water and sanitation program

Ministerio de Vivienda, Construcción y Saneamiento

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April 2005

Field Note

Alternative Technologies for Water and Sanitation Supply in Small Towns

This document is an abstract of the Proceedings of the International Symposium on Alternative Technologies for Water and Sanitation Supply in Small Towns held in Peru, in April 2004. It provides technical information on costs and requirements for the operation and maintenance of alternative technologies for small towns, as well as includes references to documents or web sites, where further information on technological options can be found.

In order to better respond to the specific needs of small towns, an International Symposium on Alternative Technologies for Water and Sanitation Supply in Small Towns was held in Lima, Peru, in April 2004.

Tabalosos small town, San Martin, Peru

Executive Summary

Water and sanitation service provision approaches have traditionally been differentiated according to rural and urban areas. The largest urban centers follow the conventional service supply through public companies or concessionaires, while rural areas apply community-based management models.

These models do not necessarily suit specific needs of small towns, which may be either too big for the rural community approach or too small to stir up the interest of public service companies operating in urban areas.

In Latin America, the proportion of inhabitants that live in small towns in comparison to the country's total population is variable: 10% in Bolivia and Chile, 15% in Peru, and 32% in Colombia. In Peru, small towns are defined in terms of population, ranging between 2,001 and 30,000 inhabitants.

Overall, water and sanitation coverage rates are lower in small towns than in medium or large urban centers. The technology to be used for the provision of water and sanitation services in small towns is part of the challenges. If water and sanitation technology similar to what is used in large urban areas is chosen, it will lead to high investments, which cannot be afforded by small towns in Latin America. It is important to choose technologies that can be operated and maintained by local service providers.

In order to better respond to the specific needs of small towns, an International Symposium on Alternative Technologies for Water and Sanitation Supply in Small Towns was held in Lima, Peru, in April 2004[1].

The symposium report includes technical information, costs and requirements for the operation and maintenance of alternative technologies for small towns. It is addressed to decision makers, municipal and local technicians and service providers. Furthermore, this report provides references to documents or web sites available on the Internet, which present detailed information about each technological option.

Concerning *water distribution*, this document describes condominial drinking water technology and the construction of structures with ferrocement for water storage.

As to *water treatment*, it outlines a series of processes that form part of the so called multiple-stage filtration (FiME, in Spanish), which is a relevant alternative to conventional processes of quick filtration that use chemical products and mechanized equipment for flocculation and filtration.

Concerning *sanitation services*, the document describes the following technological options:

Centralized or sewerage	Decentralized
• Small-bore sewerage • Condominial sewerage	• Compost or ecological latrine • Pour-flush latrine • Septic tank

For *waste water treatment*, the following criteria were provided for the selection of adequate technologies:

- Little or no energy consumption.
- Streamlining operational and maintenance procedures.
- Stable and efficient operation regardless of flow and organic load variations - a common occurrence with waste water in small towns.
- Management of the sludge generated during the process.

Among technologies meeting these criteria are stabilization ponds, bio-filters, and Upward-Flow Anaerobic Reactors (RAFA, in Spanish).

Conclusions

- There are currently interesting low-cost alternative technologies offering a level of service equivalent to that of conventional technologies that may be implemented in small towns.
- The absence of knowledge sharing and dissemination hampers its wider implementation and refinement.
- In order to provide small towns with sustainable water and sanitation services, there is more than one alternative or technology that could be useful.
- It is important to provide a range of options that shows municipal and local decision makers the advantages and disadvantages of each alternative.

[1] This event was organized by the Peruvian Vice Ministry of Construction and Sanitation, with the support of the Canadian International Development Agency (CIDA), the Swiss Agency for Development and Cooperation (SDC), the Pan-American Center for Sanitary Engineering and Environmental Sciences (CEPIS-PAHO), and the Water and Sanitation Program (WSP) administered by The World Bank. It relied on the participation of professionals and international institutions such as ACUAVALLE (Colombia), Aguas del Illimani (Bolivia), The World Bank, CARE Peru, CENTA (Spain), CIEMA-UNI (Nicaragua), CINARA (Colombia), Condominium (Brazil), COPASA (Brazil), SANBASUR (Peru), SARAR Transformación SC (Mexico) and SEDAPAL (Peru).

Experience in Latin America shows that, regardless of how complex the system may be, it is necessary to implement a regular follow-up and technical assistance process.

Lessons learned

Technology is coupled with operational and maintenance issues. There are no proper operation and maintenance modes that are low-cost by themselves. However, the application of technologies that require lower investment and operational costs makes it more likely that financial resources will be efficiently used. This can help widen the coverage of water and sanitation services in small towns and to carry out rehabilitation and extension of the system.

Notwithstanding the above, the technological aspect is just one of the variables that must be taken into consideration in the provision of sustainable water and sanitation services. It is also essential to meet the real demand of the population and to develop decentralized management models.

Often, technicians who work in small towns are not familiarized with alternative water and sanitation technologies, or are afraid that they will not be able to learn how to handle them.

Consequently, they prefer to continue designing and applying conventional technologies that are more familiar and safer for them.

On the other side, in some cases, the predominance of technical standards based on conventional technologies for urban areas can limit the development and application of alternative technologies in small towns, since they are not adapted to the local contexts.

The provision of technical assistance for the adequate management of water and sanitation services is of great importance, particularly when there are water or waste water purification processes underway. Experience in Latin America shows that, regardless of how complex the system may be, it is necessary to implement a regular follow-up and technical assistance process.

The creation of centers for technology development and promotion and technical assistance provision has a positive impact on the training of human resources, the adaptation of technology to the local area, and the effective use of those technologies. This strategy has already proved its effectiveness in Planta Experimental de Carrión de los Céspedes (PECC, Spanish abbreviation) in Andalucía, Spain, the CINARA Center in Colombia and CEPIS in Peru.

Tabalosos small town, San Martin, Peru

Water Supply through Condominial Networks

The condominial network technology for drinking water supply has been successfully implemented in the city of Parauapebas, Brazil, since 1996, and in the city of La Paz, Bolivia, since 1999.

Technology Description

The condominial model consists of two basic components:

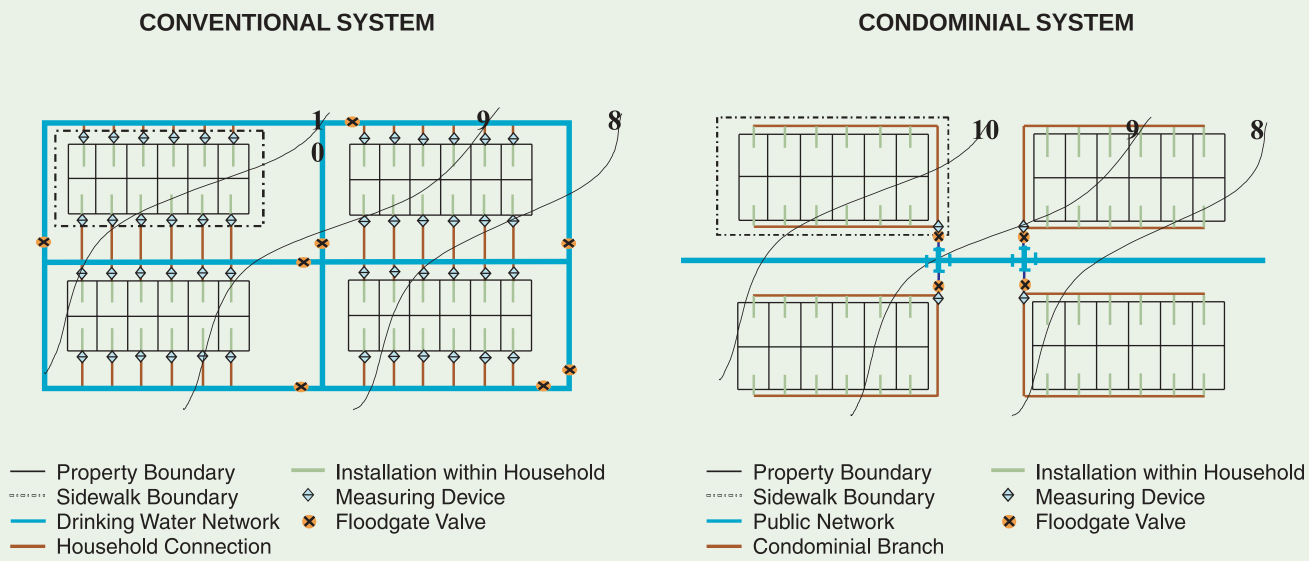
1. The model consists of extending the water and sewerage lines along sidewalks and inside lots, as opposed to in the streets. Rather than providing each individual house with a connection to the public network, a connection point is created for each group of houses (block), as if it were a condominium or apartment building, hence the name *condominial* system. This approach substantially reduces the cost of network expansion.
2. The community participates in the construction and maintenance of networks, resulting in an even greater cost reduction. Additionally, interaction with the community facilitates the adoption of actions in sanitary education.

Furthermore, this particular network design facilitates subdivision of the system into sectors comprising a specific number of blocks. Network maintenance is possible by installing a collecting chamber. In this way, only a small number of users will be affected (see picture).

Investment and Operational Costs

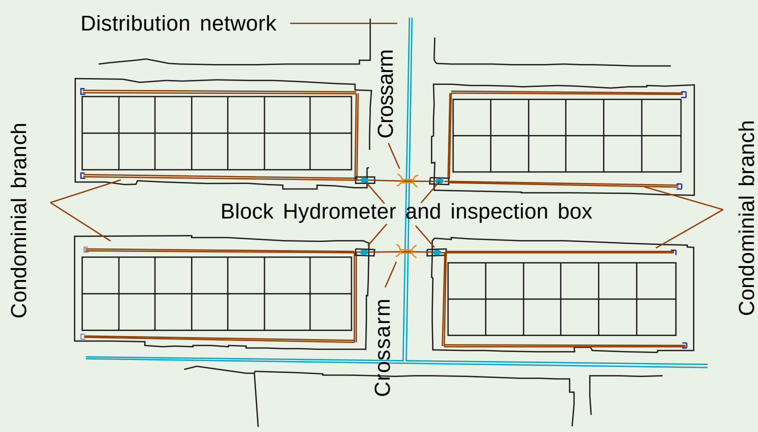
The cost of building condominial branches is significantly lower than that of conventional systems. The table in the following page compares connection costs in a project implemented in Parauapebas, Brazil.

Water Distribution Network in a Conventional and Condominial System



The simplicity of the condominial model facilitates the service control and oversight of the household connections and branches that feed each block by installing water meters at each condominium connecting point.

Description of Condominial Branches



Operation and Maintenance Experiences

The simplicity of the condominial model facilitates the service control and oversight of the household connections and branches that feed each block by installing water meters at each condominium connecting point. Similarly, service operation and maintenance becomes simpler due to the division into sectors, affecting a limited number of users when carrying out maintenance activities.

Cost Comparison Chart in Parauapebas, Brazil (Reales per connection) [2]

Item	Unit	Unit Cost (R$)	Quantity		Cost (R$)	
			Conventional	Condominial	Conventional	Condominial
20 mm PVC piping	M	3	5.5	5	8.8	8
25 mm PVC piping	M	1.6	—	5	—	9
Digging	m3	1.8	2.97	—	17.82	—
Removed /replaced concrete	m2	18.60	0.36	—	6.70	—
Removed /replaced asphalt	m2	9.7	0.63	—	6.11	—
Connection pieces	Unit	4	1	—	4	—
TOTAL COST					**43.43**	**17.00**

References:

- CONDOMINIUM Emprendimentos Ambientais Ltda. Joao da Costa Miranda Neto: mirandaneto@hotmail.com
- Foster, Vivien, 2001, Sistemas condominiales de agua y alcantarillado. Costos de implementación del modelo, Programa de Agua y Saneamiento (www.wsp.org)

[2] US$ 1= 3.13 Reales

Settled or Small-Diameter Sewerage Systems

This technology was developed in 1960 in the current Republic of Zambia. Later, these systems were installed in Australia (1962), the United States (1975), Colombia (1982), Brazil (1987) and South Africa (1989). This technology is very common in Australia and the United States where over 300 systems have been installed (www.sanicom.net).

Between 1981 and 1982, this technology was replicated in Colombia. Based on this experience, the Ministry of Economic Development of Colombia published the “Technical Guides on Settled Sewerage Systems”. The results are promising: Projects have been implemented in Granada (370 houses), San Zenón (255 houses), Tiquisio (213 houses) and Puerto Rico (326 houses).

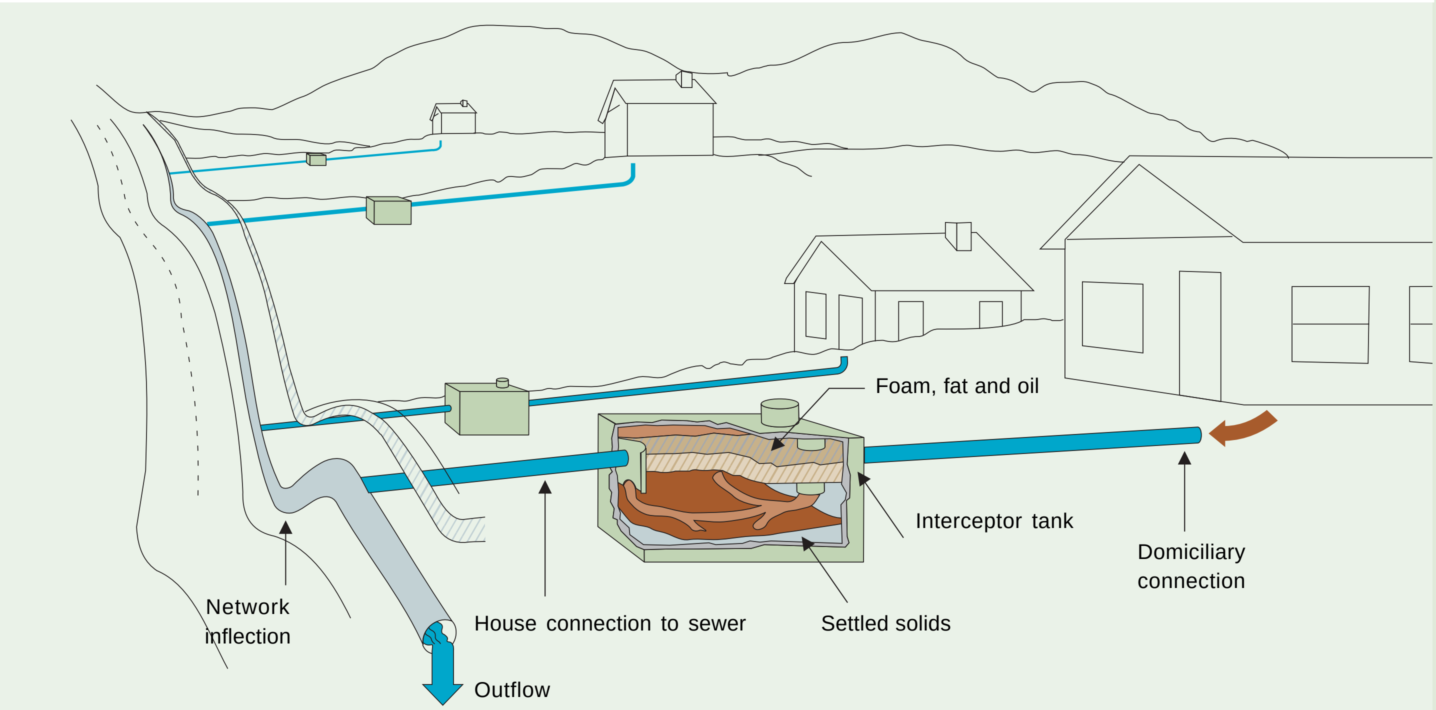
Technology Description

The settled sewerage system is a type of technology which conveys domestic waste water which has been previously settled in a septic tank, also known as a “solid interceptor tank” (see picture).

The first settled sewerage systems were designed on the basis of 100 mm.-diameter pipes laid at a minimum gradient of 1 in 200 to achieve a speed of 0.3 m/s under peak flows.

In the late 70s, the “inflective gradient” approach was developed in the United States. According to this approach, the

Settled Sewerage



Multiple-stage filtration technology consists in combining thick gravel filtration with slow sand filters. This technology has produced very good results in Colombia where there are about 50 operating plants, ten of which have been working since the mid-1980s.

sewer must follow the superficial ground contour and the flow in the sewer is allowed to vary between open channel flow and pressure (full bore). In these cases, measures must be taken to make sure that in sections where there is pressure flow, there is no refluence from the sewer to the interceptor tank. Furthermore, there must be a positive height difference between the two ends (upstream/downstream) of the sewer.

This approach is more economical than the first design, which required a specific speed at peak flows. Additionally, self-cleansing speeds are not necessary with settled sewerage since solids are retained in the interceptor tanks.

When septic tanks are located at the rear part of properties, the sewers can be laid there rather than in the road, thus resulting in considerable cost savings, as in the case of condominial networks laid in the backyard of houses. Manholes are not required at every change of direction, as cleanouts will suffice. Lift stations are only required in those areas with a very low gradient that need simple structures with a water pump rather than a more expensive sludge pump since there are no solids to be pumped.

Furthermore, when 40% of the biochemical demand of oxygen (BDO) in septic tanks is removed, the demand over treatment processes decreases proportionally.

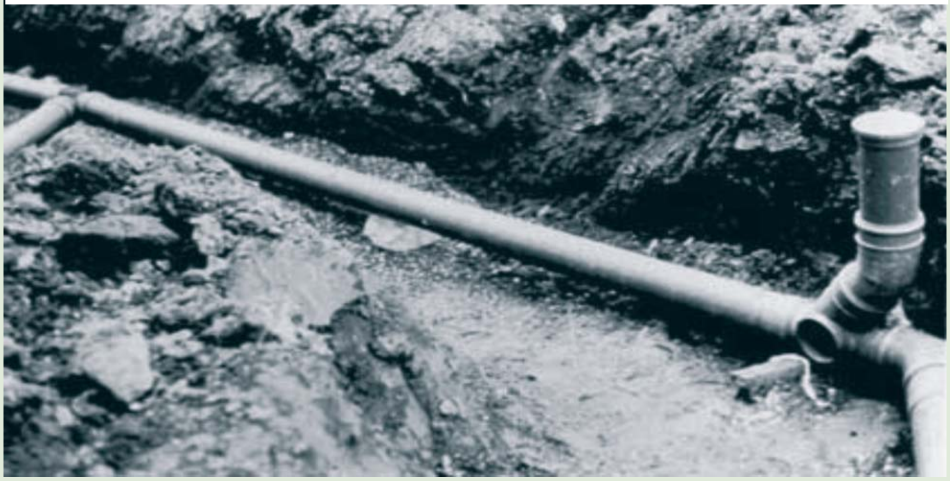
Investment and Operation Costs

Settled sewerage construction costs are typically 20% to 50% less than those of conventional sewerage in rural United States. In those areas with existing septic tanks, cost reduction will be greater (from 40% to 70%). Operation costs include, in addition to the usual maintenance cost of sewers, regular cleaning of septic tanks.

Operation and Maintenance Experiences

The operator must make sure that only connections from septic tanks are made to sewers. Furthermore, it has to be responsible for desludging septic tanks – a task that cannot be left to users because they simply would not do it, and eventually settled solids would pass through sewers causing blockages and hampering its adequate disposal and treatment. It is important to consider –as in the case of condominial systems- putting pressure on users to enlarge their houses and take up the space intended for sewers.

Inspection Register



References:
- "Guías Técnicas de Alcantarillados Decantados". Ministerio de Desarrollo Económico de Colombia
- Sanitation Connection (www.sanicon.net)
- SANBASUR. Herberth Pacheco: herberth@sanbasur.org.pe

Water Treatment without Chemical Coagulation

Multiple-Stage Filtration (MSF)

Multiple-stage filtration technology consists of combining thick gravel filtration with slow sand filters. This technology has produced very good results in Colombia where there are about 50 operating plants, ten of which have been working since the mid-1980s.

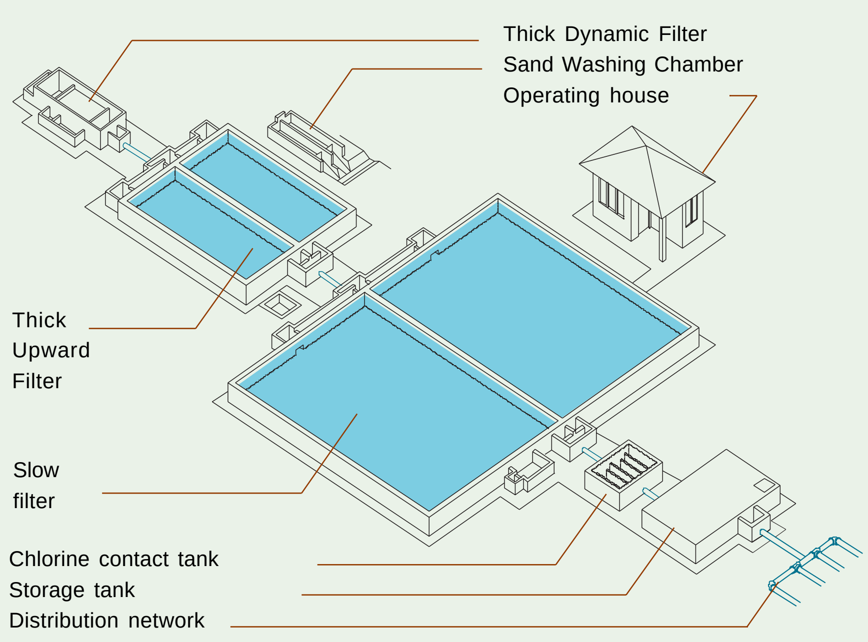
On the other side, experience shows that prior to the adoption of this technology, a detailed analysis of technical and social considerations as well as local construction and plant operation skills must be made. The availability of short- and medium-term technical assistance is a critical factor.

Technology Description

The MFS can comprise two or three filtration processes, depending on the degree of contamination of water sources. The picture shows an alternative consisting of three processes: Thick Dynamic Filters (FGDi, Spanish abbreviation), Thick Upward Layer Filters (FGAC, Spanish abbreviation) and Slow Sand Filters (FLA, Spanish Abbreviation).

The first two processes take place during the pre-treatment stage which helps reduce solute solid concentration. As water flows, the tiniest particles are eliminated on their way to the slow sand filter -known as a simple, reliable and efficient technology because it can produce low-turbidity water, free of suspended impurities and virtually free of enterobacteria, enteroviruses and protozoan cysts.

Processes involved in MSF



Thick Dynamic Filters (FGDi)

Thick dynamic filters are tanks containing a thin layer of fine gravel (6 to 13 mm) on the surface, over a thicker bed of gravel (13 to 25 mm), and a draining system at the bottom.

Water coming into the filter flows over the superficial layer of gravel horizontally. Part of the water filters through the bed and is conveyed to the next treatment stage, while the excess water returns to the original water stream. Under normal operational conditions, the layer of fine gravel retains between 70% to 80% of solute

Multiple-Stage Filtration (MSF) is cost effective in terms of initial investment, particularly in small systems where the cost of land is low and labor force and materials are available at local level.

La Quemazón, Piura, Peru

material, eventually blocking the superficial bed. If there were high concentrations of solute solids, the filtrating bed may get blocked faster, thus reducing the water flow and preventing other treatment processes.

These units must be cleaned one to two times a week, and for this purpose, the superficial bed of gravel must be scraped to remove the deposited material. This process includes base draining.

Thick Upward Layer Filter

A thick upward filter has a main compartment containing the filtrating bed of gravel. The size of gravel grains decreases as the flow moves upward. A piping system, located at the base of the structure, allows a uniform distribution of water flow inside the filter.

As the filter is used, empty spaces between gravel particles start to fill up with water retained particles. For this reason, it is necessary to carry out weekly cleanings for which quick opening valves located in the base of the structure are used. These valves open and close to remove material deposited in the filter bed.

Slow Sand Filter (FLA)

It comprises a tank with a bed of graded sand on a layer of gravel which becomes the support for the sand. The sand is confined on a drilled piping system that collects filtered water. The flow runs downward, with a very low filtration speed that can be controlled, preferably, at the tank opening.

As the filter is used, a biological layer develops on the surface as a result of the accumulation of organic and inorganic material. This layer generates the greatest discharge during the operation of the filter; therefore, cleaning consists of removing or scraping one to two cm of the filter media surface after several weeks or months, depending on factors like water turbidity and filtration speed. After several scrapings, the filter must be refilled with sand, meaning that the sand previously removed from the cleaned filter must be replaced. This must be done every three or more years.

Investment and Operation Costs

Multiple-Stage Filtration (MSF) is cost effective in terms of initial investment, particularly in small systems where the cost of land is low and labor force and materials are available at local level. However, the greatest advantage lies in its administration, operation and maintenance costs, which are significantly lower compared to costs incurred by the use and management of chemical products -like coagulants- needed in other technologies.

The CINARA institute developed a series of equations and models that help determine the investment cost of these units.

Operation and Maintenance Experiences

Tasks to be fulfilled by operators of an MSF plant include:

- Intake cleaning (daily, depending on the time of year)
- Sand trap cleaning (weekly)
- Cleaning and scraping of dynamic filters (daily or every two days)
- Cleaning and scraping of thick filters (every week)
- Washing and scraping of sand from slow filters (every two months)
- Preparation and dosage of chlorine solution
- Measurement and registration of flow when entering and leaving the plant (daily)

Experiences with this technology indicate the need of an optimal knowledge of the characteristics of the water to be treated, including its seasonal variations, and the elaboration of pilot studies prior to the implementation. It is also important to count on technical assistance during the design, construction and operation of the plant for the short and medium term.

References:

- Instituto CINARA (www.cinara.org.co). Alberto Galvis, algalvis@univalle.edu.co
- International Water and Sanitation Center (www.irc.nl)

Bio-filters

Bio-filter technology was first introduced in Latin America in Nicaragua in 1996 with the implementation of a pilot plant. A five-year monitoring process helped establish the design and construction criteria, as well as the necessary measures to ensure appropriate operation and maintenance.

Based on this experience, similar plants were built in other cities of Nicaragua, El Salvador and Honduras.

Technology Description

The bio-filter is a gravel or volcanic rock biological filter that is sown with marsh plants through which pre-treated residual waters flow horizontally or vertically. Bacteria responsible for organic matter degradation use the filtering bed surface to form a bacterial film.

The use of bio-filters requires previous treatment processes ensuring an effective removal of suspended solids, in order to prevent plugging of the filtering bed. These preliminary processes may consist of a grid, followed by a sand trap and settling units, such as an *imhoff* tank or a septic tank.

The biological treatment within the filtering bed is optional, meaning that in the filter's body there are areas with, and also without, oxygen. Plant roots allow air flow from the atmosphere to the subsoil, The use of bio-filters requires previous treatment processes ensuring an effective removal of suspended solids, in order to prevent plugging of the filtering bed.

which adds oxygen to the water increasing the number of aerobic bacteria capable of decomposing the organic matter. Water coming from the *imhoff* tank or septic chamber is uniformly distributed over the whole filtering bed surface and infiltrates into the water collection area. The water-filter feeding interval must be wide enough to allow full water infiltration and air filling into all the empty bed spaces.

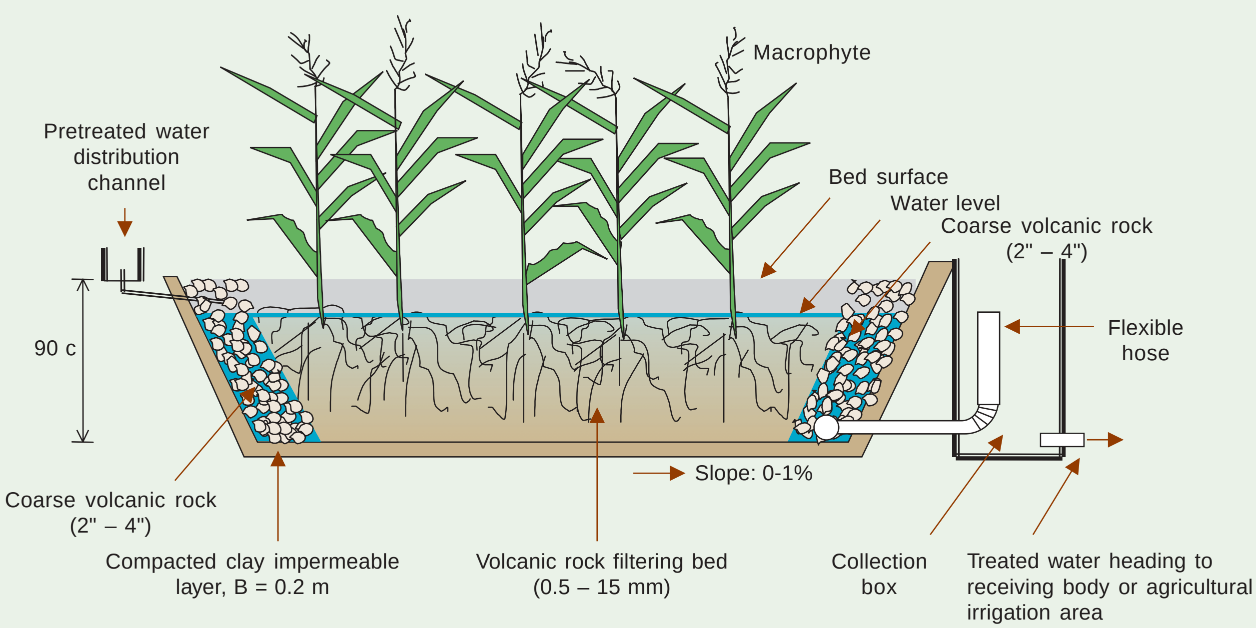
Once the biofilter has been installed and is under proper operation, it can have a long life span due to the balance between plant growth and death and bacterial mass reproduction.

The plants to be sown may be selected based on the type of contaminant that will be reduced in residual waters. Effectiveness of *platanillo*, *zacate taiwan*, reed and *tule* has been shown.

The following is a series of design reference values developed for warm climates at the Carrion de los Céspedes Experimental Plant, Andalucía (CENTA, 2004):

• *Imhoff* tank	Silting zone: hydraulic retention time = 1.5 hours at maximum flow. Digestion zone: 70 liters per equivalent inhabitant (extraction of sludge every six months).
• Bio-filter	Required surface: 5 m2 per equivalent inhabitant.

Section of a Horizontal Flow Biological Filter



Source: CENTA, 2004

Advantages	Disadvantages
• The system can operate without energy consumption. • Lack of damages due to the lack of electromechanical equipment. • Easy to operate. • Perfect integration in rural areas. • Vegetal biomass production (50 to 70 tons of dry matter/hectare year).	• A considerably large area is needed for its implementation. • Primary treatment generates sludge.

Investment and operation costs

The table below shows an example of investment and operation and maintenance costs of plants built in Central America. In general, those systems serving 1,000 or more people have a cost ranging from US$ 30 to 60 per person. In operation terms, the pilot plant of Masaya needs US$ 4 annually per person. In the plant of La Providencia, the larger number of people connected reduced the cost to US$ 1.75 annually per person.

Investment, operation and maintenance costs in Central American plants

Plant and location	Equivalent inhabitants	Investment cost (US$/inhabitant)	Operation and maintenance cost (US$/inhabitant/month)
Planta Salinas Grandes. Nicaragua	300	81.20	0.166
Planta Villa Bosco Monje. Masaya, Nicaragua	1,000	42.00	
Planta San José Las Flores. El Salvador	1,365	50.20	0.024
Planta Teupasenti. Honduras	2,812	32.80	0.01
Planta Chichigalpa. Nicaragua	8,753	45.70	0.023

Operation and Maintenance Experiences

Operation and maintenance activities are simple and low cost in every treatment stage.

- Grid and sand trap: weekly removal of coarse solids and settled matter, by using a shovel and a wheelbarrow.
- *Imhoff* tank: surface scum removal once a month by using a shovel and a wheelbarrow, and sludge removal once a year though the installed drainage pipe.
- Bio-filter: cutting of surface plants with a machete, depending on their growth cycle. Replacement of the first meter of the filtering bed when a superficial water flow is noted (every two or three years).

References:

- CIEMA-UNI, Proyecto ASTEC. Vidal Cáceres: astec@ibw.com.ni
- CENTA – Junta de Andalucía, España. Planta Experimental de Carrión de los Céspedes (www.plantacarrion-pecc.com)

The latrine consists of a toilet or "Turkish toilet" with a urinal at the front, which is linked to a receptacle through a hose, in order to convert it into fertilizer – due to its high nitrogen content and almost inexistent presence of germs as a result of its high acidity- or to pour it into an absorbing well.

Compost or Ecologic Latrine with Separate Urinal

Ecologic sanitation is a new approach to sanitation services. It revolves around four principles: recycle human excreta, prevent contamination instead of trying to control it once water and soil have been contaminated, preserve water resources, and close the nutrient cycle when recycled human excreta is used for agricultural purposes. The utilization of this type of latrine, both in periurban areas of cities like Mexico D.F. and small towns, is currently in pilot phase.

Technology Description

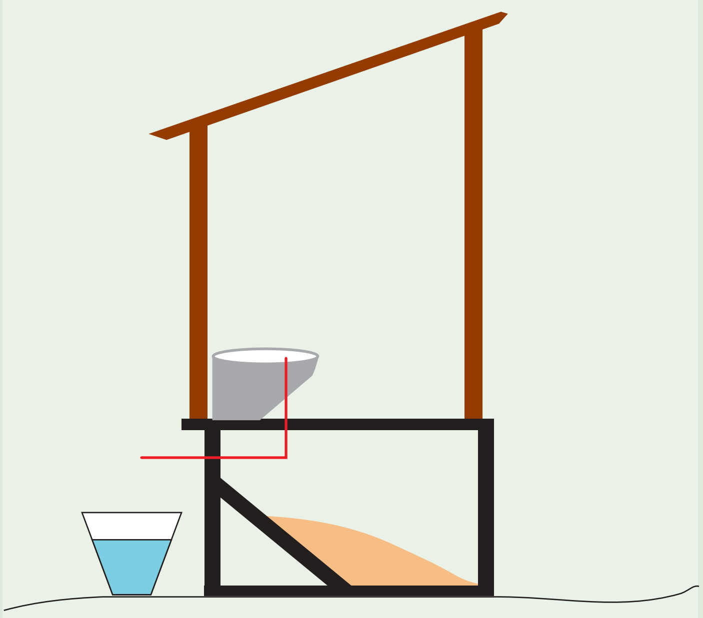
Compost or ecologic latrines isolate human excreta from urine. Dehydrated excreta may be used subsequently as fertilizer. The latrine consists of a toilet or "Turkish toilet" with a urinal at the front, which is linked to a receptacle through a hose, in order to convert it into fertilizer – due to its high nitrogen content and almost inexistent presence of germs as a result of its high acidity- or to pour it into an absorbing well. The superstructure and toilet or "Turkish toilet" are built over two chambers which are used alternatively to facilitate organic matter degradation.

The ecologic latrine can be built inside houses or in backyards.

Some criteria that must be considered when implementing ecological latrine projects are:

Advantages	Disadvantages
• It does not require or contaminate water. • Soil improvement is achieved. • Urine can be used as fertilizer. • It is appropriate in areas where there is a risk of contaminating underground water bodies. • It is appropriate for soils difficult to dig (rocky or sandy).	• Its cost is higher than that of a ventilated dry pit latrine or a pour-flush latrine due to the construction of two alternating chambers. • Urine may be isolated and treated for its final disposal. • After every use, ashes, dried sand or vegetal material must be added.

Compost or ecologic latrine



Socio-Cultural Criteria. Consideration must be given to family practices as to water management and excrement disposal, including anal cleaning practices.

Technical Criteria. For an adequate operation, the following aspects must be considered:

- Excrement is placed in one of the two chambers and, after every use, it is necessary to add approximately half a cup of sand – three quarters of sand and two of ashes or lime- in order that the inside of the chamber is dried and has a level of acidity (pH) higher than nine.
- When the chamber under use is about to get full, the deposit has to be covered with a layer of dried sand and the toilet must be placed in the empty chamber. The full chamber must be totally covered with earth in order to continue with the transformation of organic matter into harmless matter . Once the two chambers are full, the settling chamber must be emptied.
- It is advisable to have a latrine including a urinal to prevent from dampening the inside of the chamber.
- To reuse urine as fertilizer, you can dissolve it in water in a ratio of one to ten.

The latrine superstructure must meet minimum requirements in terms of size, ventilation, lighting and cleanliness.

Financial Criteria. Family's monetary contribution is critical to ensure a real and sustainable use of services.

Sanitary Service. The provision of latrines must be the result of a sanitary education process which must start before the project implementation and continue after its conclusion.

Investment and Operation Costs

The investment cost of ecological latrines is higher than that of dry latrines or pour-flush latrines. Its operation and maintenance are under the full responsibility of users.

References:

- Sanitation Connection (www.sanicon.net)
- Sarar Transformación SC. Ron Sawyer: rsawyer@laneta.apc.org
- CENCA. Juan Carlos Calizaya: jcarloscenca@terra.com.pe

ABOUT THE SERIES:

WSP Field Notes describe and analyze projects and activities in water and sanitation that provide lessons for sector leaders, administrators, and individuals tackling the water and sanitation challenges in urban and rural areas. The criteria for selection of stories included in this series are large scale impact, demonstrable sustainability, good cost recovery, replicable conditions, and leadership.

Latin America and the Caribbean Region
World Bank Office, Lima.
Alvarez Calderón No. 185,
San Isidro, Lima 27, Perú.

Phone: (511) 615-0685
Fax: (511) 615-0689
E-mail: wspandean@worldbank.org
Website: http://www.wsp.org

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Prepared by:
Alfonso Alvéstegui, consultant to the World Bank Water and Sanitation Program.

Contributed with their review:
CEPIS: Ricardo Rojas.
WSP-LAC: Francois Brikke, Rafael Vera, Oscar Castillo, Jorge Luis McGregor, and Beatriz Schippner.

Design adaptation by Fabiola Pérez-Albela 420 6881
Photography by WSP-LAC