-vacuum.com

Vacuum sewerage in U.K.

AIRVAC

4217 N. Old.U.S. 31
P.O. Box 528, IN 46975
Phone: 574-223-3980
Fax: 574-223-5566
webmaster@airvac.com
www.airvac.com

Vacuum sewerage in U.S., large company

QUA-VAC B.V.

Televisieweg 157, 1322 BH ALMERE, The Netherlands
Phone: +31-(0)-36 54 61 999
Fax: +31-(0)-36 53 50 909
info@quavac.com
www.quavac.com

Vacuum systems supplier for land and ship applications

B.1.9 Good practice examples

Shoshong (ROEDIGER)

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GTZ-ecosan team
(Christine Werner, Florian Klingel, Patrick Bracken Ulrike Mosel, Sebastian Hass)

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

Dag-Hammerskjöld-Weg 1-5
P.O. Box 5180
65726 Eschborn, Germany

fon: +49 6196 79 4220
fax: +49 6196 79 7458
email: ecosan@gtz.de
internet : http://www.gtz.de/eccosan