Chapter 3

Case studies from various countries and projects

3.1

DRY SANITATION IN MORELOS, MEXICO

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Introduction

I will present the experience of César Añorve, who promotes a modified version of the Vietnamese double-vault toilet in Mexico. His innovations include an up-scale urine-diverting toilet seat and a variety of applications, including adapting the toilet within the home. Finally, I'd like to share some reflections on the economic and political implications of appropriate technologies based on our experiences, and I'll briefly describe an urban gardening project using human urine as fertilizer.

My involvement in this project began when I met César nine years ago. I work for Espacio de Salud, a Mexican non-governmental organization working in health and environment. In addition to providing training and developing programmes in appropriate technologies and sustainable agriculture, I'm the proud owner of a "dry toilet".

Background

In Mexico, half of the population goes without sewage services and more than 30% does not have water piped into their homes. On a national scale only 13% of wastewater is treated, and only 2.6% of the total is processed in treatment plants that function adequately (Merino and Guevara, 1991).

Gastrointestinal infections are the second cause of infant mortality (Centro de Estudios de Población y Salud, 1987). Many people believe these infections are caused primarily by a lack of sanitation services.

Although it's true that the lack of sanitation systems has serious community health consequences, water pollution is, nevertheless, caused in large part by conventional sanitation systems. The massive quantity of water required by these systems also contributes to the general scarcity of this vital element. Such ecological costs are unsustainable in the long term.

It's also impossible for the entire population to be connected to the sewage system. The water and financial resources available are inadequate for the entire urban population to receive potable water, piping for the evacuation of wastes and costly treatment plants for domestic wastewater in the foreseeable future.

The metropolitan area of Cuernavaca, Morelos' largest city and capital, sits in the foothills of the Chichinautzin mountains, which run west and east and separate Cuernavaca from Mexico City to the north. Heavy rains fall on the oak- and pine-covered forest in the mountains. Where topsoil removal and clear-cutting haven't taken their toll, the water filters into the subsoil and travels to natural aquifers made of volcanic rock in the subtropical valley to the south. Unfortunately, this subterranean water route is covered on the surface by houses - houses with latrines, houses with inadequate septic tanks, houses with sewage water spilling directly over ravines and even some houses which send their sewage water to treatment plants, but unfortunately the plants are seriously ineffective.

As a result, the springs, wells and irrigation canals are heavily contaminated with faecal material. This results in waterborne epidemics such as cholera, infectious hepatitis, gastroenteritis, dysentery and typhoid fever, as well as the spread of skin diseases. In one city, old sewage and potable water pipes disintegrate, leading to the mixing of the waters, and consequently a cholera epidemic. For people of few economic resources, the problem has been literally fatal.

Urbanization and industrialization during the past 20 years in the state of Morelos have caused severe ecological problems. The population density has increased dramatically since 1985, with immigration of peasants escaping the rural crisis of neighbouring states, as well as many from Mexico City escaping air pollution and the threat of another earthquake.

In the periurban areas of Morelos' major cities, the lack of adequate infrastructure results in pollution and serious health risks. Wastewater eventually mixes with irrigation water which, until 1991, was used in vegetable production.

Because of the resulting high faecal content in vegetables, the government has prohibited irrigation for vegetable production, and has threatened to destroy crops and jail peasant farmers. This affects 43,271 hectares of rich agricultural land (MOCEDMA, 1993), where rain falls for only four months out of the year. The prohibition has intensified the crisis facing farmers, prompting them to sell their lands in small parcels, which further increases urbanization without the necessary infrastructure, and thus means more pollution.

This situation has earned Morelos its reputation as one of the most polluted states in the Republic. Fortunately, its other "claim to fame" is its active social organization. Morelos has been a hotbed of popular movements since the beginning of this century, when a poor peasant farmer, Emiliano Zapata, organized other peasants and led the Revolution in southern Mexico. The revolution of the last 25 years has been that of the Roman Catholic church, with poor members embracing Liberation Theology, organizing their communities, analysing the Bible according to their reality and working towards social transformation. Still another factor is Cuernavaca's reputation as a meeting ground for intellectuals. One of the results of this rich history of struggle and organization is the formation of a variety of popular movements and organizations.

Many groups, which initially organized around themes such as social, economic and political injustice, have also become aware of environmental concerns, especially as epidemics have increasingly affected their low-income constituency. They often request technical assistance to facilitate critical analysis of the causes, problems and alternative solutions. Their promoters are trained in popular education methodologies as well as technical aspects of dry sanitation in order to facilitate analysis, and provide training and follow-up in their communities.

Morelos gives us the perfect context for successful dry sanitation: widespread gastrointestinal epidemics, agricultural crisis, lack of water infrastructure, social organization and awareness on the part of popular sectors, and finally, the ever-worsening economic crisis which Mexico has suffered for over two decades.

César Añorve, an architect and entrepreneur, began promoting the Vietnamese double-vault toilet in Mexico approximately 15 years ago. Many individuals, groups and organizations have collaborated with him over the years, at times formally, at times informally. Although we don't share a common organization or name, we do share the following general goals.

Goals (environmental, social and economic)

1 Reduce water consumption and causes of water pollution. Because the dry toilet doesn't use water it attacks the root of water pollution problems, rather than merely treating the symptoms. One argument in favour of the dry toilet is that it avoids the costs of supplying 100-150 litres of water per person per day, as well as the corresponding infrastructure costs. And it means less water will be extracted from aquifers.

2 Facilitate the capture and absorption of water on-site. Domestic grey water, without excrement, can easily be returned to local soils, thereby recharging the water table.

3 Transform excrement into soil conditioner and fertilizer. This alternative permits cities to become once again a source of cultivable land. Dried excrement mixed with soil rich in minerals typical of the Cuernavaca valley produces a high-quality arable soil. The contribution of thousands of ecological toilets could also be a "gold mine" of fertilizer for parks, as well as the city's nurseries and gardens.

4 Enhance the credibility of alternative sanitation. Our projects go beyond the idea that alternative systems should be relegated to those areas without conventional systems. By encouraging the on-site treatment of human waste and water in the countryside and in low-income urban neighbourhoods, we demonstrate what could be a practical alternative for the entire city.

5 Foster local autonomy by reducing dependence on centralized services. Often low-income communities, especially squatter settlements, organize themselves around issues which evolve into demands for services from the government. This struggle and commitment, the unity of the community, is then transformed into a dependency upon the government. The service is eventually offered, but with political, economical and environmental strings attached. On the other hand, the dry toilet is a daily reminder that people are capable of providing their own services.

6 Strengthen the local economy - explained below.

7 Demonstrate the capability of civil society to organize itself and use its imagination. Communities make suggestions, introduce modifications, and create their own promotional and training strategies. This process of empowerment spills over into other aspects of community life, including other environmental issues, health, education and democracy (Añorve, 1994).

Accomplishments

Major accomplishments include the design of the toilet seat itself, its application in urban areas, and non-technical innovations.

Toilet seat design

When César began promoting the dry toilet, he advocated squatting (as in the original Vietnamese model) rather than using seats, for health reasons. However, the users convinced him that adopting the dry toilet was enough of a change for them - he should not push his luck. César therefore began converting 16 litre buckets, wrapping them with chicken wire to which cement was applied, and adding a funnel for urine diversion.

A period of experimentation with several models and different materials followed. However, interest and sales increased greatly in 1989, when he began to produce colourful toilet seats which copied the "conventional" design. We feel this innovation has been a major factor in the success of the project, as even the poorest sectors aspire to modern conveniences.

Client feedback brought modifications in the seat design. They complained that the first model was too small - they commented that it was probably adequate for César, but César is quite short!

Women were concerned that the urine diverter was also too small - aiming was difficult! The second was too big and much too heavy, but the latest is both of adequate size and aesthetically pleasing. Men, however, complain about having to sit down while urinating, so César again adapted the technology, designing a domestic urinal.

César designs and builds his own moulds for use in his seat production workshop, and he also distributes them to other independent workshops. After drawing the toilet seat design, a prototype is built by hand out of pressed board and covered with plaster. After drying, César applies fibreglass, in order to produce the mould.

The vast majority of toilet seats produced in his workshop are made of cement and sand. He has also used fibreglass or a polyester resin/sand mixture to make high-quality, extra-light seats. However, these are quite costly and more harmful to the environment.

A few ceramic seats have also been produced, but financial resources have been inadequate for purchasing an industrial kiln. A plastic recycling workshop is interested in producing recycled plastic seats, but the required mould (made of steel) is financially prohibitive.

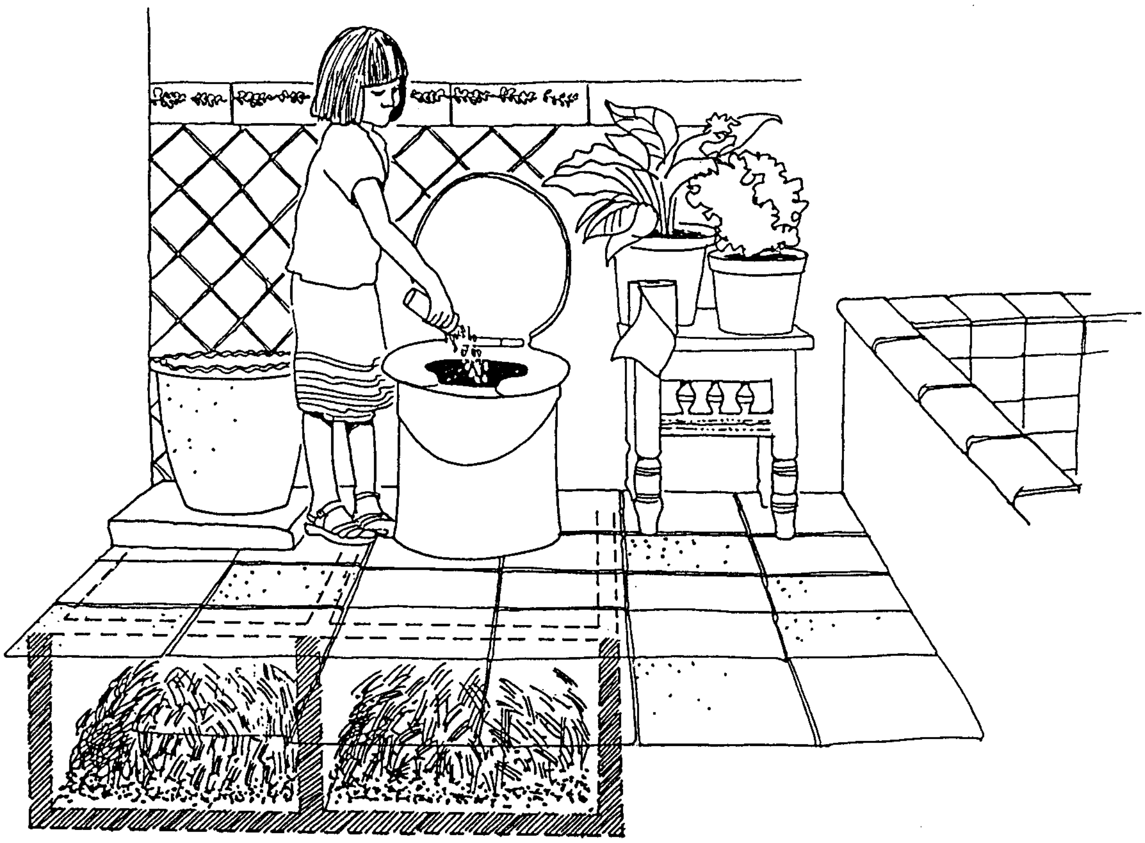

Figure 1. The bathroom in César Anorve´s house in Cuernavaca: A double-vault, dehydrating toilet with urine diversion. The seat-riser is movable. The vault not in use is covered with a ceramic tile and a pot for used toilet paper.

The toilets are sold for 130 pesos (less than US$18). The cost of production is 80 pesos. The profit is used to cover expenses incurred in providing technical assistance. An average of 30 toilet seats are produced per week in the workshop in Cuernavaca, which employs up to seven persons who produce, paint and deliver the seats, as well as giving technical assistance and follow-up.
The total cost for building the entire structure, with brick chambers and superstructure plus a cement roof is approximately $1200 Mexican pesos (US$150+), including materials and labour. This is about 1/10 of its conventional counterpart when compared on a domestic level. If the cost of sewage pipes in the streets, treatment plants etc. is added to this equation, the difference increases astronomically.

Application of the technology

We have explored and documented several applications: in rural areas, suburban zones, cities, residential neighbourhoods and even apartments. We encourage architectural inventiveness in order to offer civil society a broader range of options, for example dry toilets incorporated into the interior of a house in an urban setting. At the same time, we attempt to enrich the range of technical solutions according to the characteristics of the physical setting (slope, flooding etc.). We also try to diversify appropriate technologies and create access channels or stimulate existing networks.

Our state of Morelos offers a clear example of the adaptability of this technology to several climates. Dry latrines have been installed in each of the 36 municipalities, within three distinct climatic zones.

Northern Morelos has a humid, temperate climate, with an altitude of 2000-3000 m above sea level, an average temperature between 9 and 12°C, and precipitation over 1400 mm annually. Central Morelos drops to approximately 1500 m. It has a humid, semitropical climate with rainfall averaging between 1000 and 1500 mm and a mean temperature between 18 and 21°C. Dropping even further towards sea level, in southern Morelos rainfall averages less than 900 mm, with a mean temperature greater than 22°C (Mariaca and Narváez, 1992).

Most of the demand for dry sanitation comes from rural communities without access to water or conventional systems and/or financial resources to pay for them. Before installing the toilets, we encourage users to analyse other factors. Women tend to recognize environmental and health advantages more readily than men, and are also more active in organization and promotion. This is not surprising, as they are usually responsible for their children's health as well as managing household affairs.

Rural communities are not restricted by building codes. Although it wasn't our intention to win official recognition (by including the dry toilet technology within municipal regulations), in 1993 César obtained unanimous authorization by the Cuernavaca Public Works Department to build a house with a dry sanitation system. During this process, the State of Morelos Environmental Minister was consulted. Not only did she recommend the decision, but she also offered her support in carrying out bacterial analysis.

At this point we were able to seriously contemplate the inclusion of dry toilets within existing building codes in an innovative manner. Under César's leadership, the Morelos Academy of Architects is planning to lobby the state's municipal governments to modify their codes. The group also intends to invite the other state academies to do the same. Other proposals include incentives to users of appropriate technologies (such as dry toilets, as well as constructed wetlands and rainwater cisterns), through the reduction of water fees and/or tax incentives.

A key element which distinguishes our project from government proposals, as well as several independent projects, is that we believe the dry toilet is not only suitable but necessary in urban areas. It is not just a substitute when other water-based conventional services are not available, but rather it is a radical alternative to our current relationship with water (Añorve, 1994).
In order to encourage this transformation, César has developed modifications to the double-chamber model, including the design of a smaller, mobile system which reuses old washing machines and can be placed in a conventional bathroom, with plastic barrels fitted for large parties, picnics etc.

It is impossible to identify a precise figure for the number of dry toilets built in Mexico. César's workshop in Morelos has sold more than 6000 toilet seats, but many other actors are also involved.

At the federal government level the Secretary of Health and the Mexican Institute of Social Security have contracted César to train their promoters. One hundred local promoters in each of the three zones (north, centre and south) were trained last year, and 300 more will be trained this year. Under the Institute's programme 1337 toilets were built in 17 states in the past year. They also plan to establish local toilet seat workshops.

At the other extreme, approximately 90,000 dry toilets have been built in the state of Oaxaca alone. A project for a million toilets to be built in the state of Mexico is also at the planning stage, as well as 10,000 in the municipality of Acapulco, Guerrero.

Other innovations

César's vision of the project's self-financing capacity can be compared to the engagement of two cogwheels which represent small economic cycles. The first cycle is the toilet seat construction workshop, which employs from five to seven persons. The second is made up of masonry workers which build the toilets' superstructure.
The first cycle's income comes exclusively from the sale of the toilet seats. The cost covers the organization of training workshops and follow-up. The second cycle is financed by the users as they contract a mason to construct their toilet. The first cycle is a small, family-size business, whereas the second is a local labour exchange.

These two cycles are financially autonomous, but organically linked. The fact that a demand exists for the urine-diverting toilets does not mean that a large industry would be successful in exploiting it. Commercialization without personal follow-up - an inconceivable concept for industrial-scale economies - can only harm and even destroy the project.

The importance of follow-up after carrying out any alternative project cannot be emphasized enough, especially with the dry toilet. First, the necessary confidence in this "new" technology is obtained only after a trial period of several years, before a substantial number of community members will request it. Second, follow-up is a hygienic imperative. Although the technology is incredibly simple, the user must acquire certain habits which are consolidated only over time.

We have chosen to limit ourselves to small-scale production, in which the producer must also promote its use, organize neighbourhood groups interested in adopting dry sanitation, and offer training workshops for masons. In other words, the first cycle will rotate only if the second is put into motion, hence the image of two cogwheels organically linking the two cycles (Añorve, 1994).

One of our most important objectives is to strengthen local economies by creating local jobs, using local materials, requiring minimal investment and using simple technology. We feel the market should respond to the necessities and aspirations of local communities, protecting the strong ties which still exist in Mexico despite the overwhelming effects of globalization.

Our model offers the alternative of local, independent workshops, now numbering 15 across the country, as an alternative to migration, underemployment and exploitative wages. Our project is a very modest contribution: it is NOT a charity and would never work as such. It is a model which ensures environmental sustainability through the empowerment of local communities and economies.

We believe innovations related to the ecological dry toilet - and to industrial sanitation technology in general - should be institutional, political and economic, and not merely technical. In this sense our project has explored only an infinitely small part of the spectrum of these possible innovations. Raising public awareness is vital - through conferences, newspaper articles, political cartoons, public debates, colourful posters and other educational materials (Añorve, 1994).

Problems

In 1994, the Oaxacan state government and a businessman undertook a project which included large-scale toilet seat production. In addition to the fact that this destroyed the three small-scale toilet seat workshops based in the city of Oaxaca, this initiative produced the false expectation that industrial production would substitute the economic mini-cycles. The government established the objective of building 15,000 toilets within the first year, and 30,000 in each year afterwards.

We believe this project has two objectives: to increase the wealth of the functionaries involved, and to obtain political control. The project never goes beyond giving away the toilets, and lacks serious training and follow-up. Non-governmental organizations have had to step in to rescue this project, as the self-financing, autonomous local workshops have been destroyed.

Rather than the government facilitating the process, i.e. lubricating the motor, its role has been to destroy the initiatives of civil society. The local workshops cannot compete with international financing organizations and the government. Without the income from the sale of toilets, they cannot give away their expertise, training and follow-up (Añorve, 1994).

Another example of how corrupt government destroys local initiatives, rather than encouraging them: in a squatter settlement on the outskirts of Cuernavaca, a neighbourhood group asked for credit from the state public works department in order to build dry latrines. Although the petition was eventually approved, the department "underdelivered" materials (i.e. they stole them), and replaced the skilled mason workers with their own unskilled, lower-paid bricklayers, skimming the excess pay for themselves. As a result, the toilets were left unfinished and incorrectly built, and the residents disgusted and doubtful of the toilets. Nevertheless, the community had the organizational capacity to unite in protest, to finish the majority of the toilets without credit, and to denounce the repayment of the loan.

An example of the way that government doesn't recognize the environmental benefits of dry sanitation but uses it to co-opt communities which have suffered years of inadequate housing and services: 10,000 dry toilets are planned for the municipality of Acapulco, Guerrero. Strangely enough, the design includes a tube "for later connection to the sewage system".

The danger of these projects is that they will become a huge failure, and this impact will spread far beyond that of the geographical limits of these massive projects. It is always much easier to work in communities where dry toilets are an unknown, rather than where they are a known failure.

Plans

Plans for the future include:

- ♦ Link users to community composting centres, in which a service industry is created which empties the chambers, delivers the excrement and even urine to the local composting centre, then later sells the compost. These centres are slowly but surely emerging within the state, and thus far all are convinced of the value of the dry latrine. Some are already composting the product as a part of their work, but this has not yet led to the creation of a service business.
- ♦ Publish several materials, including:
  - + a brief how-to manual on building constructed wetlands for the on-site treatment of domestic grey water;
  - + a summary of our use of participatory methodologies and strategies for use by civil and governmental organizations working in alternative sanitation;
  - + a manual on the agricultural use of the dried excrement as well as urine, facilitated by laboratory analysis. This would include appropriate uses for different plants, and recommendations for processing and use. These products are already being used for agricultural purposes within the state, both in household gardens as well as in the larger-scale production of maize and eggplant, but not on a widespread basis.

Urine has been used in urban, family-scale gardening for a number of years through the ANADEGES network in Mexico City. This project, managed by CEDICAR, an ANADEGES affiliate, involves 1200 families who are producing vegetables in reused containers with worm-composted kitchen waste, urine and leaves.

The participants are restricted by lack of land and financial resources for investing in infrastructure or inputs such as synthetic fertilizers or pesticides. Many also require lightweight growing containers, as the only available space for vegetable production is on top of their roofs.

The plants are grown in used buckets or tyres, filled with deciduous tree leaves, leaving space for a 3-5 cm layer of worm compost, into which seeds or seedlings are placed. A drainage hole is perforated in the side of the container, 5-10 cm from the bottom. Urine, an excellent source of nitrogen, is fermented and then diluted before use in watering the plants. (Ceballos, 1997).

Conclusions

Those of us who participate in this project share the idea that a radical transformation in sanitation is urgent and possible. We believe that it is necessary to change society's current perceptions. The only way to do this is through educating each other - talking with neighbours, farmers, business people, housewives and children - so that we can all, together, change our relationship with water.

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3.2

EL SALVADOR EXPERIENCE WITH DRY SANITATION

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Introduction

Environmental factors, including a high water table, a long coastal area and low water coverage, have forced the Government of El Salvador to consider the construction of dry toilets. These require no water for the disposal of faeces and achieve almost zero discharge, therefore do not contaminate the scarce drinking water. Dry sanitation systems require that the users have a good understanding of the process involved and critical involvement in their use and maintenance. The dry sanitation concept applied in El Salvador is based on urine diversion, pathogen destruction and reuse. In this approach public health and handling problems are reduced step by step: urine and faeces are collected separately, faeces go through a process of pathogen destruction based on dehydration, and both urine and faeces can be reused.

The double-vault dehydrating toilet: the Hermosa Provincia experience

In 1987, the Ministry of Health of El Salvador, with support from UNICEF, initiated a pilot project on the Pacific coast to determine the cultural acceptance and feasibility of the double-vault dehydrating toilet with urine diversion, called in Spanish *Letrina Abonera Seca Familiar* (LASF). The LASF toilet is based on the Vietnamese double-vault toilet and was introduced in Guatemala in the late 1970s by CEMAT - Centro Mesoamericano de Estudios sobre Technolog'a Apropiada - an NGO based in Guatemala. Since then in El Salvador alone more than 100,000 of these toilets have been built.

The LASF toilet is built above ground. The receptacle consists of two compartments (vaults), each with a volume of about 0.6 m^3. On top of each vault there is a seat with a urine collector. From the collector the urine flows via a pipe into a soakpit or a jar. In one of the walls there are hatch-covered openings for the removal of the dehydrated faeces, which fall straight down into the vault. After using the toilet the user sprinkles a bulking agent consisting of ashes, lime or soil/lime or sawdust/lime mixture over the faeces. The vault thus receives only faeces and bulking agent. The paper used for anal cleansing is also recommended to be thrown into the vault, although according to Latin tradition the paper is placed in a special container next to the toilet and burnt. Every week the contents of the vault should be stirred with a stick and more ashes added.

When the first vault is nearly full, it should be topped up with soil and the seat closed. The second vault should now be used. A year later, or when the second vault is nearly full, the first vault is opened. It will by now contain about 250 kg of a completely odourless, relatively safe dehydrated faecal material. The double chamber construction allows the contents on one side to dry adequately while the family continues to use the other vault. Studies by CEMAT and the Ministry of Health indicate that after about eight months of storage there is a rapid decline in *Ascaris* eggs, reaching zero after 10-12 months. Harmful bacteria are less hardy than *Ascaris* eggs and are not likely to survive in conditions where *Ascaris* eggs cannot.

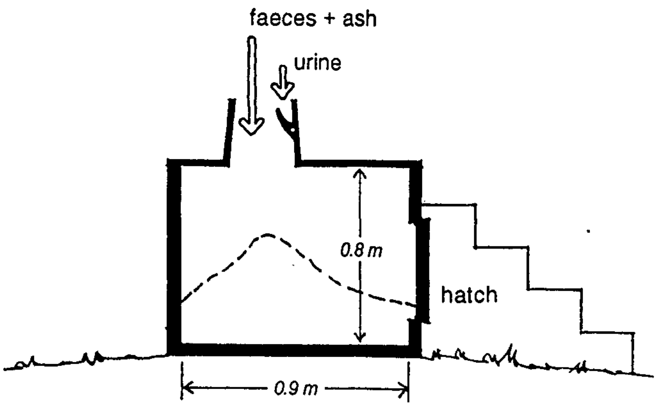

Figure 1. LASF toilet - section

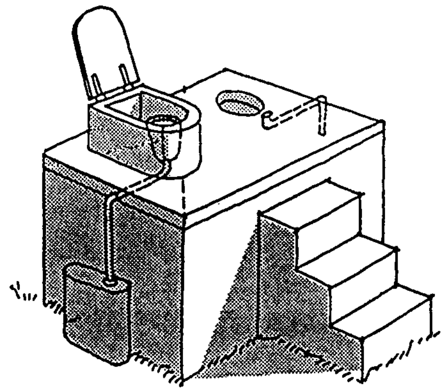

Figure 2. LASF toilet

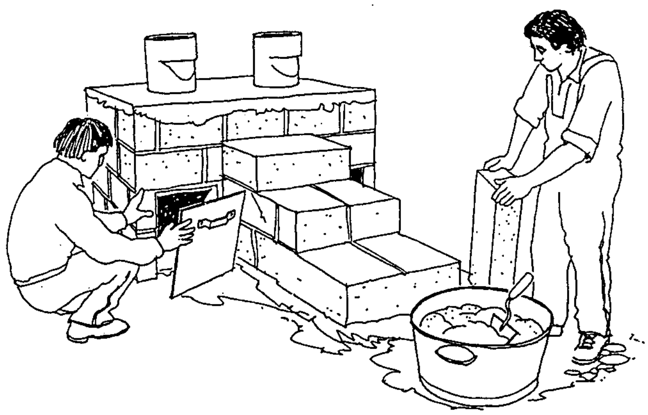

Figure 3. Hatch opening for the removal of dehydrated faeces

This type of sanitation system has been built in rural as well as urban areas of El Salvador. A project worth mentioning is the one developed in Hermosa Provincia, a low-income, high-density urban squatter community in the centre of San Salvador, the capital. Here all the 130 households built LASF toilets five years ago. There is little space between the houses and sometimes no backyards. The LASF is therefore usually attached to the house, sometimes even inside. As result of excellent community organization and adequate education, all units are functioning extremely well. As ash is not available in sufficient quantities, households sprinkle a mixture of sawdust and lime over the faeces. The dehydrated faeces are used to reclaim wasteland and in a nursery garden.

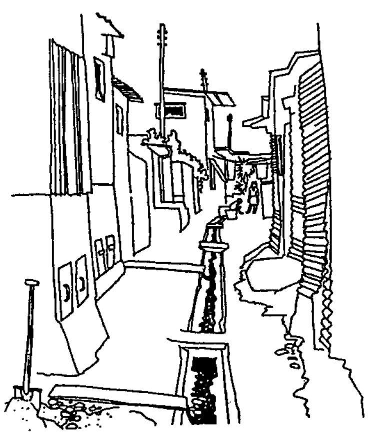

Figure 4. LASF toilet in Hermosa Provincia

Solar-heated dehydrating toilets: the Tecpan experience

On the basis of the experience gained over the past nine years with the LASF toilet a pilot project aimed at improving and expanding the concept was implemented in Tecpan, a semirural community near San Salvador, by the Ministry of Health, UNICEF and with technical assistance from SANRES, an R&D programme funded by Sida. The project attempts to answer the following two questions:

- Can the LASF concept be adapted to a single-chamber toilet?
- Does the addition of a solar-heat collector and/or an evapotranspiration bed improve the performance of an LASF toilet?

A total of 36 units have been tested. The types built were:

Type 1 - single chamber, urine diversion and solar heat collectors (Fig. 5);

Type 2 - single chamber, urine diversion, solar heat collector and evapotranspiration bed;

Type 3 - same as type 1, with vent pipe;

Type 4 - single chamber, urine diversion and solar heat collector, smaller volume and a pusher (Fig. 6).

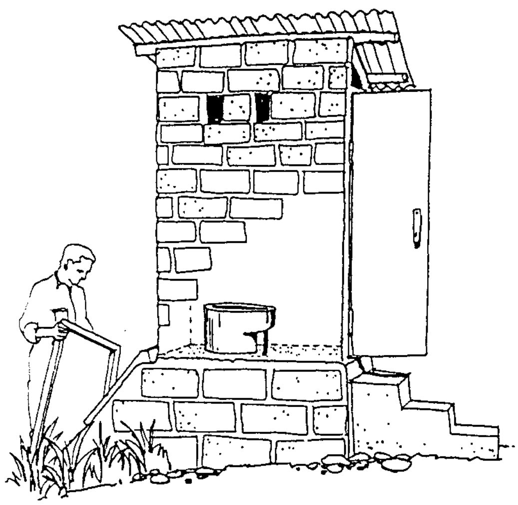

Figure 5. The Tecpan model

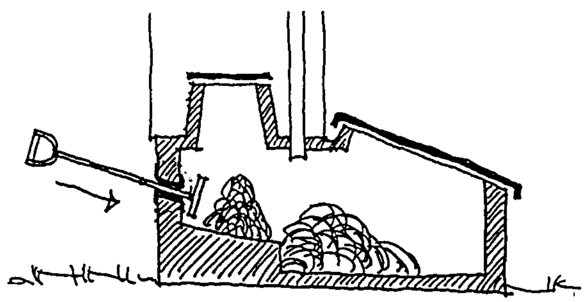

Figure 6. The Tecpan model with pusher model

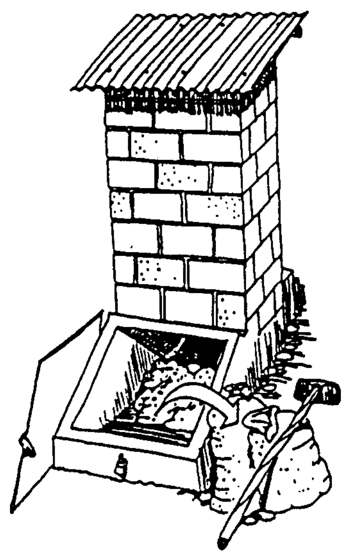

Figure 7. Management of the Tecpan

Toilets are managed as follows:

- ♦ They are used like regular LASF toilets. The input into the single chamber consists of human excreta and wood ash and/or a soil/lime mixture. Urine is piped into a small soakpit close to the toilet. Toilet paper is placed in a bag or box next to the seat and burnt periodically, according to normal practice in El Salvador.

- ♦ Every one or two weeks the lid acting as a solar-heat collector is removed and the pile of faeces plus ash/lime/soil accumulated under the seat riser is shifted to the rear of the chamber.
- ♦ Once every two months the pile at the rear of the chamber is shifted to a sack and stored outside the toilet for at least 6 months.

From the project the following conclusions are drawn:

* The test toilets are completely odour-free and there is no fly-breeding.
* The addition of the vent pipe showed no change in the improvement of the performance of the sanitation system.
* The 'pusher' is well accepted by the users.
* The operational instructions have been followed by all the participating households, and both toilet types have worked very well.
* The Type 2 toilets with evapotranspiration bed show a tendency to be marginally more humid - less dry, rather, as these toilets are extremely dry when operated properly.
* The storage of the dehydrated faeces has been reported as a problem for some households.

The project demonstrates that careful management of a toilet, resulting from high motivation and understanding on the part of the families involved, can make an extremely simple technology work very well. It is clear that if the same level of care can be maintained over time and at scale, then the dimensions of the toilet chamber can be drastically reduced with the inevitable cost savings. Also, the odour-free character of the toilet suggests that they can be attached to the house, leading to further savings.

In the long term the success of this approach will depend on a successful communication strategy to translate the high motivation of a pilot project to a large-scale project. In Tecpan, because people saw rapid results they were prepared to overcome their initial reluctance to move the pile, and now accept it as normal.

Urine diversion in pit latrines: Chicuma experience

An interesting spin-off of our project in El Salvador is the finding that conventional pit toilets function much better with urine diversion; a test project was therefore carried out by ProVida, an innovative national NGO supported by UNICEF, in the rural community of Chicuma, Chalatenango.

In this community, more than two years ago, 48 single pit latrines with urine diversion were built. A special toilet seat with a collector is used to separate urine from faeces. The urine is channelled to an absorption pit. Pit depth varied from 1.5 to 2.0 m. An evaluation study carried out in May 1997 revealed that:

* only in 28 units was urine diversion achieved properly, owing to poor construction;
* ash was added to all units;

* complete dryness was not possible to achieve, even when urine diversion was functioning properly, owing to geological conditions.

The findings indicate that urine diversion and the addition of ash to increase pH improves performance of the pit latrine, even if complete dryness is not possible to achieve. The improvements are impressive: no smells, no flies, no mosquitoes. The cost per unit is US$55 without the superstructure.

Risk of not involving communities

The government of El Salvador, through the Social Investment Fund and financed by the Inter-American Development Bank, built 50,263 LASF units between 1992 and 1994, with a total investment of US$12.5 million. These units were built by contractors without community participation and little or no training. An evaluation carried out in a sample of 6,380 families in 1994 showed that only 39% of the units were being used adequately, 25% were being used inadequately and 36% were not used at all. These findings led to the development of a hygiene education strategy that focuses on personal education for all family members through home visits, the participation of organized women in the implementation of the whole educational process, education materials and monitoring, and evaluation instruments easy to be applied by all actors at the various levels. The impact of this hygiene education model was significant: in a sample of 389 families it was found that only 20% were using the units properly, 58% were using them improperly, and 22% were not using them at all. However, after the completion of the first education module the percentage of proper use increased to 72%, and the latrines that were being used improperly or not at all decreased to 18% and 10%, respectively. The lesson learnt from this whole process is that the problem of dry sanitation is not the technology itself, but the interaction between technology and user. Therefore, the promotion of this type of technology should be on a personal and family basis, in order to provide advice on the spot, stressing the need to achieve behavioural changes, proper use and maintenance.

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ZERO-DISCHARGE SANITATION FOR PACIFIC ISLANDS AND OTHER TROPICAL COASTAL ENVIRONMENTS

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Introduction

The failure of conventional sanitation technologies to prevent pollution is of particular concern in small islands, coastal areas, places adjacent to fresh water resources and anywhere with a high water table. For example, nearly every Pacific island nation has identified critical environmental problems resulting from conventional sewage treatment technologies, including algal blooms and eutrophication in lagoons, dying coral reefs and contaminated drinking water. Only a policy of zero-discharge – based upon the presumption that excreta management should not interfere with natural systems, rather than that the environment has the capacity to assimilate contamination – can protect sensitive island environments. Several composting toilet designs have been demonstrated in Pacific island countries which overcome humid conditions to achieve zero-discharge of pollutants while requiring relatively low maintenance from users.

Sewage pollution in the Pacific islands region

In a region of small islands occupying 30 million square kilometers of ocean, it is easy to see that the wellbeing of its people is directly tied to the health of the marine environment. The natural resources provided by coastal habitats and the open ocean are the basis for traditional subsistence as well as growing commercial activity. With the exception of highland regions of Papua New Guinea and elsewhere in Melanesia, the cultures and identities of Pacific island peoples are intimately linked with the ocean. However, because their coastal ecosystems are extremely sensitive to changes in water quality, and because the groundwater tables in populated areas are generally high, Pacific islands are extremely vulnerable to pollution.

Coral reefs, for example, are particularly threatened, since corals flourish in nutrient-poor waters and suffer severe effects from the influx of nutrients from sewage discharges in several ways. The increased BOD which accompanies high levels of nutrients starves reef creatures of oxygen and encourages the growth of aquatic plants, which both benefit from the high nutrient levels and can tolerate low amounts of oxygen. Seaweeds and the growth of phytoplankton populations, which also benefit from the nutrients, prevent light reaching the corals, harming them still further. In addition, large quantities of nitrates are toxic to corals, and high concentrations of phosphates can harm coral directly by inhibiting skeletal growth.

The failure of sanitation technologies to prevent pollution is therefore of particular concern to Pacific island countries. Nearly every Pacific island nation has identified critical environmental and public health problems resulting from the disposal of human excreta. These have included algal blooms and eutrophication in lagoons, dying reefs, contaminated drinking water wells and outbreaks of gastrointestinal disease and cholera. The causes of this pollution include overflowing latrines and privies, water-seal toilets, septic systems, sewage treatment plants, and the complete lack of sanitation facilities in some places.

In fact, pollution from human sewage (along with household garbage) has been labelled by the South Pacific Regional Environment Programme (SPREP) as "perhaps the foremost regional environmental problem of the decade". For example, SPREP's Land-Based Pollutants Inventory found that the discharge of domestic wastes is the largest contributor of contaminants to the region's marine environment, fouling coastal waters with an estimated 21,675 tonnes of BOD, 12,252 tonnes of suspended solids, 10499 tonnes of nitrogen and 1,250 tonnes of phosphorus annually.

Groundwater pollution problems, which were reported by 85% of Pacific island countries in 1991, often also result from conventional on-site disposal technologies that allow nutrients and pathogens to migrate through porous soils into shallow aquifers. In addition to the threat of contamination, the use of water to flush away human excreta can tax valuable and limited freshwater resources. On low-lying atolls and the coastal areas of larger islands this not only wastes water directly, but can cause salt water incursion to the water table. Water shortages were reported by 70% of the region's countries in 1991. Salt water is used for flushing in some systems, such as on Tarawa in the country of Kiribati, but these systems have been notoriously problematic.

The following examples from Pacific island countries serve to illustrate sewage pollution problems across the region:

- On Raratonga in the Cook Islands, contamination from septic systems is carried laterally by groundwater into the lagoon, contributing to increased algal growth, and high levels of gastrointestinal disease on the country's atolls has raised concern that the use of pour-flush toilets has polluted the shallow water table.
- Central wastewater treatment plants on Pohnpei and Chuuk in the Federated States of Micronesia, constructed with funds from the US Environmental Protection Agency during the 1970s, have failed owing to the lack of trained personnel and funding for maintenance, discharging essentially raw sewage much of the time. Poorly designed septic systems and simple water-sealed toilets are frequently found directly adjacent to coastal waters, and latrines which overflow in heavy rains are common in rural areas. There is a high prevalence of water-related disease throughout the country, and a number of studies have found sewage pollution to be adversely affecting coral reefs.
- In Kiribati, high population densities and rapid urbanization have led to groundwater pollution from the percolation of sewage down into the water table, as well as contamination of lagoon water, beaches and shellfish with microorganisms from human excrement.
- In the Marshall Islands, signs of eutrophication resulting from sewage disposal are evident adjacent to settlements, and particularly near urban centres. Stagnation of lagoon waters, reef degradation and fish kills resulting from the low levels of oxygen have been well documented over the years. There is significant groundwater pollution in the Marshall Islands as well. The Marshall Islands government estimates that over 75% of the rural wells tested are contaminated with coliforms and other bacteria. Cholera, typhoid and various diarrhoeal disorders all occur.

The need for zero discharge

The severe pollution problems in Pacific islands – despite the relatively widespread application of conventional sanitation technologies – offer testimony to the failure of the conventional approach, which seeks to control pollution after it has been created rather than prevent it in the first place. Conventional sanitation technologies simply attempt to send what are considered unwanted wastes underground, or to bodies of water where we cannot see nor accurately predict their impact. This may partially reduce pollution and health problems or shift them from one place to another, but it does not solve them. Instead, it is assumed that the pollution which results from these technologies can be safely assimilated by the environment.

Although it will always be difficult to ascertain the effects of a particular sewage discharge, particularly before they occur, the cumulative evidence of widespread environmental effects resulting from the use of conventional sewage treatment technologies in the Pacific and elsewhere suggests that reliance on the assimilative capacity of the environment has been a mistake. Only a policy of zero discharge of pollution to the environment can guarantee the protection of sensitive environments and human health.

Rather than devoting limited funds to researching how much damage the environment can handle, we should instead find out how little damage we can do. The assumption that the environment has the capacity to assimilate the pollutants in sewage must be replaced by the presumption that the management of human excreta should not interfere with natural systems.

Sewage pollution can be prevented by recovering human excreta as resources rather than disposing of them as waste. In natural systems there is no waste: all the products of living things are used as raw materials by others. By flushing excreta down the toilet and turning them into sewage, we break this cycling of nutrients and create pollution problems. If instead we mimic nature by turning what had been waste into valuable products, there will be no sewage of which to dispose.

This approach is far from radical. Leaders from around the world called for just such changes in 1994, at the Global Conference On The Sustainable Development Of Small Island Developing States in Barbados:

"Given that long-term disposal options are limited and will constrain sustainable development, small island developing states will need to look for ways of minimizing and/or converting wastes, such as sewage, into a resource (e.g. fertilizer for agriculture)."_

Although adopting this new approach will require a change in attitude, it will not require a sacrifice of sanitation or aesthetic standards. As described below, technologies are available which can prevent sewage pollution and still offer the modern convenience of conventional technologies.

Pilot zero-discharge sanitation projects on Pacific islands

In addition to protecting public health and sensitive coastal environments, major design constraints imposed upon sanitation technologies for use in the Pacific include a very humid climate and sociocultural conditions in which a high level of maintenance should generally not be expected from users. Several different composting toilet designs have been demonstrated on Pacific islands in recent years, which attempt to overcome these constraints to achieve zero-discharge and low maintenance requirements.

The CCD Toilet

Following on work initially conducted by Greenpeace in the Federated States of Micronesia in 1992, the Center for Clean Development, a US-based NGO, has developed an aerobic double-vault composting (DVC) toilet with very low maintenance requirements in which faeces are transformed into humus and the urine is evaporated. The CCD toilet consists of two watertight chambers, which may be built above ground or partially buried. As with other DVC toilets, excreta are deposited into one of the two chambers, which are used alternately to provide an extended period of composting time before the humus is removed for use as a soil conditioner.

What distinguishes the design from other DVC toilets is that it promotes aerobic conditions in the digestion chambers without the need for manual turning. Excreta fall on to a mat woven from coconut palm fronds resting on top of a nylon fishing net suspended inside the digestion chamber, separating the solids from the liquids. This "false floor" allows air to penetrate the compost pile from all sides. Bulking agents, such as coconut husks, small wood chips, leaves or vegetable food scraps, are added periodically through the toilet pedestal or squat plate, both to provide a source of carbon and to increase the porosity of the pile so that air can penetrate all the way through.

A large-diameter vent pipe draws air up through the pile from an intake opening located below the net along the rear wall of the chamber. This airflow also helps to evaporate the liquids that accumulate on the floor of the digestion chamber. Evaporation is further enhanced by wicks made from strips of polyester or rayon fiber (from old clothing), which are hung from the net to draw up the liquid from below, increasing the surface area exposed to the air stream.

When the compost pile reaches a height just below the toilet seat, the chamber is closed off by moving the seat to the pedestal on the other chamber and replacing it with a heavy concrete cap. When the second chamber is full, the compost in the first chamber is removed for use as a soil conditioner by scooping it out through an access opening or removing the net entirely. This is the only real maintenance required, besides the regular addition of a bulking agent and periodic cleaning of the seat with soap and a small amount of water. Experience thus far has been that it takes a family of up to ten people over a year to fill one digestion chamber.

A prototype of this design constructed in 1992 out of concrete blocks by Greenpeace and local participants in a pilot project on the island of Yap in the Federated States of Micronesia was used regularly by four adults and three children for 1 ½ years. Four slightly modified units were then built by CCD in 1994 on the island of Pohnpei, for use by individual families of from six to 12 people. Periodic visual inspection indicates that solids in the digestion chamber have undergone biodegradation, and that all excess liquids have been evaporated. In all cases the users have expressed satisfaction with the toilets and reported no foul odours. This is especially noteworthy given the humid climate of Pohnpei, where the average annual rainfall is 4917 mm (193.58 inches).

As of May 1997 all four of the CCD toilets were reported to be functioning well, based on visual inspection and interviews with the owners by a member of the project team. Remarkably, all but one of the demonstration units had gone more than 2 years before switching over to the second digestion chamber, indicating greater than expected capacity. The FSM national government is currently building at least 40 more units in Pohnpei with funds remaining from a rural sanitation programme, and the state's environmental agency has indicated its intention to require their use in environmentally sensitive areas. In December

1996 a CCD toilet was built in Fiji in a pilot project sponsored jointly by the South Pacific Commission and the Fiji School of Medicine.

Based on the initial experience with these limited demonstration projects, it appears that in a tropical environment with relatively high ambient temperatures, the CCD toilet can attain a degree of liquid evaporation and maintenance-free operation not previously reported for DVC toilets. All of the demonstration units have achieved zero discharge of pollutants for at least one and a half years of use. The CCD toilet offers promise as an appropriate solution for providing sanitation where environmental contamination is a major concern, and even in cultural settings in which a high level of maintenance is not likely to be expected, provided there is a supply of appropriate organic bulking agents available, such as leaves, vegetable scraps, coconut husks or wood shavings. Because relatively little compost is generated and no urine is available for use as a fertilizer, it may not be the most appropriate technology in areas where the reuse of excretal nutrients is expected to be a primary motivation for using dry sanitation.

Where water is used for anal cleansing, the CCD toilet may be combined with an evapotranspiration bed to treat excess liquids and still achieve zero discharge. This technology, based on the work of Dr Alfred Bernhart at the University of Toronto, is being commercially marketed in the US as a "Wastewater Garden" by Sustainable Strategies of Concord, Massachusetts. These lined, aerated sand and gravel trenches promote the growth of aerobic bacteria which enhance evaporation through the release of heat generated by their activity, and also make the nutrients in the wastewater more readily available to plants grown in the garden bed. An integrated CCD toilet and wastewater garden has also been designed with added capacity for use in public facilities.

University of Tasmania Centre for Environmental Studies Kiribati project

In a different series of pilot projects, a team from the Centre for Environmental Studies at the University of Tasmania and local counterparts have successfully tested several aerobic batch composting toilet designs in the Pacific island nation of Kiribati. One of these designs was a simple prefabricated "Cage Batch" toilet, developed originally for use in Tasmanian National Parks, which provides a combination of aeration, passive solar heating and insulation to assist the composting process. Another design utilizes modified 240 litre mobile garbage bins as the digestion chambers. The bin is placed below the toilet pedestal to receive excreta, and is replaced with another one when full. Air is drawn into the bin through a cut-out near the base, and comes in contact with the bottom of the compost pile through a mesh false floor. In addition, perforated ventilation pipes running vertically along the inside walls of the bin help to aerate the pile.

The University of Tasmania team has also demonstrated locally built batch toilets made primarily of concrete block. Excreta and bulking agents are deposited into two digestion chambers of approximately 1 m^3 each, which are used alternately. The chambers feature a floor grate which allows liquid to drain into a tray below. Air is drawn in through mesh vent holes under the grates, up through the compost pile and exits via ventilation pipes which extend 1.5 m above the roof. Access to the chambers is provided by hinged doors which can be sealed to prevent the entry of insects.

Each of the designs relies primarily on drainage rather than evaporation of excess liquids to maintain aerobic conditions. In at least some of the trials a sealed evapotranspiration trench was used in an effort to achieve zero discharge of pollutants to the water table. The trench consists of a 2 mm plastic liner placed on a bed of coral aggregate to deter crabs from burrowing underneath, below a perforated drainage pipe which is buried under coral aggregate and a top layer of sand. The surface is mounded to maximize rainfall run-off away from the trench, and the trench and adjacent area are planted with appropriate species, such as papaya and banana, to assist with liquid removal. Preliminary results of the trials on Kiribati indicate that each of these designs have been successful at producing an innocuous humus-like residual, and they seem to be well accepted by local users.

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3.4

NIGHTSOIL COLLECTION AND TREATMENT IN JAPAN

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Introduction

The collection and treatment of nightsoil, i.e. human urine and faeces, is unique to Japan. The key points to understanding this Japanese practice are sanitation and nutrients, which have determined policy development. The policy of handling human excreta is also affected by other factors, such as water, the environment, religion, culture, technology etc. The Japanese experience of nightsoil collection may provide useful suggestions to other countries intending to introduce new sanitation practices.

History

Japan introduced the practice of reusing human faeces and urine for agriculture in about the 12th century, possibly influenced by Zen Buddhist monks who had studied in China. The Chinese reused human excreta in the very early stages of their civilization. Japan introduced various cultures and technologies from China from the 4th century AD, but the introduction of reuse of human excreta was later. There was a need to use human excreta for agriculture, because of human population pressures and food production demand. Nutrients added to agricultural fields greatly increased their productivity. China seemed to be the only civilization that positively used human excreta as nutrients for agriculture, and even food for pigs, from its very earliest development.

There was also a need for urban sanitation, especially in Kyoto City, then the capital of Japan. Every summer there was a spread of waterborne and food poisoning epidemics. People worshipped a god called Gion, who could control such diseases. This worship is still very popular and formalized in the form of a summer festival in Japan. Japanese food culture required the eating of fish influenced by Buddhist ideology, so that fresh water quality, both for drinking and for fish, was very important. The practice of collecting human excreta from urban areas was initiated by farmers, and greatly changed the environmental conditions in urban areas. Cash crops such as vegetables and fruit were grown by those suburban farmers using human excreta.

The practice of reusing human excreta as nutrients for agriculture continued until the middle of the 19th century. Cities were so clean that during the 16th century Portuguese missions reported their astonishment to the Vatican. From the 17th to the middle of the 19th century, Japan was a closed country, which forced Japanese society to be ecologically closed. The reuse and recycling of materials, including human excreta, were very much encouraged. Farmers bought human urine and faces at different prices from their customers in urban areas. Owing to its closed policy, Japan was not influenced by outbreaks of typhoid, cholera or other communicable diseases.

After the modernization of Japan in the middle of the 19th century, sewage work construction was very delayed by social factors, including war and the economy. Other factors included strong opposition by farmers to the construction of sewage pipes, demanding that the nutrients in human excreta should not be wasted by discharging them into public sewers. Big cities such as Tokyo, Osaka and Yokohama gradually introduced public sewage works with final treatment plants. Sewage sludge was not used systematically for agriculture. Chemical nutrients were also gradually introduced. However, the end of the second world war changed Japanese society greatly, including its sanitation policy. Japanese farmers began the large-scale use of chemical fertilizers and stopped collecting human excreta, thereby creating critical sanitation conditions in urban areas. In 1954 the government enacted a new law of urban sanitation and the collection of municipal wastes (Public Cleansing Law), in which local authorities became responsible for collecting and treating nightsoil.

Collected nightsoil was very different from raw sewage in quality. Japanese civil engineers had to find a solution for the problem, studying western technology and inventing a new method. Technological development is described below. Finally, a high-technology treatment for collected nightsoil was developed, e.g. introducing membrane filter technology to separate the activated sludge and treated water, allowing bacteria- and virus-free effluent from the treatment plant. Nitrogen and phosphorus are biologically and chemically removed. Partial ozonation is applied for yellow colour removal in the effluent. However, salt cannot be removed from the effluent, so that dilution by groundwater is necessary to avoid affecting rice irrigation water, fish migration in streams, and drinking water sources.

Technology development

Quality of collected nightsoil

Human excreta are stored by each household in dry deposits in a tank. No water flushing is practised. There is a collection service by vacuum truck, once a month. The collected excreta are transferred to a dedicated nightsoil treatment plant, of which there are about 1,800 in Japan. All are operated by cities or towns, or public corporations. Table 1 shows the quality of collected night soil.

Table 1. Quality of collected nightsoil

Items	Average	Range
pH	8	
BOD 5 mg/l	11,000	8,000 - 14,000
CODMn mg/l	6,500	4,000 - 8,000
Suspended solids mg/l	14,000	8,000 - 20,000
Total solids mg/l	27,000	19,000 - 35,000
Total nitrogen mg/l	4,200	3,200 - 5,200
Phosphorus mg/l	480	280 - 680
Chloride mg/l	3,200	1,200 - 4,200

Compared to raw sewage, all items except pH are very concentrated, e.g. BOD5 is 200 mg/l in raw sewage, but 11,000 mg/l in nightsoil. Nitrogen concentration is also very high, with nightsoil being about 50 mg/l compared to sewage. Chloride ion concentration in raw sewage in Japan is about 100-150 mg/l. Phosphate concentration in raw sewage is about 20 mg/l.

Table 2. Performance of treatment plants for nightsoil

Type	Anaerobic digestion/ activated sludge	Aerobic digestion/ activated sludge
Plant capacity kl/day	54- 239	40-200
Input night soil:		
BOD5 mg/l	11,490	10,570
Cl mg/l	3,780	3,590
After digestion process:		
BOD5 mg/l	2,270	2,140
CODMn mg/l	2,790	2,350
Suspended solids mg/l	3,180	4,730
NH4-N mg/l	2,790	1,800
Cl mg/l	3,190	2,840
After activated sludge process:		
BOD5 mg/l	48	26
CODMn mg/l	86	59
Suspended solids mg/l	39	47
NH4-N mg/l	137	73
Cl mg/l	241	161

Evolution of treatment processes

Figure 1 shows the trends in the amount of waste treated and the evolution of treatment processes (Magara and Kawamura, 1992). Because concentrations of all chemical items are so high, it was necessary to develop a new technology for nightsoil treatment. We first introduced anaerobic digestion treatment in 1953. This was a direct introduction of the anaerobic sewage sludge process. This process required dilution of the nightsoil with water before digestion, because of the high ammonia concentration inhibiting the activity of anaerobic bacteria. However, anaerobic digestion could not produce a good-quality effluent that could be used in paddy irrigation so far as BOD, nitrogen and chloride ions were concerned. The activated sludge process followed to treat the effluent from the anaerobic digestion process. The next process was oxidation treatment, which was basically a digestion process in which sludge was aerobically digested at a much faster rate than with the anaerobic process, and nitrification was also introduced.

Table 2 shows the performance of nightsoil treatment plants. Total BOD removal by the anaerobic digestion/activated sludge process is about 93.8%, and by the aerobic digestion/activated sludge process is 94.4%. Chloride ions were not removed but diluted with water by a factor of 13 and 20, respectively, for anaerobic digestion/activated sludge process and aerobic digestion/activated sludge process.

The next process developed was standard denitrification, which eliminated the sludge digestion process and introduced the modified activated sludge process with its two stages of denitrification and nitrification. Figure 2 shows a flowchart of nightsoil treatment in which the effluent is disinfected by chlorination. This was to remove nitrogen from the effluent, which was required by paddy farmers to whom nitrogen control was important: too much nitrogen could cause crop failure. The nitrification process was much improved after developments in

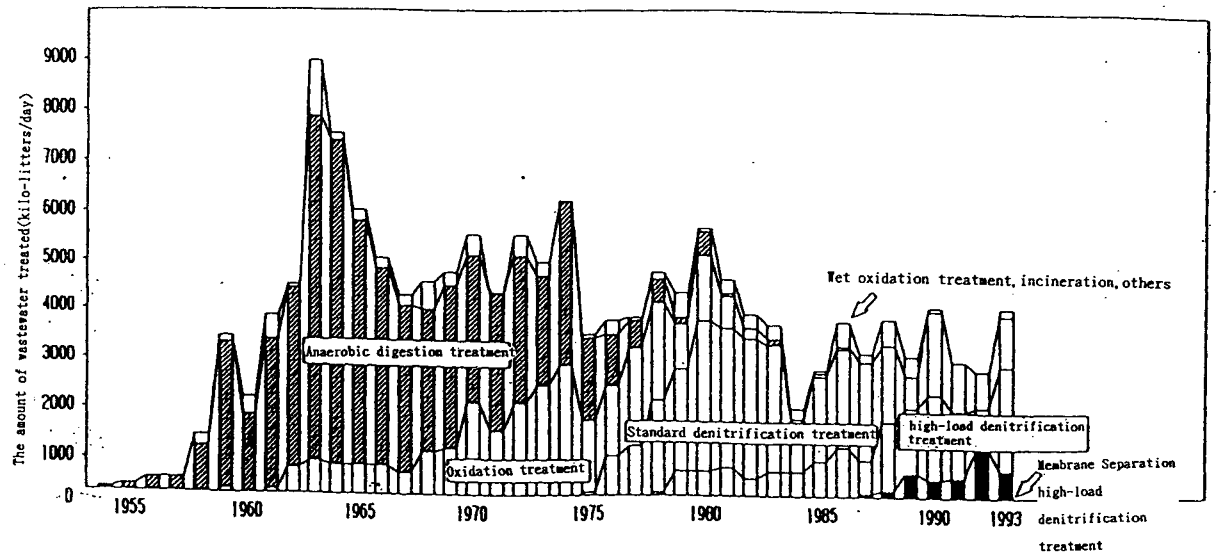

Figure 1. Trends in the amount of human excreta treated at facilities and the evolution of treatment processes

the field of biological wastewater treatment in the 1970s. Japanese scientists and engineers bravely introduced new technology into nightsoil treatment processes rather than sewage treatment processes. A high-load denitrification treatment was introduced in which dilution with water was not involved in the biological processes, but only before discharging the effluent. This process is truly a unique and most advanced biological process. Finally, membrane separation and high-load denitrification came into practice. Membrane separation provided many advantages in nightsoil treatment, such as the complete removal of bacteria and viruses, space saving for plant construction, easy control of odour etc. However, this high technology requires good engineers for operation and maintenance. It is also one of the most advanced technologies in the world.

Wet oxidation oxidates the sludge at high pressure and temperatures, but owing to difficulties in operation and maintenance it is not popular.

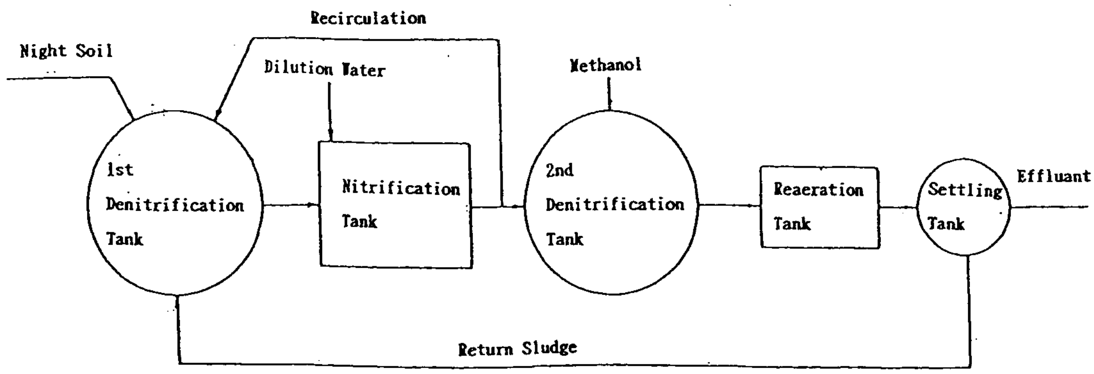

Figure 2. Biological denitrification process for nightsoil

Other approaches to sanitation

Public sewage works

Japan started nationwide sewage work construction in the 1970s, by 1996 50% of the population were covered. This construction trend will continue until early in the next century, when population coverage will reach about 90%. Until then, the collection and treatment of nightsoil is a key practice. Sewage works in Japan are not much different from any in western society, except for the high ratio of sludge incineration and the low agricultural use of treated sludge. The reasons for this are partially heavy metals in the sludge. Among the heavy metals in sludge, zinc is the most important in municipal wastewater treatment plants that do not accept industrial wastewater. Zinc concentration is highest after iron in sewage sludge, which affects plants in agricultural fields. Mercury, cadmium, lead etc. are all found in industrial wastewater, so that careful and effective management is necessary. Zinc contamination of sludge is very important, but not well understood. Human excreta contain most of the heavy metals, including zinc, but Japanese and Chinese experiences of the use of human excreta in agriculture have so far shown no significant influence on crop productivity. Sewage sludge also contains many organic micropollutants that need proper treatment before use in agriculture. However, human excreta have a very low risk compared to sewage.

Tandoku and gappei jokaso

Japan has other alternatives for sanitation than sewage and collective nightsoil treatment, which are tandoku jokaso and gappei jokaso. Tandoku jokaso means a simple treatment facility provided for WCs in each household. Treatment is basically dilution with water and sedimentation of suspended solids. Effluent leaves the household and enters the nearest stream. Regrettably, 20% of the population of Japan follow this practice. Grey water and the effluent from tandoku jokaso now contribute to non-point pollution in Japan. Gappei jokaso was introduced to treat both water-flushed human excreta and household grey water. Gappei jokaso is a compact biological wastewater treatment facility for each household. Treatment efficiencies with BOD5 and suspended solids are almost equivalent to those of conventional treatment in municipal wastewater plants. However, this practice involves less than 1% of the Japanese population.
Figure 3 shows conceptual figures for a number of Japanese human excreta and grey water treatment systems (Sakurai and Kitawaki, 1994).

Both gappei jokaso and tandoku jokaso need periodic subtraction of excess sludge from the treatment facilities. The sludge is transferred to collective nightsoil treatment plants for further treatment: it is incinerated, or reused in agriculture, or put into municipal solid waste landfill. Agricultural use is not very popular.

Reuse of human excreta in agriculture

Urine

Human urine is different from faeces in terms of sanitation practices and agricultural use. It is clean with respect to bacterial and virus contamination just after discharge from the body, but it soon attracts vigorous bacterial growth. The old Japanese practice of nightsoil recovery from urban areas separated urine and faeces. Urine was a good, fast-working fertilizer. In the middle of the 19th century farmers would place buckets on the street corners to collect free urine from passers by, providing a simple public toilet. Urine should be collected for agricultural use: any feasible system should be created to achieve this.

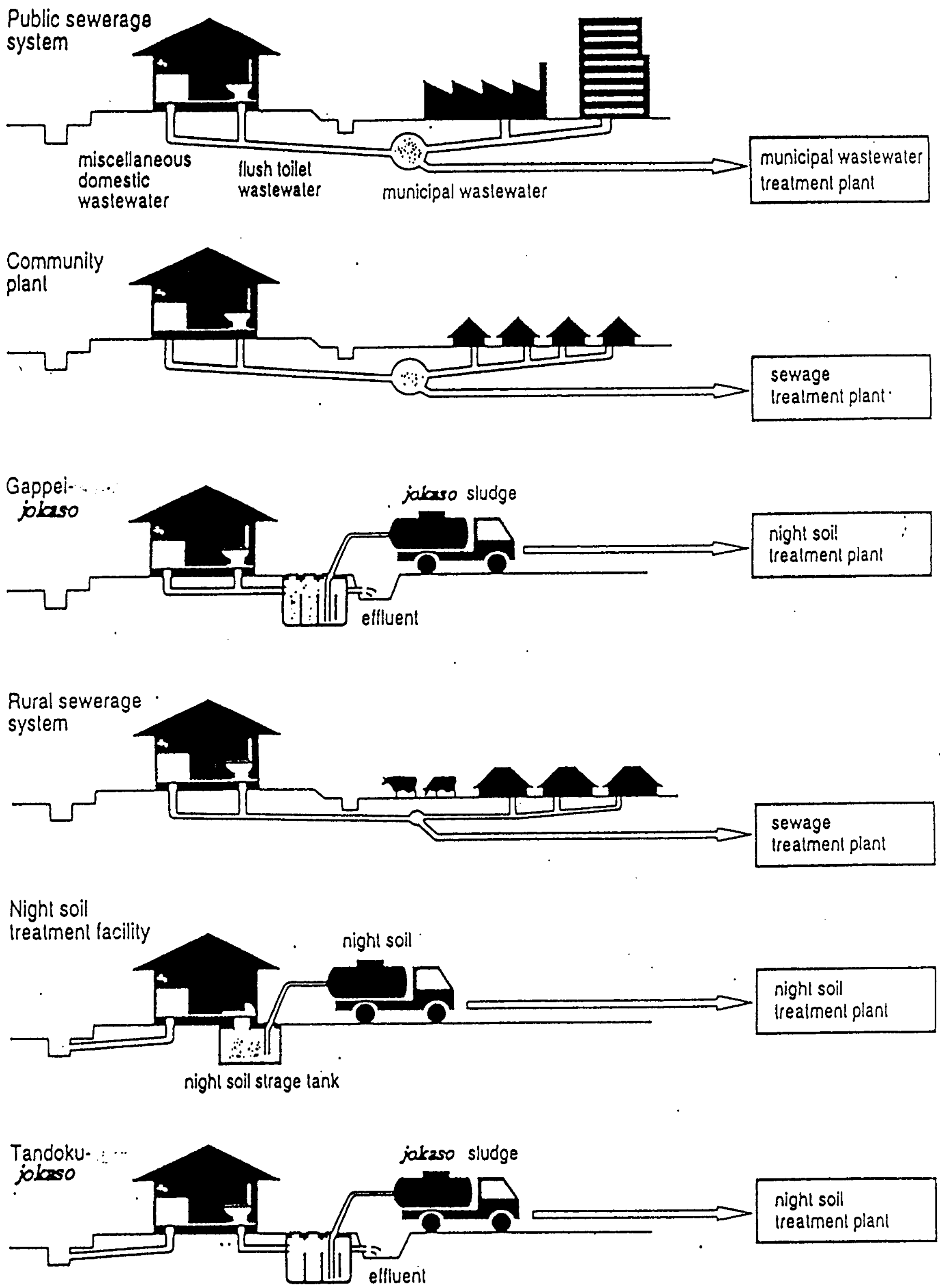

Figure 3. Conceptual sketches of several Japanese human excreta and gray water treatment systems

Faeces

Human faeces are not an easy matter to handle properly as they contain many microbes that are hazardous to health. The simplest treatment for collected faeces is composting. However, this needs good quality control to prevent disease. The basic technology of composting is anaerobic bacterial processes to decompose organic material by non-harmful bacteria, controlling pathogenic bacteria in the process. According to recent Japanese studies of pathogenic bacteria control in sewage sludge, *Enterococcus* sp. are not easy to control compared to faecal coliforms and *Salmonella* sp. (Watanabe et al., 1997). Figure 4 shows remaining faecal coliform groups (MPN/g) in sewage sludge at different levels of treatment. Composting or natural drying was very effective on faecal coliforms. Figure 5 shows remaining *Salmonella* sp. (MPN/g) in sludge. Mechanical dewatering is effective compared to other methods of composting or natural drying. Figure 6 shows remaining *Enterococcus* sp. (MPN/g) in sludge: surprisingly, no method is effective for controlling this pathogen and we must consider a new approach. There are many other pathogens in human faeces: it is obvious that new approaches must be introduced to control them.

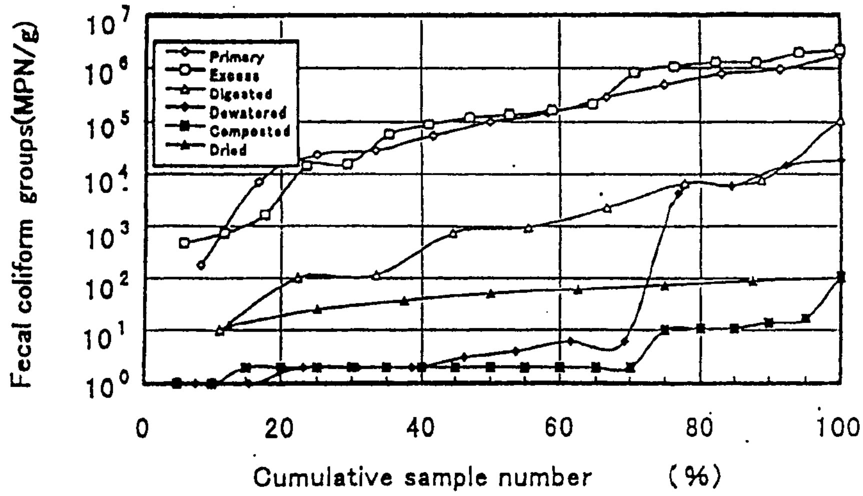

Figure 4. Faecal coliform groups in sewage sludge

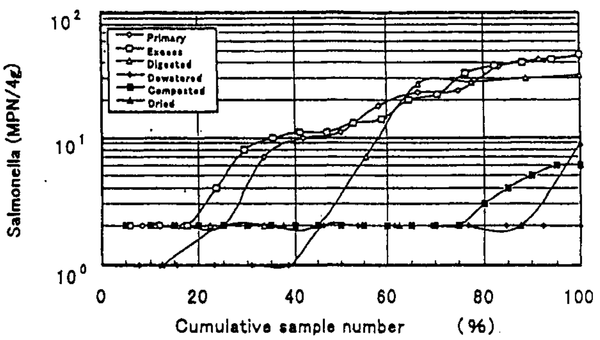

Figure 5. Salmonella in sewage sludge

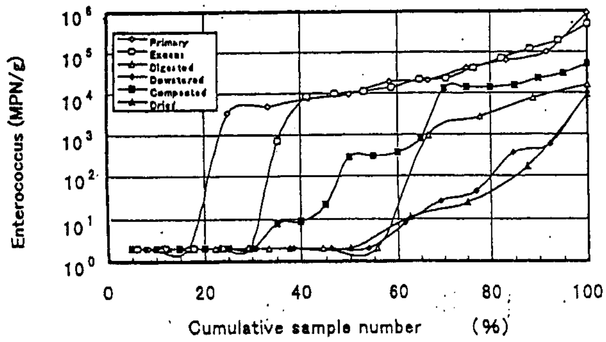

Figure 6. Enterococcus in sewage sludge

Conclusions

The Japanese practice of sanitation is different from western practices that require sewage pipe networks and treatment plants. The collection and treatment of nightsoil requires a very high level of technology to meet the effluent standards of the treatment plants. It is economical compared to public sewage treatment costs in Japan. However, people demand water toilets, which will lead to a gradual decrease in the system of truck collection and treatment of nightsoil in the next century.

When we consider the global environment issues there may be a new approach to sanitation, especially for human excreta. Human excreta have two important aspects, namely sanitation and the potential for agricultural nutrients. Global environmental awareness is an important driving force to change the status of human excreta from a simple hazard to a valuable resource.

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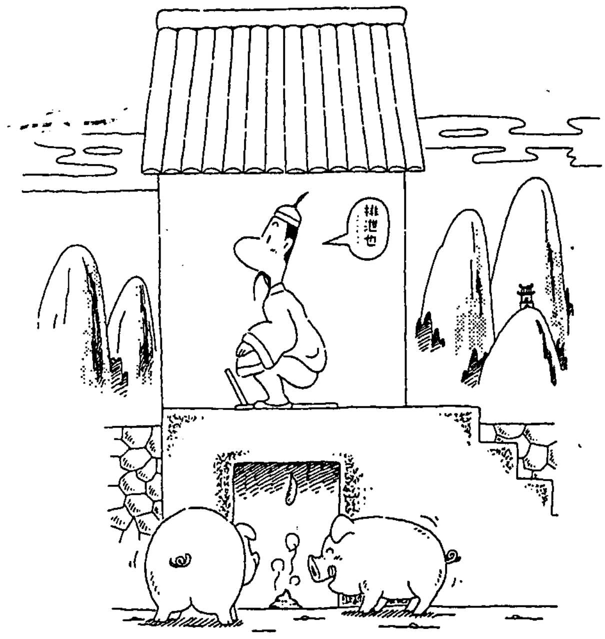

Figure 7. The Chinese developed a pig toilet to use human excreta. The pig toilet has a very long history. Even today there are pig toilets in the northern part of China.

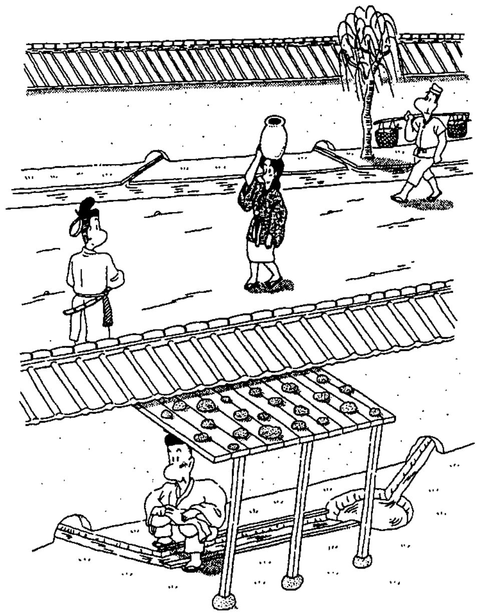

Figure 8. The old Japanese capital, Heijo, used water toilets, showing no evidence of reuse of human excreta. 8th century AD. (After S. Henry, "Toilet and Culture")

Figure 9. A variety of ladles and buckets were developed for the collection and transport of urine and faeces, 18th century AD.

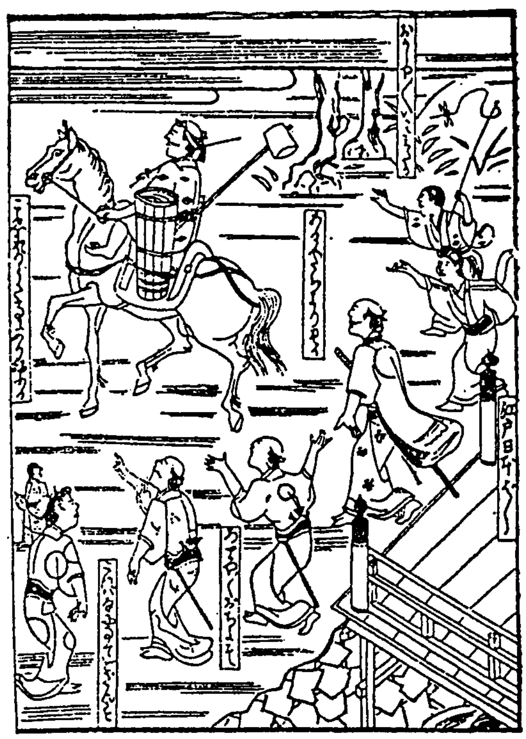

Figure 10. People laughing at a samurai transporting urine on horseback with a specially designed bucket, in the centre of Edo City, 18th century AD.

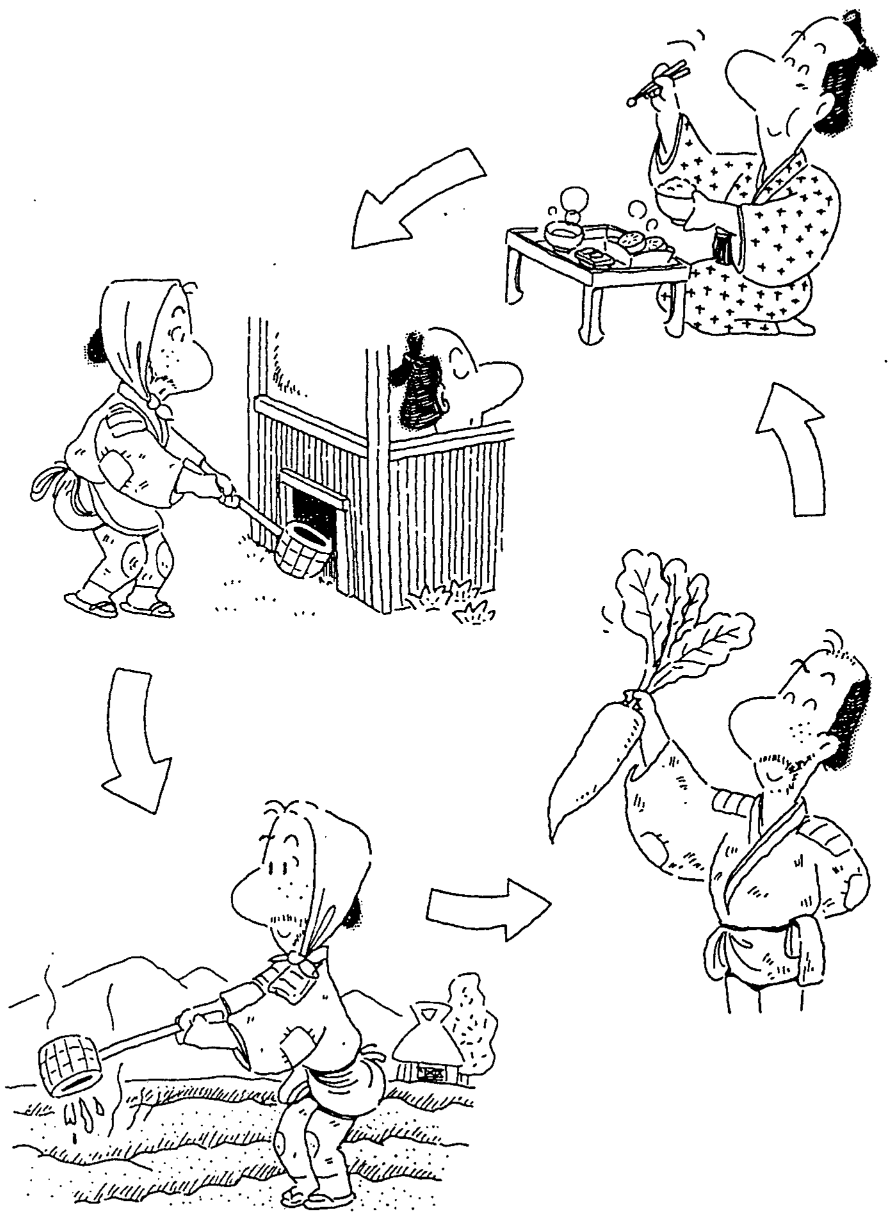

Figure 11. Japanese farmers practised nutrient recycling between food production and human excreta, 15th century AD.

3.5

SOME NOTES FROM THE SITES OF THE FIELD VISITS

Clivus Multrum

Clivus Multrum is a composting toilet without urine diversion (Fig.1). It has two chutes, one from the bathroom for faeces, urine, toilet paper and diapers and one from the kitchen for food scraps, peelings etc.

The unit we are visiting is in the house that used to belongs to Mr Rikard Lindström, the inventor and developer of the Clivus Multrum system.

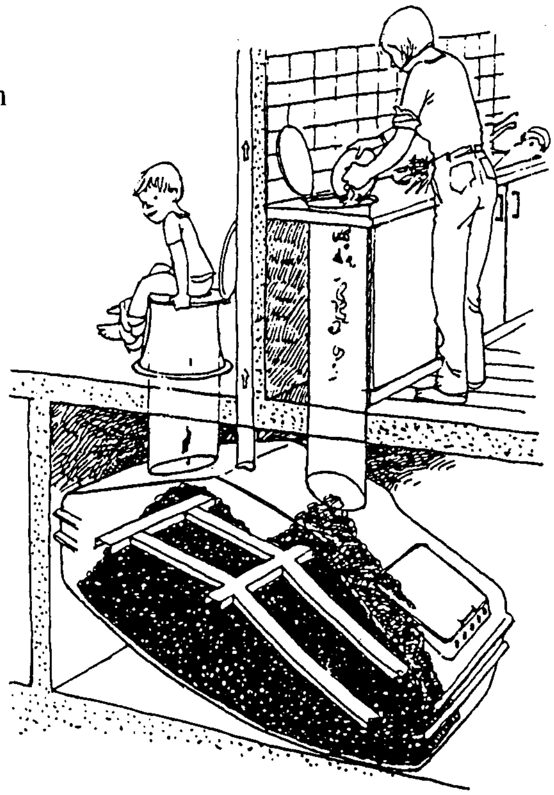

Figure 1: Clivus Multrum

Rikard Lindström described the system in an article in Compost Science, vol 6. no 1, 1965:

> "The key to the process is that wastes are deposited into a naturally ventilated chamber. They then move by gravity from this chamber into a second chamber. The speed of movement is chosen so that the wastes are substantially decomposed as they reach the second chamber.
> ... It is possible to achieve with this arrangement an aerobic biological change in wastes of all kinds, such as excrement and refuse, with a first-class manure as an end product. This is all done without mechanisms and without the addition of chemicals or water. ... It serves as the toilet, as garbage container, as the apparatus for biological conversion, and as collection and storage place for the converted wastes (compost). ... The necessary ventilation for the desired treatment and for a complete freedom from odors is achieved through natural ventilation. ... Rich bacterial cultures developing in the mixture of excrement and refuse provide extremely rapid decomposition, considerably faster than with refuse alone."

Porcelain pour-flush latrine with urine -diversion

Sanitation system with urine diversion, storage of urine in underground tanks, local treatment of faeces and greywater: 44 flats in Understenshöjden, Stockholm, a suburban residential area built 1995.

Three stations were studied: a) the treatment works and storage tanks for urine and the lower pond; b) the upper pond, the leca-trench, the trench to the lower pond and a compost for kitchen refuse; and c) a toilet in one of the flats.

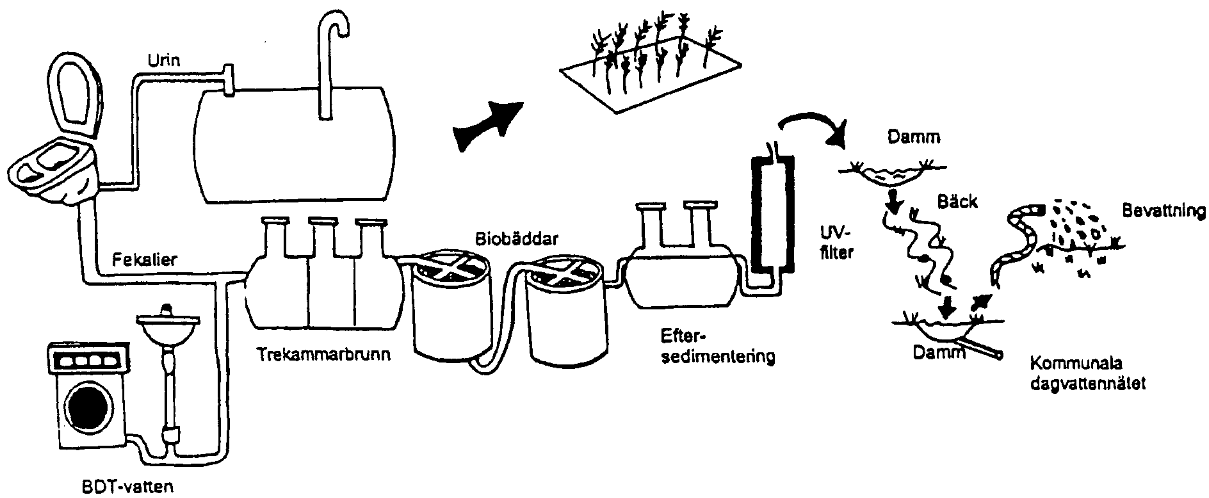

Figure 2: The sanitation system in Understenshöjden

Farm-use of urine as fertilizer

The farm using the urine from households in Understenshöjden is owned by Stockholm Water Company and run by farmers. They collect the urine from households twice a yaer and store it in three balloon-type tanks, each with a capacity of 150 m^3. Most of the urine is used for ordinary farming, but some is used for field experiments. This year the effect of nitrogen from human urine on spring barley is similar to that of chemical fertilizers. Last year a similar results were found for oats.

Urine diversion in flats in the town of Norrköping

Last year 18 households in a multi-storey block of flats installed toilets with urine diversion and and local treatment.

This block of flats was originally built in the 1960s. Last year it was converted into an "ecological building". The aim is to reduce energy consumption and to reuse sanitized human excreta. Potable water is taken from the municipal system. Low volume faucets and and nozzels reduce the water and energy consumption. Urine is diverted and flushed with 0.2 litres of water to a storage tank. Faeces are flushed with 4 litres of water to an "Aquatron" separator in the basement of the building. The "Aquatron" separates faeces and toilet paper from flushing water. Faeces and paper are composted together with household garbage for some eight months before the compost is used as a fertilizer in the residents´ allotment gardens near the block. The flush water is sanitized with UV light and collected together with greywater in a septic tank. The effluent from the septic tank is filtered into a root zone design. Rainwater is handled locally.

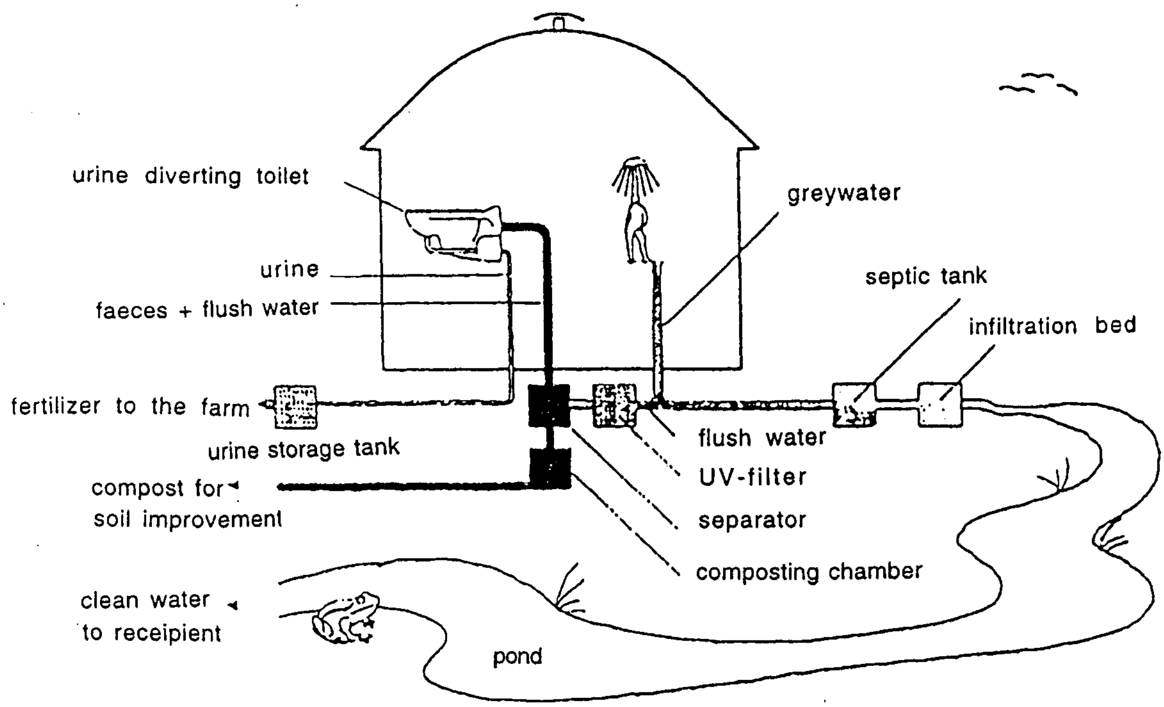

Figure 3: The sanitation system in Norrköping

Public urine-diversion toilet

Staff toilet with urine diversion and dehydration of faeces: Bergianska Botanical Garden, Stockholm. The toilet has a flush only for the urine (0.1 litre). Urine is stored in a tank until used in the garden.

Faeces and toilet paper fall straight down into a bin. There are five bins, each with a volume of 200 litres. The bins are standing on a carousel. When the first bin is full the carousel will automatically place the next bin under the toilet. Each bin has the capacity to receive the deposits from 500-600 visits.

For experimental purposes two of the bins will be provided with worms and and the other bins with some bulking agent.

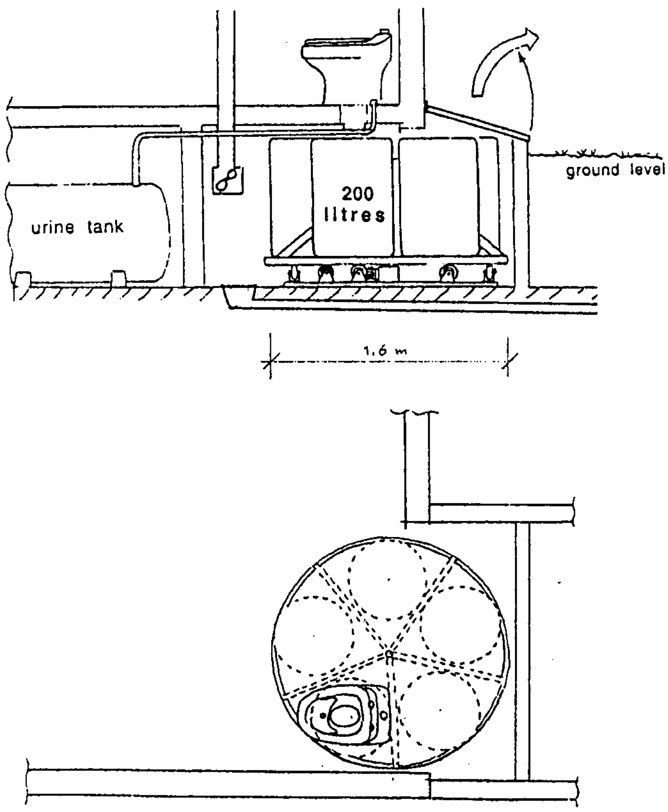

Figure 4: Section and plan of staff toilet at the Bergianska Botanical Garden