ECOLOGICAL SANITATION

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Coordinator/editor
Uno Winblad

Copy Editor
Sheila Jones

Illustrations by
Hans Mårtensson (1.2, 1.3, 2.3–2.7, 3.3–3.10, 3.15, 3.17–5.4)
Kjell Torstensson (3.1, 3.2, 3.11, 3.12)
Uno Winblad (1.1, 1.4, 2.1, 2.2, 3.13, 3.16)

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Uno Winblad

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Steven A Esrey
Jean Gough
Dave Rapaport
Ron Sawyer
Mayling Simpson-Hébert
Jorge Vargas
Uno Winblad (ed)

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CONTENTS

FOREWORD

The two most commonly used sanitation technologies today are the pit toilet and the flush toilet. Conventional waterborne sewage systems have proven to be inappropriate to solve sanitation needs in developing countries. The systems are too costly to be provided to all, and only wealthier upper- and middle class areas are normally provided with those services. Approximately 90% of the sewage in cities in developing countries is today discharged untreated, polluting rivers, lakes and coastal areas. Pit toilets also have limitations, especially in densely populated areas, with severe risks of contaminating groundwater.

Within 20 years from now, it is expected that an additional two billion people will live in towns and cities, mainly in developing countries, demanding safe sanitation. Furthermore, many of the rapidly expanding towns and cities are located in arid and semiarid areas where water scarcity is severely reducing the volume of water available.

In a situation of food insecurity, decreasing soil fertility and escalating prices for fertilizers in world markets, there is a need to utilise the nutrients, especially in human urine, rich in nitrogen and phosphates, for agricultural purposes, thereby increasing productivity and reducing the needs for fertilisers.

It is obvious that this enormous challenge leads to a need to rethink, a need to raise the status of sanitation and a need for new approaches, techniques and methods.

This book puts forward an alternative to conventional sanitation called 'ecological sanitation'. It is based on an ecosystem approach and treats human urine and faeces as a valuable resource to be recycled. It further shows that ecological sanitation is by no means untried – there are hundreds of thousands of dehydrating and composting toilets in use around the world today, mostly in rural areas and small communities. What we need now is to develop large-scale applications of the ecological sanitation concept in urban areas both in developed and developing countries.

The book is based on a Sida-funded research and development programme and we hope that it will contribute to the urgent need for a rethinking in sanitation.

Stockholm in June 1998

Johan Holmberg
Director, Department for Natural Resources and the Environment

1. INTRODUCTION

1.1 The challenge

In many cities, towns and rural areas of the world today people live and raise their children in highly polluted environments. Urban and peri-urban areas in developing countries are among the worst polluted and disease ridden habitats of the world. Much of this pollution, which leads to high rates of disease, malnutrition and death, is caused by a lack of toilets and inadequate sanitation services. The lack of sufficient or adequate services is a result of many factors, including: inadequate financial resources, insufficient water, lack of space, difficult soil conditions and limited institutional capabilities. As cities expand and populations increase, the situation will grow worse and the need for safe, sustainable and affordable sanitation systems will be even more critical.

The sanitation practices that are promoted today fall into one of two broad types: 'flush-and-discharge' or 'drop-and-store'. Over the past hundred years flush-and-discharge has been regarded as the ideal technology, particularly for urban areas. Many municipalities in developing countries, often with the help of international financing, try to copy this model. For those without access to flush-and-discharge the conventional alternative is a drop-and-store device, usually a pit toilet, based on containment and indefinite storage of human excreta. Drop-and-store is often regarded as an inferior, temporary solution compared with flush-and-discharge.

Most cities in the Third World cannot afford the necessary resources, in terms of water, money and institutional capacity, to provide a flush-and-discharge system. Many of these cities will face extreme water shortages by the year 2010, threatening the life and health of the inhabitants. Globally, some 80 countries with 40% of the world's population are already suffering from water shortages at some time during the year[1]. Chronic fresh water shortages are expected by the end of the decade in much of Africa, the Middle East, northern China, parts of India and Mexico, the western United States, north-eastern Brazil and in the former Soviet Central Asian republics. China alone has 300 cities facing serious water shortages[2].

Flush-and-discharge approaches can work well and achieve an acceptable level of pathogen destruction. However, in the Third World, sewage is nearly always discharged into the environment at large without treatment[3].

Globally, sewage discharges from centralized, water-borne collection systems are a major component of water pollution, contributing to the nutrient overload of water bodies, toxic algae blooms (e.g. red tides) and adversely influencing tourism in some coastal areas[4]. Although such systems are acceptable to the vast majority of people, they are not simple and require institutional capability and technical skills not presently available in many Third World cities.

Box 1.1 Flush-and-discharge

Over a year for each person some 400–500 litres of urine and 50 litres of faeces are flushed away with 15,000 litres of pure water. Via a pipe system the bath, kitchen and laundry water, often called 'greywater', from the household is added. This may add up to another 15,000–30,000 litres for each person every year. Further down the pipe network rainwater from streets and rooftops and heavily polluted water from industries are often added.

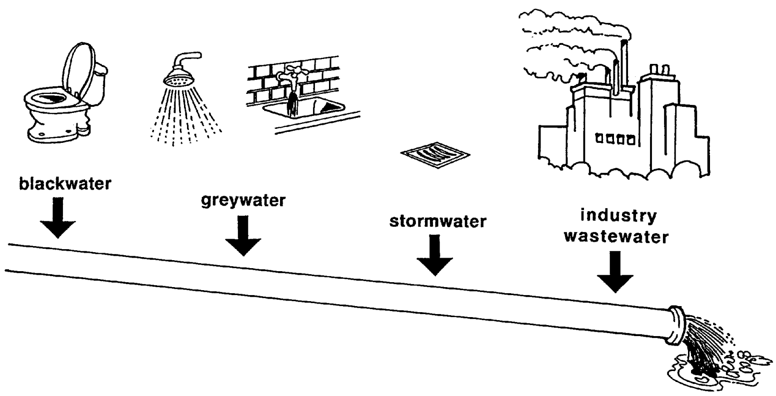

Figure 1.1 *In a flush-and-discharge system a relatively small amount of dangerous material – human faeces – is allowed to pollute a huge amount of water. In most cases the resulting sewage is discharged completely untreated into surface waters.*

Thus at each step in the flush-and-discharge process the problem is magnified: the really dangerous component, the 50 litres of faeces, is allowed to contaminate not only the relatively harmless urine but also the huge amount of pure water used for flushing and an equal or even larger amount of greywater. Towards the end of the system there is supposed to be a treatment plant but in most cases there is none: over 90% of all sewage in Third World countries is discharged completely untreated, in Latin America the figure is 98%[5]. If treatment is carried out it only separates the water from what has been added.

Most urban growth is taking place in informal settlements where municipal governments are unwilling or unable to provide services such as piped water, sewerage, drainage and collection of garbage. Effective sewage treatment is so expensive that it is rarely achieved in practice, particularly in the fast-growing urban centres of developing countries. In consequence, low-income households rely on some kind of drop-and-store sanitation technology to deal with their needs.

Although drop-and-store technologies can prevent pollution in some places, in urban areas they are often not feasible because of lack of space for digging deep pits, difficult soil and groundwater conditions, destabilization of foundations of nearby houses, and odours.

Box 1.2 Drop-and-store.

The most common sanitation system in the world, the pit toilet, is based on containment and indefinite storage of human excreta. We call this system drop-and-store.

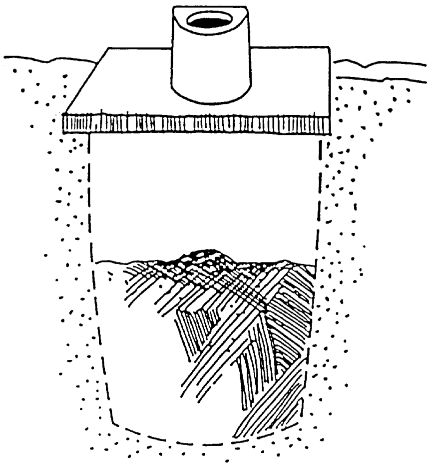

Figure 1.2 *Drop-and-store systems can be simple and relatively low-cost but they have many drawbacks. Often drop-and-store systems cannot be used at all: in crowded areas, on rocky ground, where the groundwater level is high and in areas periodically flooded.*

Drop-and-store requires access to the ground, a reasonable amount of open space, soil that can be dug, a low groundwater level and a site that is never flooded. No water is required for flushing, the technology is simple and any material (paper, solid objects or water) can be used for anal cleaning. The disadvantages are soil and groundwater contamination, bad odours, fly breeding, pit collapse, destabilization of nearby buildings and risk for overflow during heavy rains. Although a simple pit toilet can be built at very low cost an improved version, like the VIP toilet, is quite expensive.

Furthermore, nutrients and pathogens seeping from pour-flush toilets, pit toilets and septic tanks have been documented as the cause of contamination to groundwater and nearby surface waters throughout the world[6].

Leaders and communities are currently faced with two options: expand existing sanitation approaches, with all the limitations and weaknesses, or seek entirely new solutions. Existing approaches to sanitation are not viable or affordable to the vast majority of people, neither do they offer people an approach towards a sustainable society. This book is about seeking new solutions to these problems.

1.2 The vision

The approach to sanitation that we are exploring in this book is based on three fundamental aspects: rendering human excreta safe, preventing pollution rather than attempting to control it after we pollute, and using the safe products of sanitized human excreta for agricultural purposes. This approach can be characterized as 'sanitize-and-recycle'.

This approach, we call it 'ecological sanitation' or 'eco-san' for short, is a cycle – a sustainable, closed-loop system (see Figure 1.3). It treats human excreta as a resource. Human excreta are processed on site and then, if necessary, further processed off site until they are completely free of disease organisms (see Section 2.1.3). The nutrients contained in the excreta are then recycled by using them in agriculture.

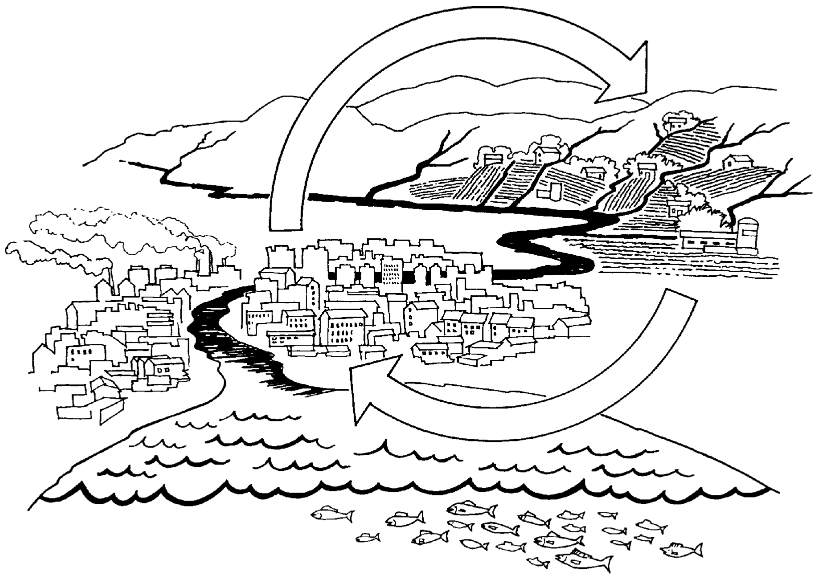

***Figure 1.3** Ecological sanitation replicates nature by returning sanitized human urine and faeces to the soil. Instead of polluting the environment, human urine and faeces are used to improve soil structure and supply nutrients.*

It is essential to sanitize human excreta before its recovery and reuse. Usually urine is sterile, and most of the fertilizer value of human excreta is in urine (see Chapter 2). In this book we discuss three ways to recover the resources in urine – diversion, separation and combined processing (see Section 4.2.1). **Diversion** is when urine is diverted away from faeces – they are never mixed with each other. **Separation** is when urine and faeces are mixed together then separated from each other. In **combined processing** urine and faeces are mixed together, processed together and their resource value is captured together.

Human faeces, not urine, are responsible for most diseases spread by human excreta. Thus, a method is needed to sanitize faeces. Two methods are discussed in this book: dehydration and decomposition. Dehydration, or drying, of faeces is easier if they are not mixed with urine and water. When faeces decompose, the different living things in them die and are broken down into smaller parts. Thus with either method germs, eggs and other potentially unsafe, living things are made harmless. It is only then that faeces can be safely recovered and recycled. (The terms 'dehydration' and 'decomposition' simply indicate which conditions are predominant, see Section 4.2.2.)

Key features of eco-san are prevention of pollution and disease caused by human excreta, treatment of human excreta as a resource rather than waste, and recovery and recycling of the nutrients. In the natural world, excreta from humans and other animals play an essential role in building healthy soils and providing valuable nutrients for plants. Conventional approaches to sanitation misplace these nutrients, disposes of them and break this cycle.

The criteria needed to achieve a new vision are simple, but achieving the vision requires a change in how we think about sanitation. The challenge addressed in this book is to offer a sanitation system that contributes to this new vision, including constraints (Chapter 4) and advantages (Chapter 5).

1.3 The criteria

Sanitation is a key determinant of both equity in society and society's ability to sustain itself. If we cannot meet the sanitation challenge described above, we will not be able to provide for the needs of the present generation without hindering that of future generations. Thus, sanitation approaches must be resource minded, not waste minded. Similarly, there can be no equity as long as half the world's population goes without even basic sanitation.

A system of sanitation that contributes toward these goals (equity and a sustainable society) must meet or at least be on the way towards meeting the following criteria:

1. **Prevent disease:** A sanitation system must be capable of destroying or isolating faecal pathogens.
2. **Affordable:** A sanitation system must be accessible to the world's poorest people.
3. **Protect the environment:** A sanitation system must prevent pollution, return nutrients to the soil, and conserve valuable water resources.
4. **Acceptable:** A sanitation system must be aesthetically inoffensive and consistent with cultural and social values.
5. **Simple:** A sanitation system must be robust enough to be easily maintained with the limitations of the local technical capacity, institutional framework and economic resources.

Successful implementation of the eco-san vision and application of these criteria require an understanding of sanitation as a system. They also require that all the components of the system are considered together, not just one or two, when designing and making sanitation systems work. The main components of that system are nature, society, process and device (see Figure 1.4).

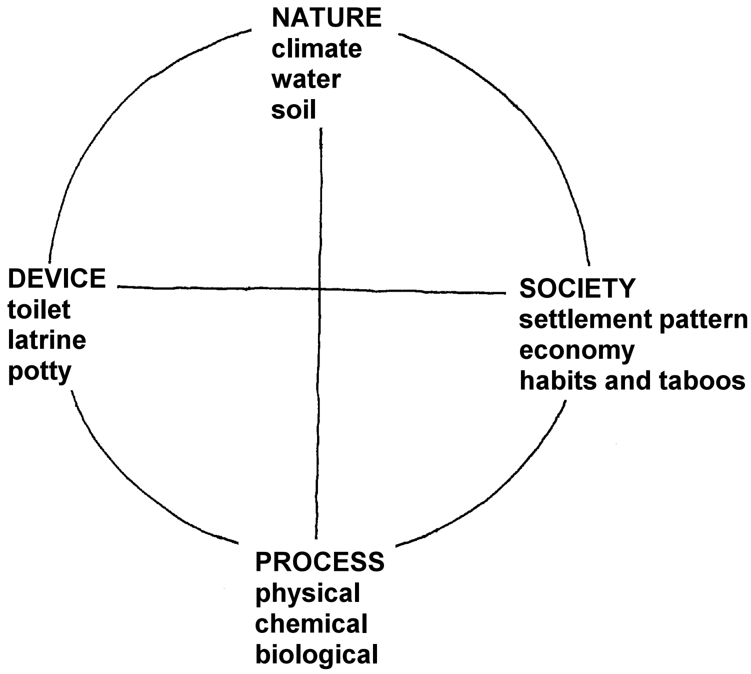

Figure 1.4 *Sanitation is a system where the main components are nature, society, process and device. All these components must be considered together.*

- The most relevant **nature** variables are climate (humidity, temperature), water (amount available, ground water level), and soil (stability, permeability, pickability).
- **Society** includes settlement pattern (concentrated/dispersed, low/high rise), attitudes (faecophobic/faecophilic), habits (washers/wipers), beliefs and taboos related to human excreta as well as the economic status of the community in question.
- By **process** we mean the physical, chemical and biological processes by which human excreta are turned into a non-dangerous, inoffensive, useful product. In this book we discuss two such processes: dehydration and decomposition.
- By **device** we mean the on-site structures specifically built for defecation and urination. Much of the literature on sanitation is focused on devices, without relating them to the other components of the sanitation system.

The principles underlying eco-san are not novel. In different cultures sanitation systems based on ecological principles have been used for hundreds of years. Eco-san systems are still widely used in parts of East and South-East Asia. In Western countries this option was largely abandoned as flush-and-discharge became the norm but in recent years there has been a revival of interest in ecological sanitation.

Applying the criteria above and developing and implementing a systems approach to sanitation requires a change in our thinking. We must move away from an approach based on disposal to one aimed at zero-discharge and recycling. In doing so we also conserve fresh water resources.

1.4 This book

What then is new about this book? – Our book does three major things:

1. It relates sanitation devices to sanitation as a system. The book examines critically the advantages and shortcomings of various sanitation technologies under different physical and cultural conditions.

2. It systematizes experience from different parts of the world into a single, coherent approach that meets eco-san standards. By unearthing underlying common principles, the book provides a new conceptual framework to many scattered sanitation initiatives.

3. It describes how to proceed with such systems and what to consider when developing and implementing eco-san approaches.

This book is neither a technical nor a policy manual although it does deal with technical and policy issues. It is rather a down-to-earth discussion of the options available. The eco-san concept is particularly relevant to cities where water, space and financial resources are scarce. But it should not be regarded as a second-rate solution only for the poor. Eco-san options are available for a whole range of socio-economic conditions, as shown in Chapter 3.

This book is intended for all who share the will to explore new ways of tackling urban sanitation problems:

- Municipal authorities who want to deliver high quality urban services but have inadequate budgets to deal with ever increasing demands.
- Grassroots and community leaders seeking to improve living conditions through local organization, environmental awareness and a more democratic governance.
- Private entrepreneurs looking for commercially viable ideas.
- International institutions advocating environmentally and financially sustainable interventions.
- Scholars, engineers and practitioners who want to test and/or further develop ecological sanitation.

2. SANITIZE-AND-RECYCLE

2.1 Sanitize: how pathogens are destroyed

The first and most important criterion of ecological sanitation, and all sanitation approaches, is that the system forms a barrier against the spread of diseases caused by harmful living things (pathogens) in human excreta. In this chapter we discuss the relationships between sanitation and disease and various ways of pathogen destruction. Our conclusion is that dry methods, specially those based on dehydration, seem to kill pathogens more effectively than other commonly used methods. This is particularly true for the pathogens that live the longest.

2.1.1 Sanitation related diseases

Human excreta contain germs, eggs and other living things (organisms). Some organisms cause disease and are called pathogens. Some organisms live at the expense of man and are called parasites. The majority of them are found in faeces. Urine is usually sterile and poses a risk only in special cases[1]. The major pathogens found in urine can cause typhoid, paratyphoid and bilharzia. Urine is a major source for the spread of bilharzia. Faeces are the major source of pathogens for typhoid and paratyphoid even when they are found in urine.

Pathogens and parasites found in human excreta can result in a wide variety of illnesses, including diarrhoea and malnutrition. Poor growth, iron deficiency, vitamin A deficiency and other micronutrients deficiencies also occur, with the effects sometimes lasting a lifetime. Not all pathogens and parasites result in death but the continual debilitation of disease and malnutrition predisposes people to continual disease or ill-health and death from other causes.

In fresh faeces there are four main groups of organisms of concern to humans: bacteria, viruses, protozoa and helminths. These organisms once excreted:

- may be immediately infectious;
- may require a period of time outside of the body to become infectious; or
- may require an intermediate host before becoming infectious.

Bacteria and viruses are immediately infectious once excreted. Protozoa are excreted primarily as cysts, and can be immediately infective or require a period of time outside the body. The eggs of helminths, many of which are resistant to environmental conditions, require a period of time outside of the body. Some parasites, such as bilharzia, also require an intermediate host before becoming infectious.

When a person excretes a pathogen which is not contained or destroyed, the environment becomes contaminated. Once human excreta gain access to the larger environment (see Figure 2.1), they can contaminate fingers (hands, clothes and utensils), fluids (e.g. drinking and cooking water, beverages and other water bodies), fields (e.g. vegetables and household yards) and flies (e.g. houseflies and blowflies, domestic animals and snails).

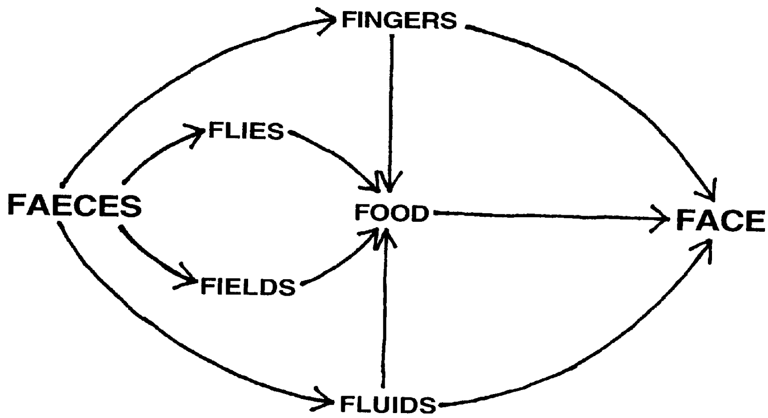

Figure 2.1 *The F-diagram summarizes the main ways diarrhoea is spread: by faecal pathogens contaminating fingers, flies, fields, food and fluids and then eventually swallowed.*

People may be exposed to pathogens and parasites directly through these routes or via food.

A contaminated environment puts people at risk of exposure to the pathogens, leading to infection and disease. Newly infected people then excrete into the environment and there is a repeated cycle of infection, contamination and infection.

The spread of pathogens can be reduced or stopped by using barriers to prevent them moving from one place, such as the ground, to another (fingers, food and/or water, see Figure 2.2). A primary barrier would prevent faeces from reaching fingers, flies, fluids, fields and foods; it would prevent the spread of pathogens. However, if pathogens gain access to fingers, foods and so on, secondary barriers (e.g. washing hands, cooking food) must be relied upon to prevent exposure. In this chapter we will argue that a dry system based on eco-san principles can be an effective primary barrier.

Once excreta leave the body and before they gain access to the larger environment there are a number of options for preventing the spread of pathogens. The traditional approach is to flush away the excreta (flush-and-discharge) or to store it in a deep pit (drop-and-store) as described in Chapter 1.

These disposal methods lead us to believe that environmental contamination has been prevented. However, this is a false belief as over time the contents of the pit may leak into the groundwater or be washed out by heavy rains.

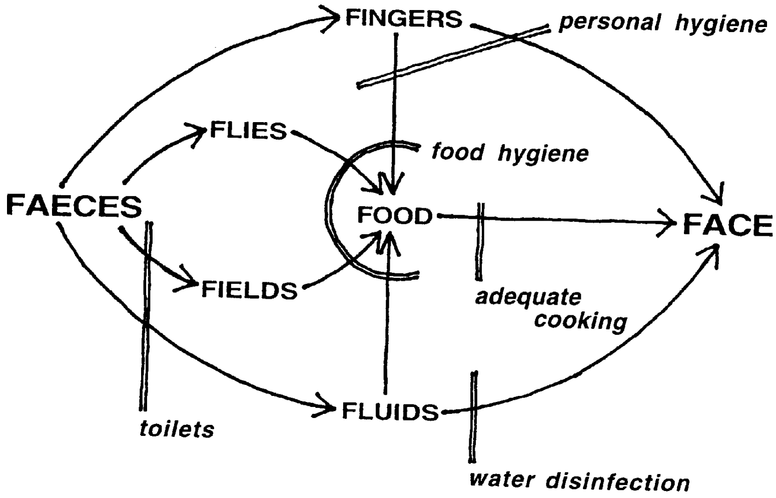

Figure 2.2 *A set of barriers is required to prevent the spread of pathogens.*

In the flush-and-discharge system the sewage may be adequately treated and made safe before being discharged; but in most cases it is discharged totally untreated, or only partly treated[2]. Either way the pollution problem just spreads downstream.

Another way to break out of this cycle is to treat people with disease. For instance, a child with diarrhoea is given oral rehydration solution (ORS) or an antibiotic. Usually the disease will be cured or resolve by itself. However, the infected person will excrete pathogens into the environment until the treatment takes effect and excretion of pathogens can continue, for some illnesses, even after the symptoms disappear. The rapid evolution of drug-resistant strains of infectious disease emphasizes the need for prevention in preference to treatment[3].

To break out of the vicious cycle of infection and reinfection, we must take preventive measures where the cause of the problem begins – we must keep the pathogens out of the environment in the first place. People excrete pathogens for some period of time, from days to weeks or even months. In some communities a large proportion of the people will excrete different pathogens during the same period. We must work out a way to destroy excreted pathogens or prevent their access to the environment. The answer is either to keep excreted pathogens in safe storage or sanitize pathogens quickly. In practice we need a combination of the two: safe storage and quick destruction.

2.1.2 How pathogens die

A large number of pathogens or parasites' eggs are excreted in faeces, and many thousands or even millions are excreted each time. However, after they are excreted into the environment all pathogens eventually die or become incapable of causing disease. Some organisms remain alive and capable of causing disease longer than other organisms of the same type.

The time it takes for all the organisms of the same type to die is referred to as the die-off rate. This rate varies for each pathogen. Two exceptions are salmonella and some other bacteria, which may temporarily increase in number outside the body; and the eggs produced from those parasitic worms with developmental stages. Eggs from most worms do not increase in number, but they take a longer time to die than other pathogen types.

A number of environmental conditions (see Table 2.1) will speed up or slow down the time it takes a pathogen to die, depending on the characteristic or level of the condition. The major conditions considered to be important for die-off are: temperature, moisture, nutrients, other organisms, sunlight and pH. Each of the conditions can vary naturally (e.g. wet and dry seasons) or artificially (e.g. addition of lime). This means that the time it takes a pathogen to die-off can be increased or decreased from the average die-off time. In general, under natural conditions the greater the number of disease organisms present, the longer it will take all of the organisms to die.

Table 2.1 *Environmental conditions speeding up the death of pathogens*[4]

Environmental factors	How
temperature	increase in temperatures
moisture	decrease in moisture
nutrients (organic matter)	decrease in nutrients
microorganisms (including other pathogens)	decrease in organisms
sunlight	increase in sunlight
pH	increase in pH

Each of the above environmental conditions has ranges that favour pathogen survival. As nature or man changes the conditions, pathogen die-off rates also change. For instance, as temperatures are increased pathogens will begin to die at a faster rate; 99% of faecal coliforms (bacteria commonly found in faeces) in soil will die in about 2 weeks in summer (hot season) and in about 3 weeks in winter (cold season). A temperature above 60°C will result in near instant kill for most pathogens excreted in faeces. Temperatures in the range of 50–60°C result in no growth for bacteria and death within minutes, usually within 30 minutes and sometimes less, for most pathogens. These temperatures can be achieved by various methods (e.g. high temperature composting). By changing more than one factor at the same time die-off of pathogens may be speeded up even further. For instance, decreasing moisture and increasing temperature may work together to produce a faster die-off than if only one factor is altered.

All pathogens are affected by these environmental conditions. However, pathogens have different die-off rates when subjected to disposal and treatment methods[5].

Bacteria, viruses and protozoa usually die-off within several months, sometimes less (see Table 2.2). Helminth eggs survive for many months, and eggs of the species *Ascaris* can survive for years. Of the methods for pathogen destruction, high temperature composting is best able to destroy most pathogens quickly. In reality it is difficult to achieve optimal conditions as parts of the compost heap may not reach the required temperature. This means that some pathogens may survive. Waste stabilization ponds are effective in destroying protozoa and helminths, but bacteria and viruses may still be present in the end product.

Table 2.2 *Survival times of pathogens in days by different disposal/treatment conditions*[4]

Condition	Bacteria	Viruses	Protozoa*	Helminths**
soil	400	175	10	many months
crops	50	60	not known	not known
night soil, faeces, sludge 20-30°C	90	100	30	many months
composting anaerobic at ambient temperatures	60	60	30	many months
thermophilic composting 50–60°C maintained for several days	7	7	7	7
waste stabilization ponds retention time > 20 days	20	20	20	20

*excluding *Cryptosporidium parvum*
**mainly *Ascaris*; other parasitic eggs tend to die quicker

It is generally assumed that if the pathogens most resistant to destruction are destroyed effectively, then all other pathogens will also be destroyed. Two pathogens that meet these criteria (widespread and resistant to destruction) are *Ascaris lumbricoides*, (the common roundworm) and *Cryptosporidium parvum* (a type of parasite, protozoon, that causes diarrhoea). *A. lumbricoides* is found all over the world. It is estimated that up to 20% of the world's population may be infected[6]. The prevalence of *C. parvum* is more difficult to estimate but it has been identified in samples of faeces from more than 50 countries around the world[7]. Both pathogens infect children more than adults. Both infections lead to malnutrition, and if severe enough, death.

Cryptosporidium parvum oocysts, the excreted form of the protozoon, have been shown to be very resistant to destruction. They may even survive environmental stress, such as freezing, high temperatures, and water treatment with chlorine and ozone, better than *Ascaris*[8].

Dehydration, however, destroys *C. parvum*. Tests have shown that after only 2 hours of air drying at room temperature, 97% of the oocysts are killed. After 4 hours of air drying all the oocysts are destroyed[9].

Survival times of *Ascaris* eggs can be very long, but the die-off rate varies considerably according to the conditions. Death rates in soil are speeded up by dryness and sunlight. In sandy, sunny soils, *Ascaris* eggs have been reported to die-off within 2 weeks. In cool, moist, shady soil types, *Ascaris* eggs may survive for years. After several weeks, more than 95% of *Ascaris* eggs will still be viable (capable of causing infection) in loamy, clay or humus soils. The eggs will survive longer if they remain under a thin layer of soil, rather than on the surface of the ground.

There have been various studies on the survival of *Ascaris* eggs in different treatment systems. The most effective methods for destroying eggs were drying and heat. For example, in Guatemala, where *Ascaris* infestation is present in up to 50% of the population, thousands of eggs per gram (epg) of faeces were found inside the Lasf toilets (see Chapter 3.1.2 for details of the Lasf). Storage and dehydration in the toilet's processing vault followed by dehydration reduced the egg numbers to zero after an additional six months of sun drying[10].

Conventional sludge stabilization treatment processes (e.g. digestion at 20–25°C without oxygen) is not very effective at destroying *Ascaris* eggs, but the use of sludge beds is consistently effective[11].

2.1.3 Stepwise pathogen destruction

Dry methods of processing faeces are more effective at destroying pathogens than wet methods (flush-and-discharge). The combination of low moisture, low amount of organic matter/nutrients, and high pH make for the most rapid destruction. The most effective method of pathogen destruction seems to be dehydration.

Wet methods of disposal, like flush-and-discharge, are not particularly efficient at pathogen destruction. Wastewater is an ideal environment for pathogen survival because it mimics the intestines in many ways. First, it is rich in organic matter and nutrients. It is also moist and anaerobic. The one difference is the temperature. Wastewater and treatment plants usually operate at temperatures well below 37°C. The use of wastewater not only increases survival of pathogens, it also increases disease rates of people when spread on crops or discharged into water courses before effective treatment.

Pathogen destruction in theory is simple to achieve, but in practice it often requires careful attention through a series of steps. We recommend the following four-step process to render excreta safe for handling and recycling:

- **Keep the volume of dangerous material small** by diverting the urine and not adding (flushing) water.
- **Prevent the dispersal of material containing pathogens** by storing it in some kind of secure device until safe for recycling.
- **Reduce the volume and weight of pathogenic material** by dehydration and/or decomposition to facilitate storage, transport and further treatment.

- **Reduce pathogens to a harmless state,** by sanitization: primary treatment on-site (dehydration/decomposition, retention), secondary treatment on/off site (further dehydration, high temperature composting, changes in pH by the addition of lime), and, if necessary, tertiary treatment (incineration).

2.2 Recycle: how nutrients are returned to the soil

Ecological sanitation regards human excreta as a resource to be recycled rather than as waste to be disposed of. The use of human excreta for crop fertilization has been widely practised in many regions of the world. The Chinese have been composting human and animal excreta for a few thousand years[12] and Japan introduced the practice of recycling human faeces and urine for agriculture in the twelfth century[13]. In Sweden, where urine diversion has begun to be practised, farmers collect urine from underground tanks for a fee, and apply it to their crop land with mechanized equipment.

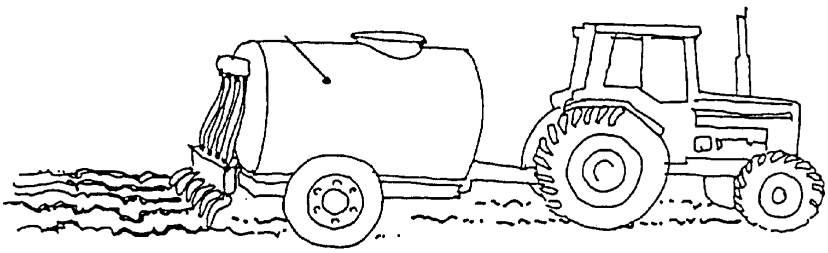

Figure 2.3 *In current R&D projects in Sweden human urine is stored in tanks on site, periodically collected by farmers and applied to their crop land with mechanized equipment.*

The very idea that excreta are waste with no useful purpose is a modern misconception. It is at the root of the pollution problems which result from conventional approaches to sanitation, particularly flush-and-discharge. In nature there is no waste: all the products of living things are used as raw materials by others. Recycling sanitized human urine and faeces by returning them to the soil serves to restore the natural cycling of life-building materials that has been disrupted by our current sanitation practices. Further, the energy efficiency of this process is greater the more locally this recycling takes place.

There are many reasons for recycling the nutrients in excreta. Recycling prevents direct pollution caused by sewage being discharged or seeping into water resources and ecosystems. A secondary benefit is that recycling returns nutrients to soil and plants, and reduces the need for chemical fertilizers. It restores good soil organisms to protect plants, and it is always available locally, wherever people live.

Nutrients recovered from human excreta can be used to enhance the productivity of horticulture and agriculture in home gardens and farms, in urban as well as rural areas. A large proportion of people who live in urban areas depend on food they grow themselves[14]. Even where this is not the case, and where it may be infeasible to transport recovered excreta to distant farmland, it may be used to restore ecologically degraded non-agricultural lands to create parks and green spaces.

Box 2.1 Growing vegetables in Mexico City

In response to rapid inflation, high unemployment and inadequate nutrition in Mexico City, Anadeges (a network of NGOs), has perfected a method of growing vegetables in containers using human urine as a fertilizer. The project was launched in Mexico City in 1988 and more than 1,200 urban households are currently participating.

The technology used was selected and adapted to fit the local circumstances, which include no land available for conventional kitchen gardens, participants unable to afford the required investment in containers and fertilizers, and the need for growing containers of lightweight materials to allow rooftop cultivation.

Vegetables are grown in containers (ideally 18–20 litres plastic buckets filled with deciduous tree leaves or grass clippings topped with a 3–5 centimetre layer of soil). This soil is made from the bottom layer of plant material from previous year's containers, which has composted into a rich humus, and household garbage, which has been composted with worms. A drainage hole is made in the side of the container, 5–10 centimetres from the bottom, depending on the type of plant to be grown, so that there will be a permanent reservoir of water and fertilizer. Urine, which has been stored in 2–5 litre containers for 3 weeks, is applied to the containers after dilution with water on a 1:10 ratio.

The problem of how to provide adequate space to grow root crops or very wide leafy vegetables was solved by using discarded car tyres. The Anadeges experimental centre in Mexico City is now testing a prototype machine for cutting and turning used tyres inside out to form wide-mouthed containers that have sufficient room for crops of this type.

After several years of study, certain conclusions are now obvious from this low-cost urban production of organic vegetables:

- Plants fertilized with urine grew more rapidly, larger and healthier than those grown with conventional agricultural techniques – and less water was needed.
- Plants that produce edible leaves (for example spinach, Swiss chard, parsley, as well as nopal, a nutritious, widely available cactus) performed particularly well. Leaves were big and dark green in colour.

➔

- Some fruit-bearing plants grew well and produced abundantly, particularly chilies, the hot peppers essential in the Mexican diet, although they were not as hot as those conventionally grown.
- Other fruit-bearing plants, such as tomato, tomatillo (green tomato), squash, bean, cauliflower and cucumber, responded well during the early stages, but did rather poorly in terms of fruit yield.
- All plants did particularly well in their early stages and proved remarkably resistant to insect pests and diseases.

Anadeges sells a kit to each family. A kit consists of 10 containers, three tyres turned inside out, a wide variety of plant seedlings, and a kilogram of worms (*Eisenia foetida*), to assist with garbage composting. About 80% of the cost of the starting kit is covered by a loan from a revolving fund. Fed on kitchen scraps, the worms reproduce quickly. After only a few months, 2 kilograms of worms, worth more than the family owes, are returned to Anadeges, thus paying off the loan with interest.

In an attempt to recycle human excrement various composting toilets have been developed in a number of countries. While the resulting product, humus, is a valuable soil conditioner, much of the nutrient value is lost during the composting process. As has been discussed in the first chapter, the most efficient way to recover excretal nutrients is to collect urine and faeces separately by using a specially designed squatting pan or seat riser to divert urine into a separate storage container.

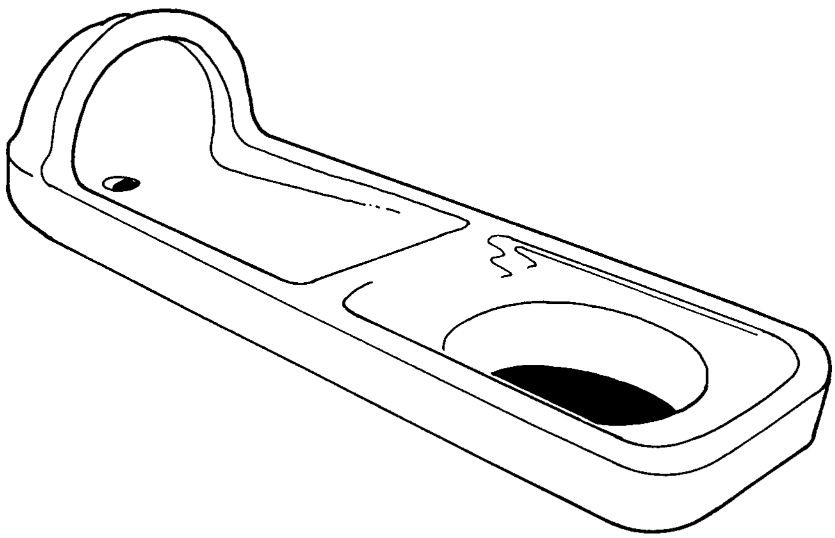

Figure 2.4 *Squatting pan with urine diversion, made of porcelain. The pan was developed by the Sanres funded project in China in 1997 and is now produced at a factory outside Beijing and sold at an ex-factory price of the equivalent of USD 10.*

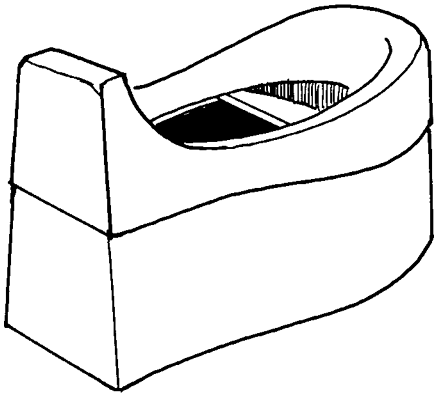

***Figure 2.5** Seat riser with urine diversion, made of fibreglass. The pan was developed by the Sanres funded project in Mexico in 1994.*

2.2.1 Urine

Most of the plant nutrients in human excreta are found in the urine. An adult may produce about 400 litres of urine a year containing 4.0 kg of nitrogen, 0.4 kg of phosphorus and 0.9 kg of potassium[15]. Interestingly, these nutrients are in ideal forms for uptake by plants: nitrogen in the form of urea, phosphorus as superphosphate and potassium as an ion. The total quantities of nutrients in urine are more appropriate when compared with the quantities of nutrients in the chemical fertilizers used in agriculture. In Sweden the total yearly production of human urine contains nitrogen, phosphorus and potassium equivalent to 15–20% of the amounts of these nutrients used as mineral fertilizers in 1993[16]. The heavy metal concentrations in human urine are much lower than those of most chemical fertilizers – an important advantage[17].

When urine is collected for use as a fertilizer, it is important to store it in such a way as to prevent odours and the loss of nitrogen to the air. Swedish research indicates that most of the nitrogen in urine, which is initially in the form of urea, is quickly converted to ammonia within a collection and storage device. However, ammonia loss to the air can be minimized by storage in a covered container with restricted ventilation[18].

Human urine can either be used as fertilizer by the producer household or else collected at a communal level and used by commercial farmers. When urine is applied on open soil it can be undiluted. If used on plants it must be diluted to prevent scorching, typically one part to 2–5 parts of water. Where there is no interest in actively using urine it is possible to dispose of it in an evapo-transpiration bed or by evaporation until the producer households have become aware of its value as a fertilizer.

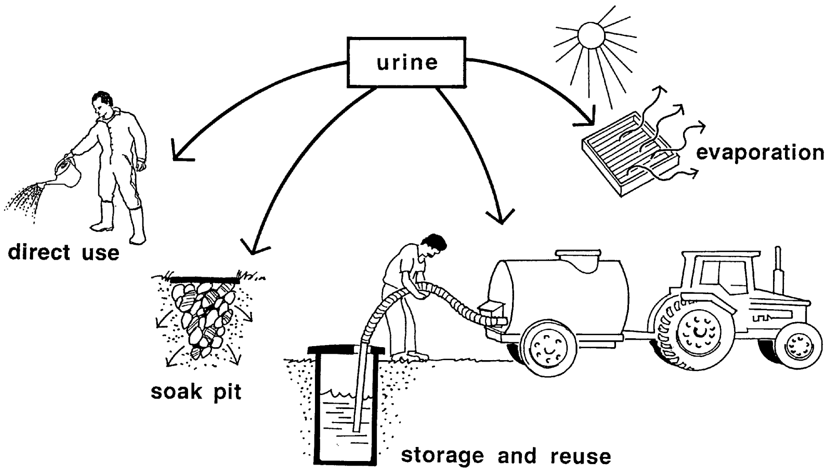

Figure 2.6 *Alternative ways of handling/using urine diverted from toilets.*

There is growing experience with the recovery of nutrients through urine diversion in Sweden. There are now several commercial manufacturers of urine diverting toilets. Most of them are installed in small systems catering for single households but increasingly they are used for systems serving groups of houses and flats as well as institutions. (Some examples are described in Chapter 3, see Sections 3.1.3, 3.2.1 and 3.2.2.)

A number of research institutions in Sweden are at present involved in a joint study of urine diversion and reuse. In the project, urine is collected from urine diverting toilets at two housing estates in Stockholm. The urine is stored on-site in tanks at each housing estate before being transported by trucks to a farm south of Stockholm. There it is stored in air-tight containers for 6 months before being spread on cereal crops. The overall goal of the project is to perfect a system for reusing the nutrients in agriculture. Risks of disease transmission, potential environmental impact, agricultural value and various technical, social and economic issues are all being examined. Among other findings, research so far has demonstrated that most of the nutrients in the urine are not lost through the collection and storage process, and that the fertilizing effect of the urine is almost as good as that of corresponding amounts of chemical fertilizers[19].

2.2.2 Faeces

Human faeces consist mainly of undigested organic matter such as fibres made up of carbon. The total amount per person per year is 25–50 kg containing up to 0.55 kg of nitrogen, 0.18 kg of phosphorus and 0.37 kg of potassium[15]. Although faeces contain fewer nutrients than urine, they are a valuable soil conditioner. After pathogen destruction through dehydration and/or decomposition (see Section 2.1.3) the resulting inoffensive material may be applied to the soil to increase the organic matter content, improve water holding capacity and increase the availability of nutrients. Humus from the decomposition process also helps to maintain a healthy population of beneficial soil organisms that actually protect plants from soil-borne diseases.

The simplest form of recycling is when the individual household can use the product as fertilizer in its own garden or on its own farm land. In urban situations not all householders will have either the land or the inclination to use the product themselves. Lack of land need not hinder food production as seen in the example from Mexico City in 2.1. Another example is the 'vertical garden' in Botswana in Box 2.2.

Box 2.2 Vertical gardens in Gaberone, Botswana

A Swedish horticulturist, Dr Gösta Nilsson, who has lived in Botswana since 1967, has developed a container gardening system for dry areas. It is based on walls with built-in growth boxes made of hollow concrete blocks.

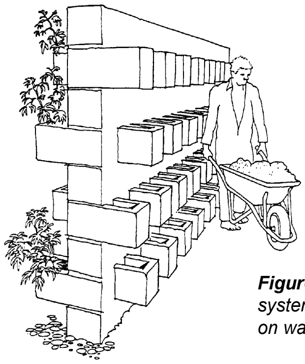

Figure 2.7 *In Botswana Dr Gus Nilsson has developed a system of intensive horticulture for dry tropical areas, based on walls with built-in containers (see also Figure 5.3).*

When building the wall some of the blocks are turned through 90 degrees and the protruding hollow part is provided with a floor and a small hole for drainage. The core of the wall is filled with a weak concrete mixture. The protruding containers are filled with sand on top of a layer of fertilizer. The containers can be arranged in various patterns and the wall can be provided with containers on one or two sides. In the tropics the containers may face any direction and the walls can be quite closely spaced (1.2–1.5 metres).

On the walls surrounding the demonstration homestead in Gaberone, Botswana, there are 2,000 containers (see Figure 5.3). Also the tanks for storage of rainwater are made as container walls.

A variety of vegetables and ornamentals are grown in the containers. Dr Nilsson is able to produce 2 kg of tomatoes per container four times a year. The retail price of the tomatoes produced on 1 square metre of wall during one year is roughly equivalent to the cost of building 1 square metre wall so cost is recouped quickly and profit can be made.

Winblad, U (1992): The productive homestead. Report to Sida, Stockholm.

3. ECOLOGICAL SANITATION: ANCIENT PRACTICES AND NEW IDEAS

The purpose of this chapter is to clarify what eco-san may look like in practice and to demonstrate the adaptability of the concept. We present a number of examples, both ancient and modern. In its own context each of these examples does, to a certain extent, meet the criteria listed in Chapter 1: disease prevention, environment protection, return of nutrients, acceptability, affordability and simplicity. All of the examples have a great potential for disease prevention[1] and all of them do protect the environment and conserve water. The variety of eco-san systems available makes it possible, in most cases, to find one that is culturally acceptable. Affordability is relative and while some of the systems described here are sophisticated and expensive, others are simple and low-cost. There is often a trade-off between cost and operation: lower cost solutions mean more manipulation and care of the sanitation system – with higher cost solutions, manipulation and care can be reduced.

The examples that follow are organized according to the main process used to achieve pathogen destruction: **dehydration** or **decomposition**. It is important to distinguish between process and device (see Chapter 1.3). Some of the sanitation devices illustrated here can be used either for dehydration or decomposition. The process is determined by the input. The major design and management options are discussed in more detail in Section 4.2.2.

3.1 Sanitation systems based on dehydration

When something is dehydrated all the water is removed from it. In a dehydrating toilet the contents of the processing vault are dried with the help of heat, ventilation and the addition of dry material. The moisture content should as quickly as possible be brought down to below 25%. At this level there is a rapid pathogen destruction (see Chapter 2.1), no smell, and no fly breeding.

The use of specialized collection devices (squatting pans or seat risers), which divert urine for storage in a separate container, allows the faeces to be dehydrated fairly easily (see Figures 2.4, 3.2 and 4.3). As discussed previously, since urine contains most of the nutrients but generally no pathogens, it may be used directly as a fertilizer without the need for further processing. It is generally difficult to dehydrate excreta without urine diversion, although in extremely dry climates this is possible as illustrated by the example from Ecuador below.

3.1.1 The double-vault dehydrating toilet in Vietnam

The classic example of an ecological sanitation system based on dehydration is the Vietnamese double-vault toilet. It is widely used in northern Vietnam and over the past 20 years the concept has also been used in Central America, Mexico and Sweden (see 3.1.2 and 3.1.3).

In northern Vietnam it used to be common practice to fertilize rice fields with fresh excreta. As this was a dangerous practice the health authorities in 1956 started campaigns to construct double-vault dry toilets. The campaigns were followed by long and persistent health education programmes[2]. The objective of the new toilet design was to kill pathogens before the faeces were spread on the fields.

The Vietnamese toilet consists of two processing chambers each with a volume of about 0.3 cubic metres.

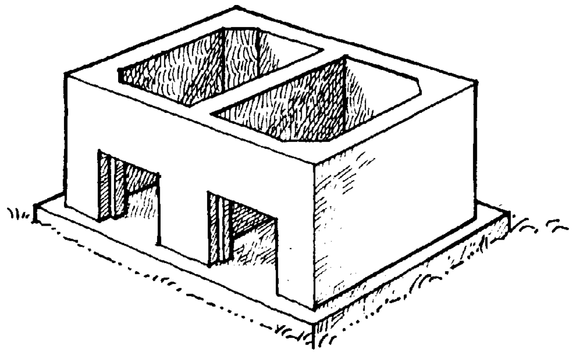

Figure 3.1 *The processing chambers of the Vietnamese double-vault toilet. Each vault is 0.8x0.8x0.5 metre. The picture also shows the two 0.3x0.3 metre openings for removal of dehydrated material.*

The toilet is built entirely above ground with the processing chambers placed on a solid floor of concrete, bricks or clay. The floor is built up to at least 10 cm above ground so that heavy rains do not flood it. The toilet is often placed at the back of the garden, sometimes next to a pig-pen.

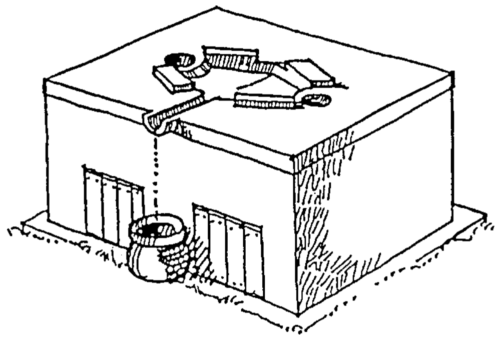

Figure 3.2 *The processing chambers of Figure 3.1 provided with a squatting slab for urine diversion, a pot for collecting urine and lids for the two openings for removal of dehydrated material. The drop hole not in use is closed with a stone and sealed with mud or mortar.*

The processing chambers are covered with a squatting slab that has two drop holes, footrests and a groove for urine. Both holes have tight-fitting lids (not shown in Figure 3.2). At the back there are two openings, 30 x 30 cm, for the removal of the dehydrated material. These openings are kept sealed until it is time to empty one of the chambers.

People excrete in one of the chambers. Before the vault is used for the first time, the household members cover the floor with a layer of powdered earth. The purpose of this earth is to absorb moisture from the faeces and to prevent them from sticking to the floor. After each use people sprinkle two bowls of ashes over the faeces. The ashes absorb moisture, neutralize bad odours and make the faeces less attractive to flies.

Urine drains away through the groove in the slab and collects in a jar behind the toilet. Paper used for anal cleaning is dropped in box or jar and burnt. Thus in the receptacle there are only faeces, ashes and soil. The contents are therefore fairly dry and compact. The jar for collection of urine can be placed in position either empty or partly filled with water, lime or ashes. The urine or the urine-soaked ashes are used as a fertilizer (see Section 2.2.1).

The first vault can be used for about 2 months by a household of 5–10 persons. When it is two-thirds full, someone in the household levels the content with a stick. He or she then fills the vault to the brim with dried, powdered earth, and seals the vault. All openings are tightly closed with lime mortar or clay. The other vault now comes into use instead. When after another two months the second vault is nearly full, he or she opens and empties the first vault. The dehydrated faeces, now odourless, are used as fertilizer[2].

In Vietnam the experience of this system is mixed (see Section 4.1.2, Lack of education and training). There is no doubt that the system, when properly used, does function very well. A retention time of 2 months seems, however, rather short for total pathogen destruction. The real problem in northern Vietnam though is that some farmers tend to empty the processing chambers whenever they need fertilizer, regardless of the retention time. This means that partly processed and even fresh faeces are spread on the fields. It takes a long time to break age-old habits and in Vietnam there is definitely a need to intensify and continue hygiene education until the practice of using fresh faeces as fertilizer can be halted (see also Section 4.1.2).

3.1.2 The double-vault dehydrating toilet in Central America and Mexico

The Lasf (Letrina Abonera Seca Familiar) is a slightly modified version of the Vietnamese toilet. It was introduced into Guatemala in 1978 by Cemat (Centro Meso-Americano de Estudios sobre Tecnología Apropriada) and over the past 20 years thousands of units have been built in Central America, particularly in El Salvador. A similar development has taken place in Mexico where the system is promoted under the name of Sanitario Ecologico Seco by César Añorve, an architect-entrepreneur based in Cuernavaca.

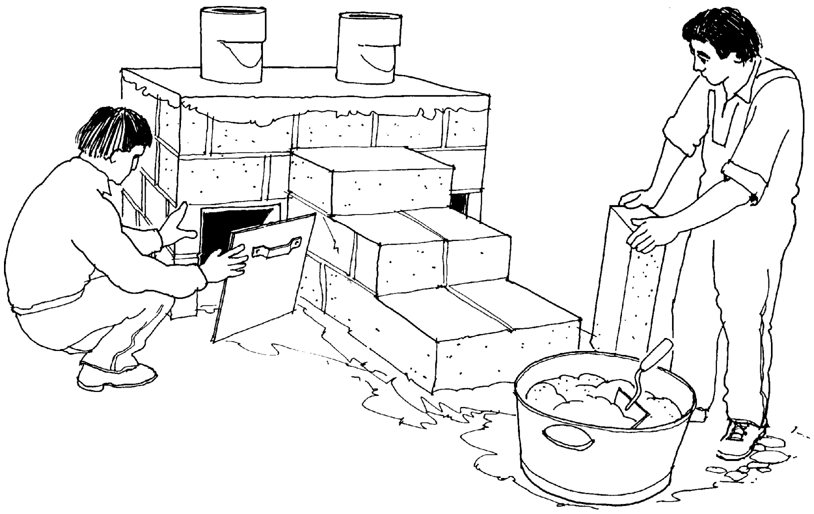

Figure 3.3 *A Lasf toilet under construction. On top of each vault is a seat riser with a urine collector. The seat riser not in use is usually covered with a plastic bag.*

Like the Vietnamese original, the Lasf toilet and the Sanitario Ecologico Seco consist of two chambers built above ground, each with a volume of about 0.6 cubic metres. From the collector the urine flows via a pipe into a soakpit under the toilet chambers. (In Central America there is no tradition of using human urine as fertilizer.) The faeces fall straight down into the processing vault. After using the toilet the user sprinkles some dry material like ashes, soil or a soil/lime or sawdust/lime mixture over the faeces. The paper used for anal cleaning is, according to the Latin tradition, placed in a special container next to the seat-riser and burnt. The vault thus receives only faeces and ashes (or whatever dry material is used). Every week the contents of the vault are stirred with a stick and more ashes added.

When the first vault is nearly full it is topped up with soil and the seat closed. The second vault is now used. A year later, or when the second vault is nearly full, the first one is opened. A household of 5–6 persons will produce almost half a cubic metre of dehydrated completely odourless material per year[3].

In Mexico and Central America there are many examples of urban use of this type of sanitation. One example is in El Salvador: Hermosa Provincia is the name of a small, densely built up low-income barrio in the centre of San Salvador. Water is scarce, plots are small and the subsoil is hard. Here all the 130 households built Lasf toilets in 1991. As there is little space between the houses and often no backyards, the Lasf toilet is usually attached to the house, sometimes even placed inside the house (Figure 3.4).

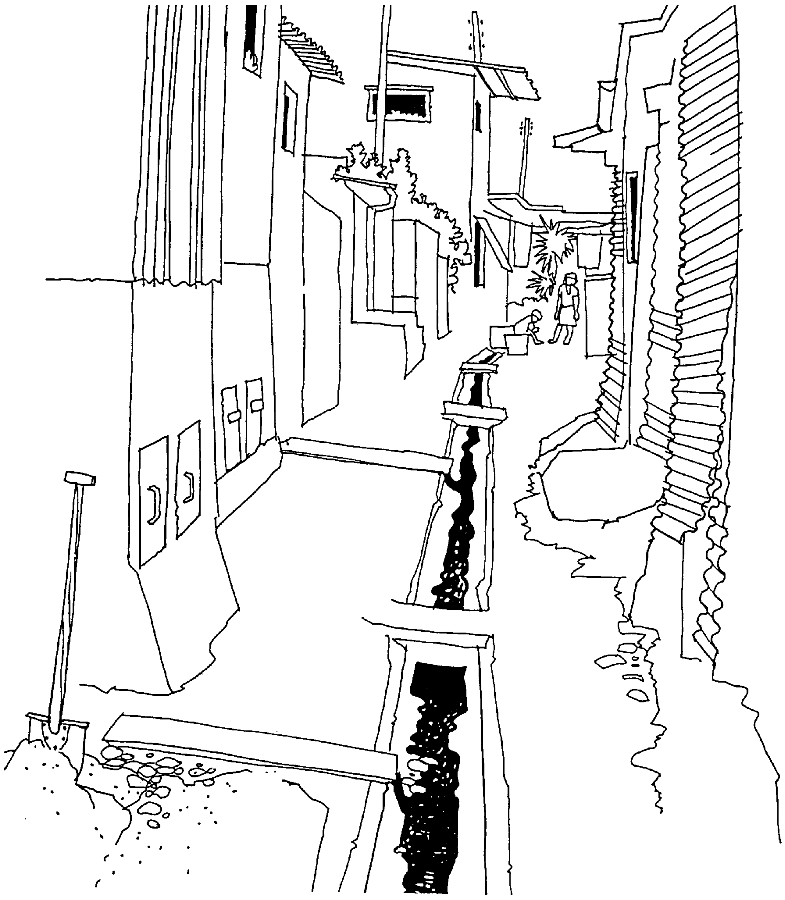

Figure 3.4 *A street in Hermosa Provincia, a high density squatter area in the centre of San Salvador. Each household has its own Lasf toilet, most are attached to, or placed inside, the house.*

All the units in Hermosa Provincia are still, after 6 years, functioning extremely well thanks to a high level of community participation. There are no bad odours from the toilets and no fly-breeding in the processing chambers. The dry mixture from the toilets is used to reclaim wasteland or put in bags and sold.

Another example is from Mexico where César Añorve has spent the past 15 years promoting the Vietnamese sanitation system. His version of the Vietnamese toilet is conceived as a high-standard, in-house solution.

César Añorve supports his operation almost entirely from the profit of the sale of urine diverting toilet seat-risers. His own workshop in Cuernavaca, a small family business, produces about 30 seat-risers made of polished concrete per week. He also sells fibreglass moulds for the seat-risers and assists local groups in establishing small workshops. The first independent workshops were established in Oaxaca and Yucatan in 1990. There are now 15 independent small-scale manufacturers in different parts of Mexico.

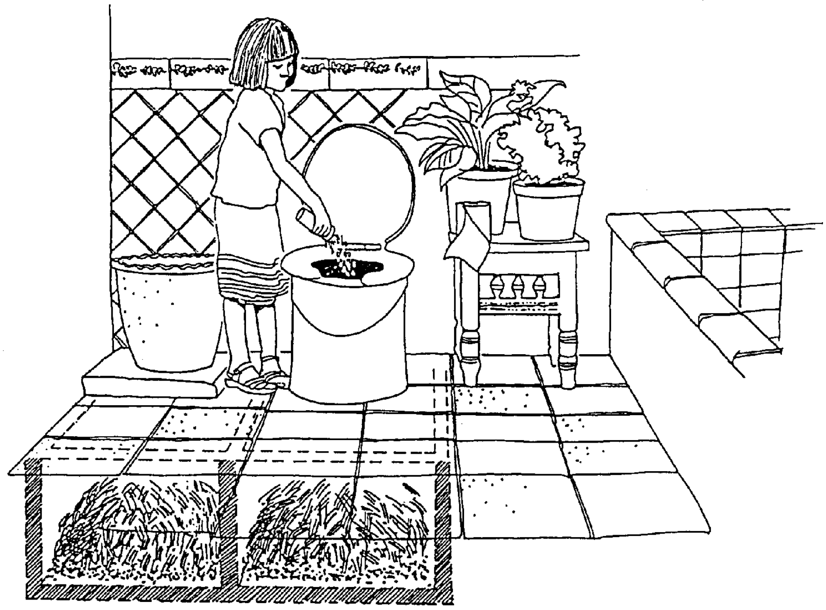

Figure 3.5 *The Mexican version of the Vietnamese double-vault toilet, here built into a bathroom in a modern, high standard house in the city of Cuernavaca. The toilet has a movable seat riser with urine collector. The processing chambers below the bathroom floor are accessible from outside the house.*

Plans for the future include linking toilet users to community composting centres. These centres, acting as a service industry, would empty processing chambers and urine tanks and bring the material to the composting center for further processing and sale.

The price (1997) of a seat-riser in polished concrete is the equivalent of USD 16 (Mexican Pesos 126). A complete freestanding unit including superstructure is the equivalent of USD 150 (Mexican Pesos 1,200). César Añorve sells the fibreglass moulds for the equivalent of USD 250 (Mexican Pesos 2,000). In El Salvador the current (mid-1997) cost of a contractor built Lasf toilet (excluding superstructure) is the equivalent of USD 125 (Colones 1,100).

The experience of almost 20 years of use of the Vietnamese double-vault system in Mexico and Central America is overwhelmingly positive. Properly managed there is no smell and no fly breeding in these toilets. They seem to work particularly well in the dry climate of the Mexican highlands. Where the system has failed (wetness in the processing chamber, odours, fly breeding) it was usually due to non-existent, weak or bungled information, training and follow-up.

Two urban applications are particularly significant. In San Salvador the system has been successfully used in a poor, high density squatter area; in Cuernavaca by a *number of middle class families living in modern, high standard houses. The projects demonstrate, perhaps more than any other so far reported in the literature, that careful management of an eco-san system, resulting from high motivation and understanding on the part of the families involved, can make an extremely simple technology work very well.*

3.1.3 The 'WM Ekologen' dehydrating toilet in Sweden

The 'WM Ekologen, type ES' system was developed by professor Mats Wolgast, Karolinska Institutet, Stockholm, Sweden, in the early 80s. Like the Vietnamese system it relies on a process of dehydration and is designed for urine diversion.

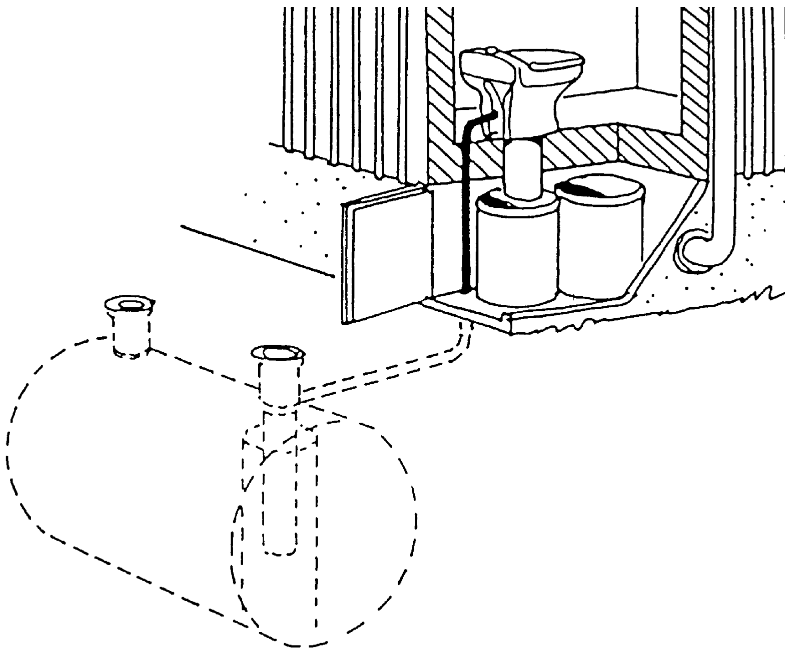

Figure 3.6 *A dehydrating toilet of type 'WM Ekologen, type ES' installed inside a house in Sweden. Faeces and toilet paper are dropped into a large bucket. Urine is piped into an underground storage tank.*

Urine is flushed into an underground storage tank with 0.1 litre of flush water. The volume of the tank is 0.5 cubic metres per person. Faeces and toilet paper drop down into a insulated vault where it is collected by an 80 litre plastic container. When the container is full (after 2–3 months) it is put aside and an empty container is placed under the toilet. The full container is left in the vault for about 6 months. The dehydrated contents can then be further treated (secondary treatment) in a ventilated compost bin (for the toilet paper to decompose) or burnt.

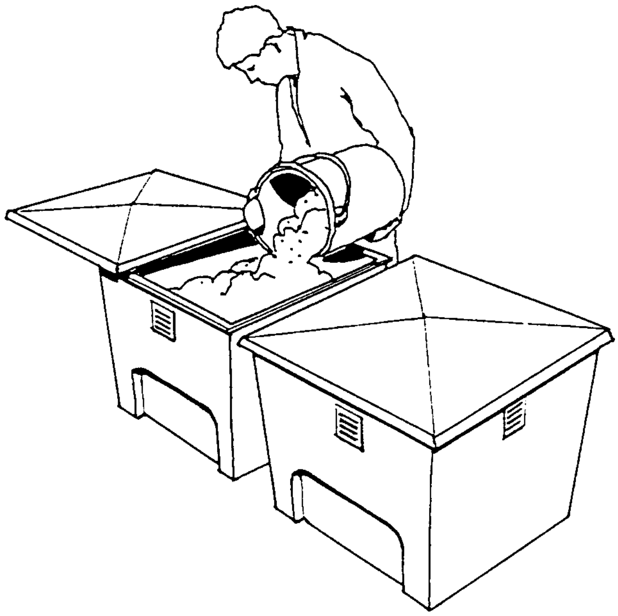

Figure 3.7 *The dehydrated contents of the buckets are transferred to composting boxes for secondary treatment.*

The system uses a fan to suck air from the bathroom, down the toilet to the processing vault and out through a ventpipe.

The retail price of the porcelain toilet seat-riser with urine diversion is about USD 360 (SEK 2,900). The total on-site cost for for a toilet like this (seat-riser, fan, processing vault, transport container and a 1,000 litre urine tank) is in Sweden USD 650–750 (SEK 5,200–6,000). There are at present about 800 units installed in Sweden: in weekend houses, permanent houses, industries and institutions.

The 'WM Ekologen' is a well-tested, high standard sanitation system suitable for indoor use in modern bathroom. It is used in urban as well as rural areas and in institutions as well as private households.

3.1.4 The 'Tecpan' solar heated toilet in El Salvador

The greatest risk of failure with a sanitation system based on dehydration is wetness, as pointed out in Chapter 4. By adding a simple solar heater to the processing vault this risk can be reduced. After some early experiments with solar heated toilets in Tanzania the concept was further developed in Mexico (see Section 3.2.3) and more recently in El Salvador and Vietnam[4].

The purpose of the Tecpan project in El Salvador 1994–97 was to test and develop a sanitation system based on dehydration, urine diversion and solar heating in a single-vault device. A total of 36 prototypes have been used for several years by households in the community of Tecpan near San Salvador[5].

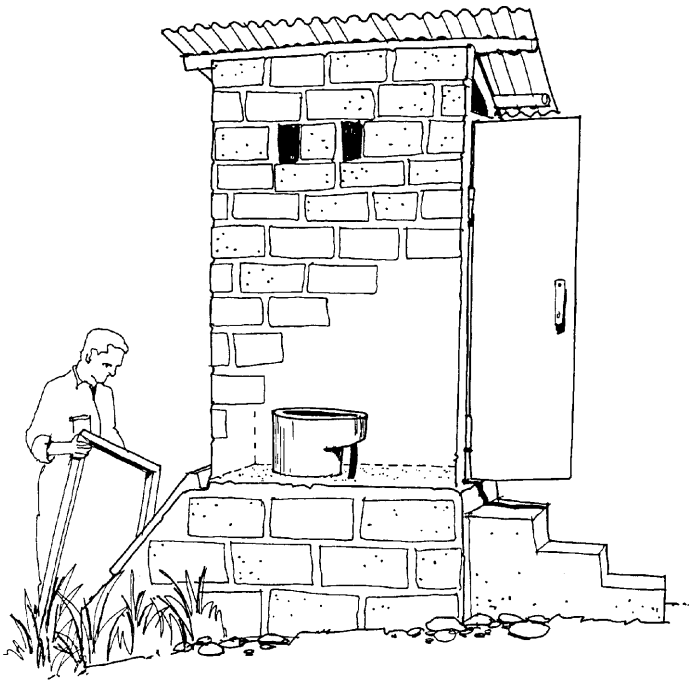

Figure 3.8 *The dehydrating toilets in the Tecpan community outside San Salvador have a solar-heat collector to increase evaporation from the processing chamber.*

The toilets are used in the same way as regular Lasf toilets. The input into the processing vault consists of human excreta and wood ash and/or a soil/lime mixture (proportions 5:1). Urine is piped into a small soakpit near the toilet (since human urine is usually not used as fertilizer in Central America). Toilet paper is placed in a box or bag kept next to the seat-riser and burnt periodically according to normal practice in El Salvador.

Every 1 or 2 weeks the lid acting as solar-heat collector is removed and the pile of faeces + ash/lime/soil accumulated below the toilet seat is shifted to the rear of the vault with a hoe or rake. (This tool can be stored inside the vault.) Once every second or third month the dry and odour free pile at the rear of the vault is shovelled into to a sack and stored outside the toilet until recycled in the garden.

Some of the units have been equipped with a 'pusher' to make it possible to shift the pile to the rear of the processing vault, see Figure 3.9.

The cost of a contractor built Tecpan toilet with solar-heater and prefabricated seat-riser made of plastic but without a pusher is approximately USD 164 (Colones 1,437).

The Tecpan toilets are functioning very well. The solar heater accelerates the dehydration process. Most of the test units are completely dry and odour free and there is no fly breeding. Further test will show if the addition of a solar heater to the

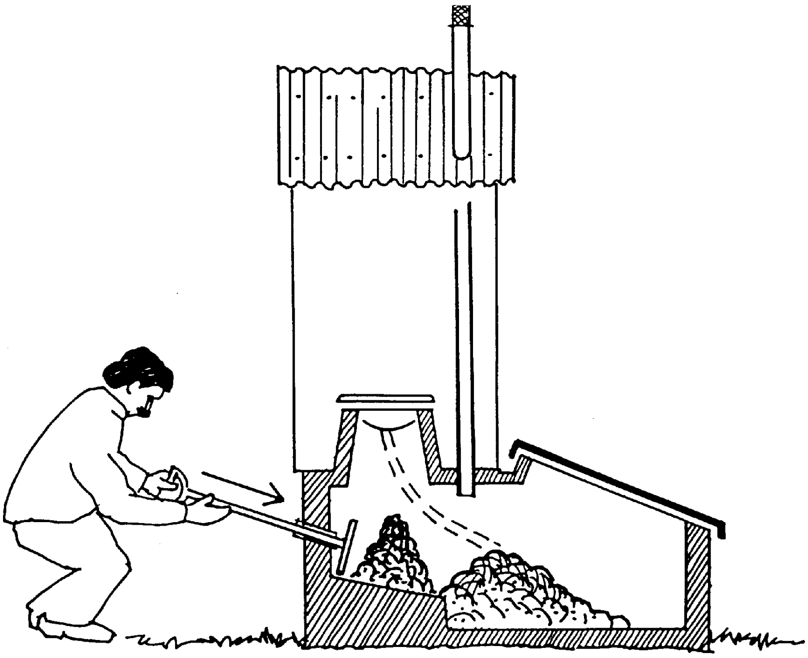

Figure 3.9 *A few times a month a fixed pusher is used to shift the pile of faeces and ash from below the toilet seat into the solar heated processing chamber.*

processing chamber has any effect on pathogen destruction.

The building cost of a single vault device is less than that of a double-vault but makes it necessary to shift the pile every one or two weeks. This shifting of the pile probably facilitates the dehydration process.

3.1.5 The double-vault solar heated toilet in Ecuador

Since 1985 some 300 double-vault toilets with solar-heated lids have been built in the Province of Cotopaxi in the high Andean region of Ecuador. A recycling system was chosen in an attempt to help the chronic problems of falling soil fertility in the high altitude (3,500–4,000 m) region.

Because of the dry atmosphere in this region there has been no need to develop techniques for urine diversion. After each use a handful of sawdust and/or ash, is added. Each vault is used for 6 months before switching to the other vault. Each vault has a lid made of a wooden frame covered with thin galvanized iron painted black in order to absorb the sun's energy and assist the dehydration process. The chambers are ventilated by a vent-pipe and the vault lids each include a vent to let air in. The vent-pipe and the lid-vents are covered with metal fly-screen mesh.

The toilets are built from sun-dried mud bricks made on-site, combined with prefabricated wooden elements: seat-riser, lid for the toilet hole, vent-pipe and a door.

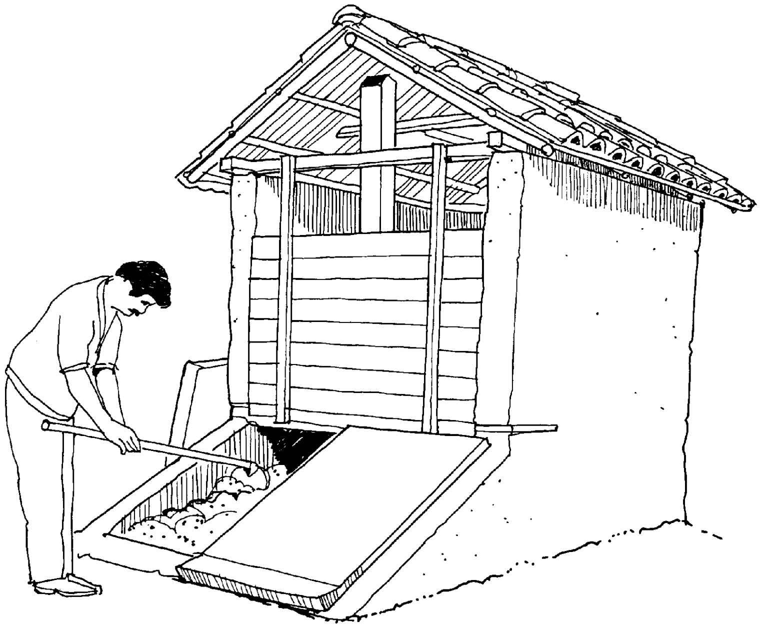

Figure 3.10 *Double vault toilet with solar heaters in Ecuador.*

The experience in Ecuador is interesting in that it shows that the extremely dry climate of the Andean mountains creates conditions which eliminate the need for urine diversion as well as solar heat collectors (which originally were added in a humid climate in an attempt to speed up the evaporation from the processing vault).

3.1.6 The indoor, long-drop dehydrating toilet in Yemen

In the old parts of the city of Sana'a, as in other Yemeni towns, the traditional houses are tall, rising five to nine stories from narrow streets. A house is usually occupied by one extended family. Each upper floor has one or two toilet-bathrooms next to a shaft (a long, narrow vertical passage). Figure 3.11 shows how this shaft runs from the top of the house to the level of the street.

Each bathroom has a toilet. The urine drains away from the squatting slab to a groove in the stone floor. From there it goes through an opening in the wall of the house, down a vertical drainage surface on the outer face of the building. (These surfaces are often elegantly shaped and decorated.) Most of the urine evaporates on its way down the drainage surface and the rest, if any, is drained into a soakpit.

The faeces drop through the squatting-hole, down the shaft, to a vault at the street level from where the dried faeces are periodically collected, further dried on the roof of the neighbourhood public bath and finally used as fuel for heating water.

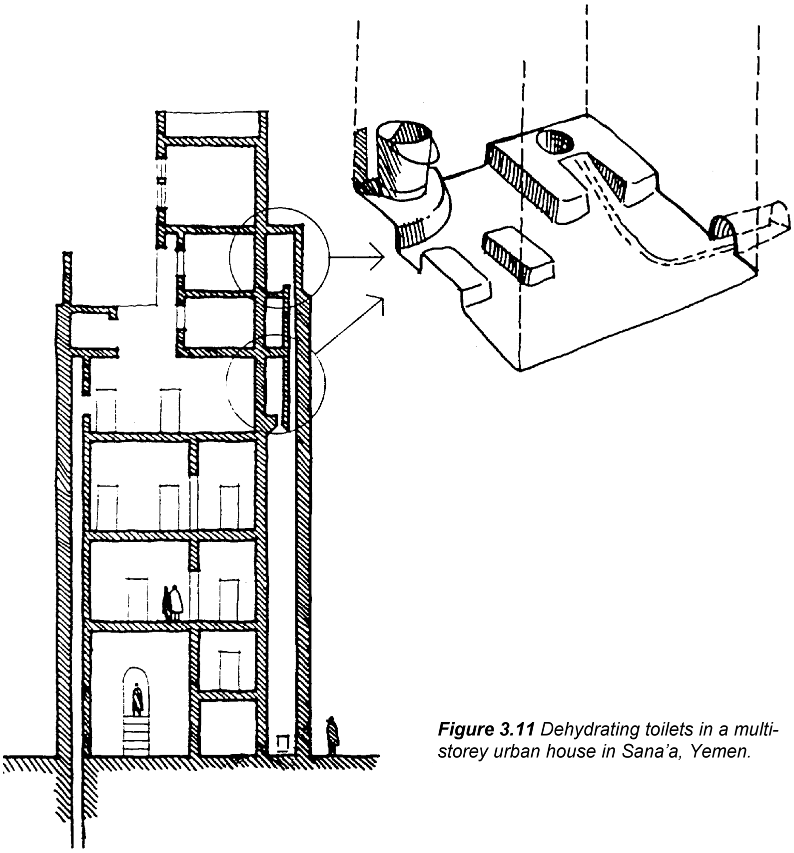

Figure 3.11 *Dehydrating toilets in a multi-storey urban house in Sana'a, Yemen.*

Anal cleaning takes place on a pair of square stones next to the squatting slab. The water used for anal cleaning as well as bath water is drained in the same way as the urine. No liquids are thus led into the long drop shaft or the vault below. As Sana'a has a hot, dry climate, the faeces quickly dry out[6].

Next to the toilet there is, during morning hours, a charcoal fire in a bucket. After anal cleaning with water, the Yemenites dry themselves by squatting over the bucket[7].

This is an example of the eco-san approach to sanitation applied to an urban situation with multistorey housing and communal collection of dehydrated faeces by special staff. It's also an example of a dry sanitation system used in a culture where people are washers. (Another example of this is 3.2.6.) It is a traditional system and has been used in the towns of Yemen for hundreds of years. There is no smell and no fly-breeding. Urine and cleansing water are evaporated and faeces are processed in three steps: first they are dehydrated on site, second they are further dehydrated and subject to direct solar radiation at the public bath, and finally they are burnt.

3.1.7 The indoor, dehydrating toilet in Ladakh, India

Ladakh is a dry highland region in the western Himalayas at an altitude of 3,500 m. Most traditional houses have an indoor toilet on the upper floor, see Figure 3.12. Due to the dry climate it is possible to dehydrate the faeces without prior diversion of urine.

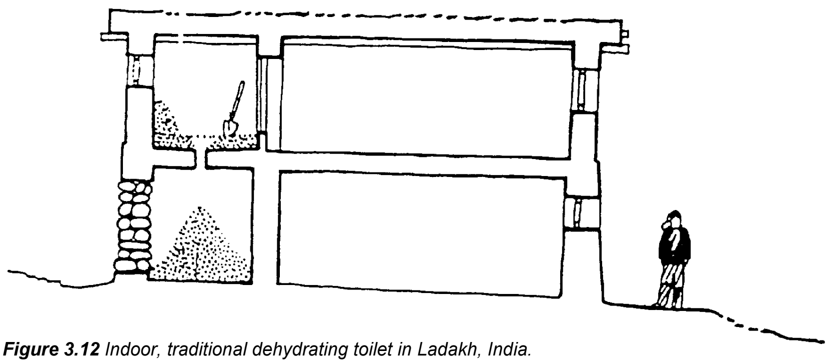

Figure 3.12 *Indoor, traditional dehydrating toilet in Ladakh, India.*

On the floor of a small room next to the kitchen/living room there is a thick layer of soil from the garden. In the floor a drop hole leads to a small ground-floor room. This room can only be reached from the outside. People excrete on the soil which is on the floor. Then they push soil and excreta together down the drop hole. Urine goes the same way. Ashes from the kitchen are added from time to time. The household members bring loads of soil into the room when necessary. For the long winter a supply of soil is piled into one corner of the toilet room upstairs. A spade or shovel is also kept in the room. Normally there is no anal cleaning. The decomposed excreta are removed in spring and at the end of summer and spread on the fields.

As long as the toilet is well maintained and enough soil is pushed down the drop hole every day, there are no odours. In some cases there is a faint smell of ammonia from urine splashed on the soil-covered floor of the toilet room. There is no fly breeding due to the dryness of the soil/excreta pile. The system has worked well in rural areas for hundreds of years but in recent years there have been some problems in the central part of the town of Leh where households have no easy access to soil.

3.2 Sanitation systems based on decomposition (composting)

Composting is a biological process in which, under controlled conditions, bacteria, worms and other types of organisms break down organic substances to make humus, a rich, stable medium in which roots thrive. In a composting toilet human excreta, along with additional bulking agents such as vegetable scraps, straw, peat moss, wood shavings or coconut husks, are deposited into a processing chamber where soil-based micro-organisms decompose the solids – just as eventually happens to all organic materials in the natural environment. Temperature, airflow and other factors are controlled to varying degrees to promote optimal conditions for composting. The humus produced by the process is an excellent soil conditioner, free of human pathogens when the right conditions are achieved and adequate retention time is allowed in the digester. Odours, if any, can be extracted directly out above the roof through a ventilation system.

A composting toilet tries to achieve optimal conditions for biological decomposition. This means that sufficient oxygen should be able to penetrate the compost heap to maintain aerobic conditions, the material in the composting vault should have a moisture content of 50–60%, the carbon:nitrogen balance (the C:N ratio) should be within the range 15:1 to 30:1 and the temperature of the composting vault should be above 15°C.

A variety of organisms contribute to the breakdown of the material in a composting toilet. They range in size from viruses, bacteria, fungi and algae to earthworms and insects. They all play a major role in mixing, aerating, tearing apart and breaking down the contents of the pile in the toilet's processing vault. As long as they remain inside the vault their activities are good and should be encouraged. It might even be a good idea to place earthworms in the toilet. If the environment is favourable for them they will multiply, burrowing holes through the compost heap, eating odorous organic matter and thereby converting it into rich organic soil, see Box 3.1.

Although we believe that composting systems could often benefit from urine diversion, most examples of composting toilets collect urine and faeces together. In order to create conditions that promote composting, they usually rely on various design strategies to separate faeces and other solid material from urine after they have been mixed together within the processing vault (see Section 4.2.1 and Figure 4.4). Since the urine is contaminated with pathogens once it has had contact with the faeces, it is more problematic to use it directly for fertilizer and it must be dealt with in some other way. Some composting systems allow the separated liquid to infiltrate into the ground, while others have adopted strategies to get rid of it through evaporation. While much of the nitrogen in urine is lost in composting systems, the resulting humus, or compost, retains other nutrients and is a valuable soil conditioner.

3.2.1 The 'Clivus Multrum' single-vault composting toilet in Sweden

Composting toilets for use in weekend houses were introduced in Sweden more than 50 years ago. Since then a wide variety of models have come on the market and they are now used in different parts of the world, including North America and Australia. Commercially available composting toilets range from small units about the size of a standard flush toilet fixture to larger ones which utilize a simple toilet pedestal in the bathroom connected by a drop chute to a composting vault below the floor.

The 'Clivus' Multrum shown in Figure 3.13 is the classic model. It is a single vault composting toilet with combined processing of urine, faeces and organic household residues. It consists of a composting vault with a slanting floor, air conduits and at the lower end a storage space. A tube connects the toilet seat-riser with the receptacle and there is often a special chute for kitchen refuse. There is a constant draught due to natural convection from an air intake in the composting vault, through the air conduits and out via a ventpipe.

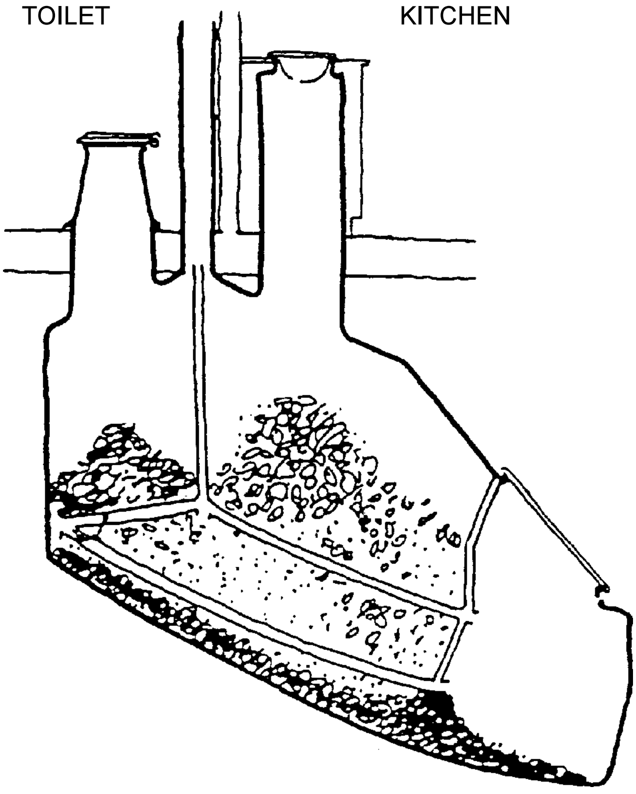

Figure 3.13 *The 'Clivus' Multrum composting toilet from Sweden placed in the basement of a house. This model has a separate chute from the kitchen for food left-overs etc. Perforated pipes bring air into the centre of the compost pile.*

Into the Multrum goes not only faeces, toilet paper and urine but all kinds of organic kitchen and household residues: vegetable and meat scraps, peelings, bones, eggshells, floor sweepings, sanitary napkins and grass clippings (but not cans, glass, plastic or large amounts of liquids of any kind).

Because the floor of the Multrum slopes, the contents are slowly sliding down from the fresh deposits at the upper end down to the storage part of the vault. The process of decomposition reduces the heap to less than 10% of the original volume.

The owner must provide a starter bed covering the floor of the composting vault before using the Multrum the first time. The bed consists of a 0.4–metre thick layer of peat moss and a 0.2–metre layer of garden soil rich in humus. You should first mix this soil with grass cuttings. The purpose of this bed is to absorb liquids and to provide the microbes required for the oxidation of urine.

The heap gradually becomes humus: a black, lumpy substance similar to good garden compost. It may take 5 years until a household has to take out the humus for the first time. After that they may have to take it out once a year. (The large part of the receptacle is never emptied. Only material that has passed under the partition separating the storage vault from the rest of the receptacle is removed.) The amount of humus produced varies from 10 to 30 litres per person per year.

Box 3.1 Earthworms in a Clivus Multrum

Composting with earthworms had always seemed a good idea ... that earthworms should be an important part of the ecology of the composting of human excreta. Yet for the first 15 years after the introduction of the Clivus to the US from Sweden, earthworms (redworms) simply refused to live inside the composter. ... there was no question that environmental conditions inside the Clivus were not favourable to them. So we ... tried a daily misting with water ... The new moist conditions ... were evidently very good for them as they multiplied at an astounding rate. Within three months there were thousands.

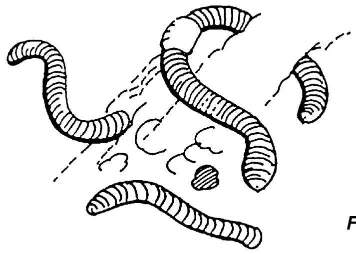

Figure 3.14 *Earthworms in a composting toilet.*

The effect of the redworm community on the Clivus Multrum composting process has been remarkable. Except for two mounds under the toilet and kitchen chutes, the rest of the composting material is flat – flattened by the worms, their castings covering the entire surface. We observe that the worms prefer food scraps to excrement but they like excrement just fine.

Besides proper nourishment the key to redworm happiness and productivity in the composter is regular moistening with water.

Rockefeller, A (1995): Clivus Multrum loves worms, in Worm Digest No 8

The maximum number of users depends on factors such as temperature, humidity, amount and type of refuse, proportion of urine to faeces, and volume of the receptacle. In most cases the maximum for one Clivus Multrum in regular, year-round use is 8–10 people.

The humus from the Clivus Multrum has a similar bacterial content to soil. In Sweden it is considered safe to use directly as a fertilizer and soil conditioner.

Nowadays Clivus Multrums are used not only in weekend houses but also in regular houses, in institutions and as public toilets. About 10.000 Clivus Multrum toilets are in use worldwide[8].

If the Multrum is properly built and looked after well, then it is reasonably nuisance free. Because there is no diversion of urine and because of the slanting floor there is a risk, except in very dry climate, that liquid accumulates at the lower end of the composting vault. To cope with this problem the second generation Clivus Multrum has a container for liquid storage below the composting vault, see Figure 4.3.

3.2.2 The 'Carousel' multiple-vault composting toilet in Norway

The 'Carousel', manufactured by Vera Miljö A/S of Norway, has long been one of that country's most popular composting toilets, and reportedly over 30,000 units have been manufactured there and in the US since 1972. A similar type is also manufactured in Sweden. Outside Scandinavia the carousel-type toilet is manufactured in Australia under the name of 'Rota-Loo'. In addition to sales in Australia and New Zealand, a small but growing number of Rota-Loos are in now in use on some of the islands in the South Pacific.

The design of the 'Carousel' features a below-the-floor processing vault consisting of a cylindrical outer tank in which a slightly smaller inner tank is able to rotate on a pivot. The inner tank is divided into four chambers (six on some models). The one in use is positioned directly below the drop chute from the toilet in the bathroom. When a chamber is filled, the inner tank is rotated so that the next chamber is positioned below the toilet. In this way each chamber is filled in sequence. The system is designed so that it will take at least a year for all of the chambers to be filled when use is within the design capacity of the unit. After this point, when a chamber is filled, the material in the oldest one is removed through an access door in order to make room for fresh material. Liquid drains through holes at the bottom of the inner tank into the outer one, where it may be evaporated or discharged into an evapo-transpiration bed. Several different size units of varying capacity are available at prices between USD 1,700 and 2,300 (SEK 14,000–19,000).

The carousel is basically a multi-vault toilet. As such it effectively keeps fresh and sanitized faeces separate. The same effect can be achieved at a much lower cost by using a series of collection buckets shifted manually instead of a rotating tank (see also Figure 5.4).

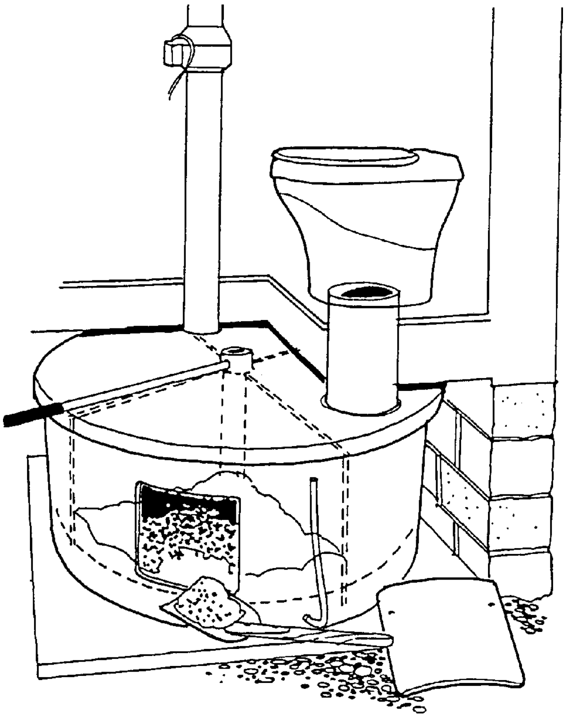

Figure 3.15 *The 'Carousel' composting toilet from Norway.*

3.2.3 'Sirdo Seco' solar heated composting toilet in Mexico

A prototype double-vault, solar-heated composting toilet was tested in Tanzania in the mid-1970s. The idea was further developed in Mexico where a prefabricated fibreglass unit has been in production for more than 15 years. Like the Vietnamese toilet, the Mexican type has a receptacle divided into two vaults. Above the dividing wall there is a baffle (see Figure 3.16). The baffle directs the excreta into one vault. When the vault is full, the person looking after the toilet turns a handle which makes the baffle direct the excreta into the other vault.

A ventpipe, which goes from the receptacle to above the roof, takes away odours. As there is a screen on top of the ventpipe, it also acts as a fly trap. The two vaults have lids made of black painted aluminium sheets. The lids face the sun to collect a maximum of solar heat. This increases the evaporation from the vaults as well as the temperature of the surface of the compost pile.

Each vault has a volume of 1.2 cubic metres. When the pile has reached the baffle, the person looking after the toilet can shift the pile to the lower end of the receptacle. This means that people need to empty the toilet only once a year at the most (if 6–8 people use it regularly). When properly managed this toilet has a high capacity and works very well. It is easy to change from one vault to the other because of the baffle.

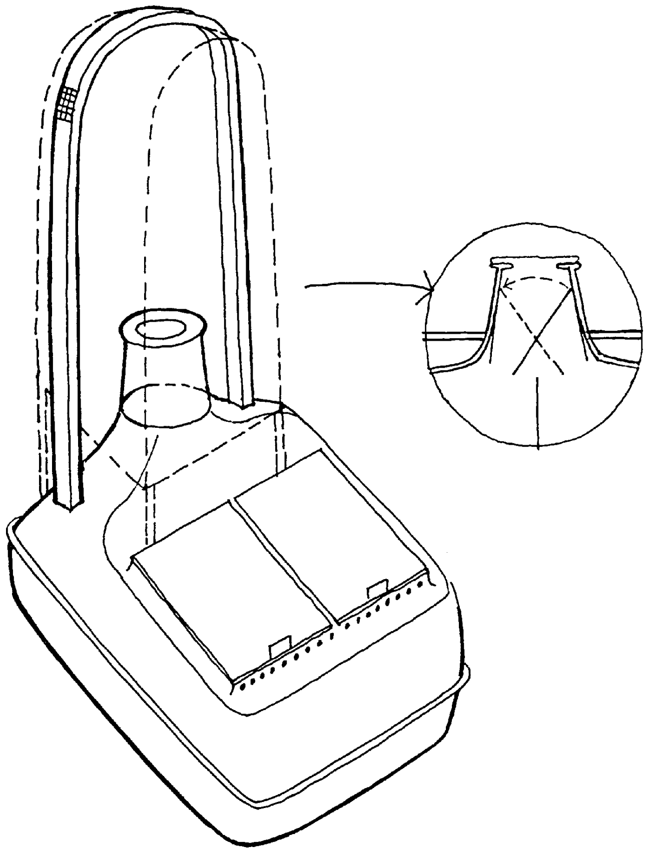

***Figure 3.16** The 'Sirdo Seco' double-vault, solar-heated composting toilet in Mexico. The whole toilet, including the superstructure, is made of fibreglass.*

The cost of a prefabricated toilet substructure of fibreglass was in 1994 the equivalent of USD 445 (Mexican pesos 1,488). The cost of a prefabricated superstructure was USD 109 (Mexican Pesos 360)[9].

The 'Sirdo Seco' has been used with good results in Mexico for over 15 years. One particular advantage with this lightweight, prefab model is that it is mobile. People living in squatter settlements can be evicted at short notice. If this happens they can arrange to have the toilet emptied and take it with them like a piece of furniture.

3.2.4 The movable bin toilet in Kiribati

In a series of pilot projects, a team from the Centre for Environmental Studies at the University of Tasmania and local counterpart have successfully tested several composting toilet designs in the Pacific island nation of Kiribati.

One design uses two 240 litre standard wheeled plastic refuse bins as composting chambers. Near the base of each bin is a false floor of mesh which allows liquid to drain through to the base and from there through a tube to a sealed evapo-transpiration bed. Air is drawn into the bin through a cut-out near the base and comes into contact with the bottom of the compost pile through the mesh-floor. In addition, perforated ventilation pipes running vertically along the inside walls of the bin help to aerate the pile.

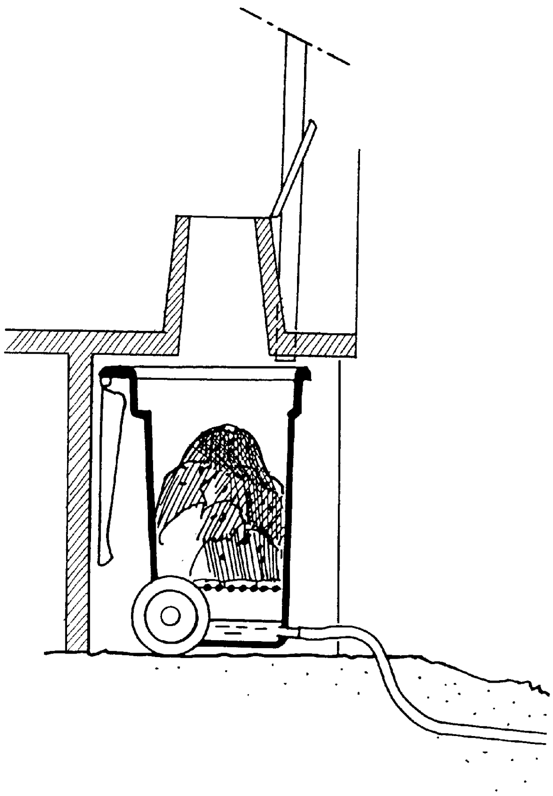

Figure 3.17 *A composting toilet with liquid separation. The processing chamber is a standard wheeled plastic refuse bin modified to drain away excess liquid.*

One bin is placed under the seat-riser to receive excreta, and is replaced with another one when full[10].

Preliminary results of the trials in Kiribati indicate that the design, even though the air on the island is extremely humid, has been successful at producing an innocuous humus-like residue.

3.2.5 The CCD toilet in the South Pacific

A sanitation system for small island nations of the Pacific, developed by David del Porto for Greenpeace and the Centre for Clean Development, focuses on zero-discharge rather than diversion and recycling of urine.

The CCD toilet consists of two water-tight chambers built above ground. As with other double-vault toilets, excreta are deposited into one of two chambers which are used alternately, to provide an extended period of composting time before the humus is removed for use as soil conditioner.

Excreta fall on a mat woven from coconut palm fronds resting on top of a nylon fishing net suspended inside the digestion vault, 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 via the seat-riser or drop hole periodically, both to provide a source of carbon (energy) and to increase the porosity of the pile so air can penetrate all the way through.

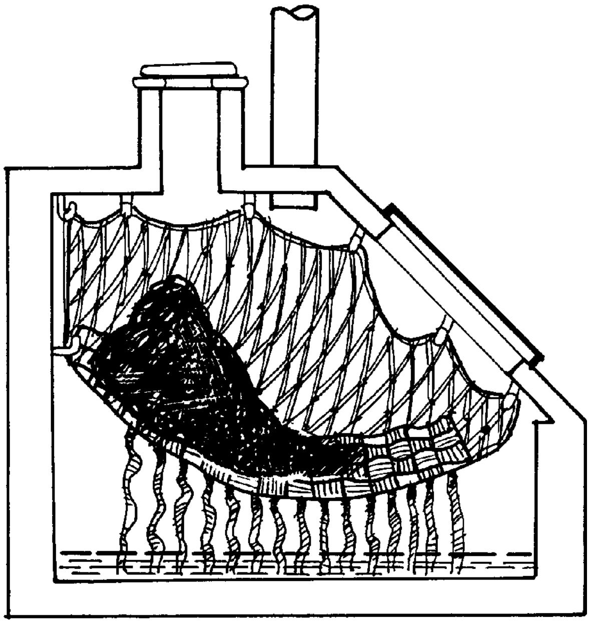

Figure 3.18 *The CCD composting toilet, designed for the extremely humid climate of the South Pacific. It has a 'false floor' made of a fishing net to separate liquids and solids, and wicks from old clothing to increase evaporation.*

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 vault. This airflow also helps to evaporate the liquids that accumulate on the floor of the digestion vault. Evaporation is further enhanced by wicks made from strips of polyester or rayon fibre (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. Another solution is to drain the liquid to an evapo-transpiration bed (see Box 3.2 and Chapter 4.3).

When the compost pile reaches a height just below the toilet seat-riser, the vault is closed off by moving the seat-riser to the pedestal on the other vault and

Box 3.2 The CCD toilet in Micronesia

A prototype of the CCD design constructed in 1992 out of concrete blocks by Greenpeace and local participants on the island of Yap in the Federated States of Micronesia was used regularly by four adults and three children for one year. 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 twelve people. Periodic visual inspection indicated that solids in the digestion vault had undergone biodegradation, and that all excess liquids had been evaporated. In all cases the users expressed satisfaction with the toilets and reported no foul odours. This is specially noteworthy given the humid climate of Pohnpei, where the average rainfall is nearly 5,000 mm per year.

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 vault, indicating greater than expected capacity. The Federated States of Micronesia national government is currently building at least 40 more units in Pohnpei and the state's environmental agency has indicated its intention to require their use in environmentally sensitive areas.

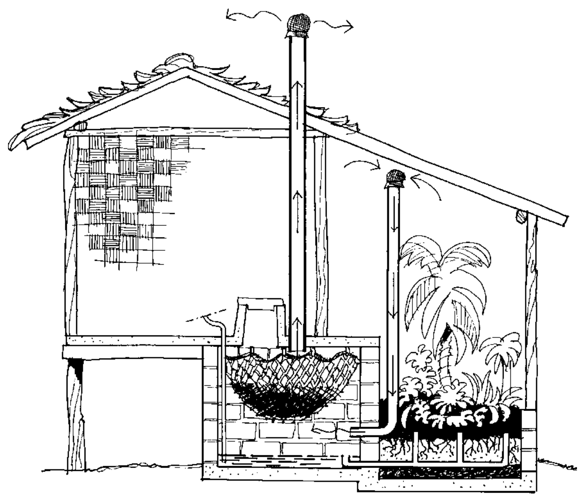

Fig 3.19 *The CCD composting toilet with attached greenhouse and evapo-transpiration bed.*

replacing it with a heavy concrete cap. When the second vault is filled, the compost in the first vault 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 regular addition of a bulking agent and periodic cleaning of the seat-riser with soap and a small amount of water.

Experience thus far has been that it takes a family of up to 10 people over a year to fill one digestion vault[11].

The experience so far indicates that with a system of the CCD type it is possible to attain a degree of liquid evaporation and maintenance-free operation not previously reported for composting toilets in a humid environment. All of the demonstration units have achieved zero-discharge of pollutants for at least one-and-a-half years of use. The CCD toilet is promising as an appropriate sanitation solution 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 recycling of nutrients is expected to be a primary motivation for using an eco-san system.

3.2.6 The double-vault toilet in India

In Kerala, India, the Vietnamese sanitation system has been adapted to a population of 'washers'. Not only urine, but also the water used for anal cleaning is diverted – in this case into an evapo-transpiration reedbed next to the toilet. The vault is lined with straw before use. This provides a carbon-rich bed to receive the faeces and also absorbs moisture. A handful of ashes are sprinkled over the faeces after each use. Occasionally some straw, leafy material and paper scraps are also added, which means that there is a process of decomposition rather than dehydration. A reduction in volume of the vault contents confirms that decomposition is occurring. The first vault is opened after one year or more of operation.

The evapo-transpiration bed requires very little maintenance. All that is required is that excessive growth is cut back, chopped into small pieces and added to the processing vault.

A dry, above-ground toilet was chosen because this area has a high water-table and wells have been contaminated by seepage from pit and pour-flush toilets. The new system has been introduced cautiously over the past 3 years: so far to 135 households in a number of villages. Many of the toilets are built close to the house, as there is very little space available. In a few cases they are built right against the house wall. The results are promising: the toilets are well maintained and free of flies and smells. These toilets are built for about USD 100(INR 4,500), including superstructure[12].

This example is interesting because it shows that a dry system of sanitation can work very well in a humid climate where the users are washers. It also shows that the device (a double-vault toilet with urine diversion) that works in Vietnam by using a dehydration process can, with different operation (the addition of carbon-rich material), work by using a decomposition process instead. The success to date is due to good mobilization of the local population, specially the women, to effective hygiene education and to regular follow-up.

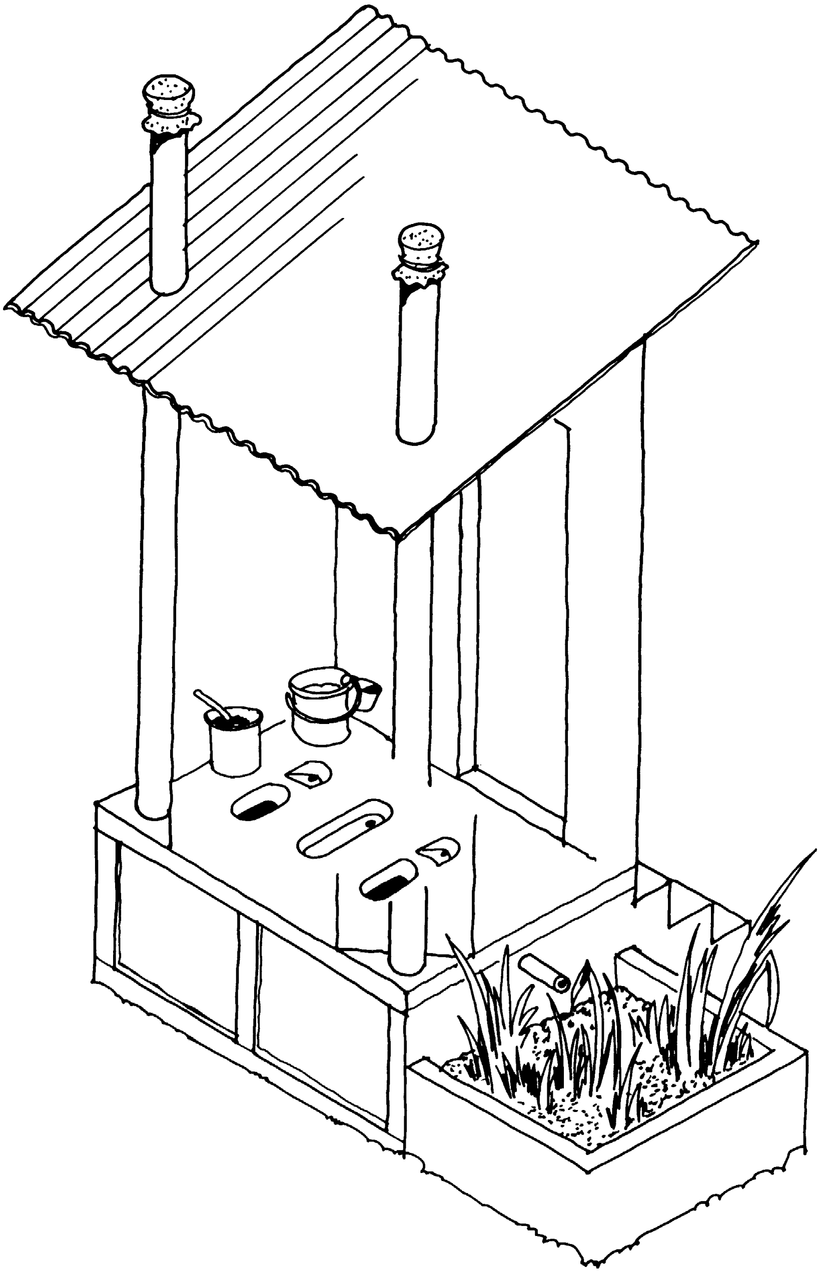

Fig 3.20 *The Kerala double-vault toilet. Over each vault there is a drop hole for faeces and a funnel for urine. Between the two vaults is a trough over which anal cleaning is performed. The water used for anal cleaning and the urine flow into the evapo-transpiration bed planted with bitter gourd, plantain or Cana indicus.*

4. MAKING ECOLOGICAL SANITATION WORK

The ecological sanitation systems described in Chapter 3 are neither widely known nor well understood. They cannot be replicated without a clear understanding of how they function and how they can malfunction. They have several unfamiliar features, such as urine diversion toilet seats and squatting slabs, which raise questions about their cultural acceptability. In addition they require more promotion, support, education and training than ordinary pit, VIP or pour-flush toilets.

Much has been learned about ecological sanitation systems from the many units in use in the world today. In northern Vietnam hundreds of thousands of rural households have double-vault toilets and recycle their products in agriculture. In Mexico and Central America there are tens of thousands of units of a similar type (the Lasf toilet) and in USA and Sweden there are many thousands of Clivus Multrums and similar devices. In Ladakh and Yemen there are hundreds of their traditional versions. Among these, there are successes and there are failures and we can learn from both.

In this chapter we describe the design and management features of ecological sanitation systems, so that mistakes can be avoided, and suggest promotion and support strategies that have proved to be essential for proper functioning of these systems. We begin, in Section 4.1, by addressing the unfamiliar aspects and sensitivity of these systems so that the reader can better appreciate the need to consider carefully both the design and management options and the promotion and support aspects which follow.

4.1 Cautionary tales

4.1.1 The unfamiliar aspects

Probably the most unfamiliar aspect of ecological sanitation options is that it requires some handling, at the household level, of the products. Some concerns have been voiced about the cultural acceptability and health aspects of this handling in different parts of the world. While some cultures do not mind handling human excreta (what we call faecophilic cultures), others find it ritually polluting or abhorrent (we call these faecophobic). Most cultures are probably somewhere in between these two extremes and our experience is that when people see for themselves how a well-managed eco-san system works most of their reservations disappear. We should not therefore presuppose how a culture will react but rather carry out a trial and gauge the reaction.

A more important point about handling is that once ecological sanitation has gone to scale and hundreds or thousands of units are in use in towns and cities, individual households no longer need handle the products at all. At that scale the output from eco-san toilets can be collected, further processed and sold by neighbourhood or centralized collection centres with trained personnel.

A second cultural issue, which causes debate, is whether eco-san toilets will be used properly in cultures where washing after defecation is mandated by tradition and religion. It is assumed that such cultures would always require users to wash over the vault and this additional water would soon spoil the delicate process going on inside. This concern is again overcome with greater familiarity of where these systems are used. Two Muslim cultures, in Yemen and Zanzibar where a kind of eco-san systems have been traditional, wash away from the toilet opening. This is done by tradition, for the principles behind their dry systems require that it be done this way. As this has posed no problem in these traditional systems (see the Yemen example, Section 3.1.6), there is no reason to believe it should pose insurmountable problems in other washer cultures. The example from India (3.2.6) shows that such a modification of toilet behaviour is indeed possible.

Urine diversion toilet seat-risers and squatting slabs are a unique innovation intended to keep vault contents dry and in some cases to allow the urine to be used as a fertilizer. These are so unfamiliar in most areas of the world that newcomers to the systems often find it hard to believe that they work properly. Sometimes newcomers to the systems remark that they do not believe they can be used by males. Others question whether they can be used by females. Experience shows that these designs work equally well for both sexes, as long as they squat or sit, see Figure 2.4. Some communities have designed their toilet units with separate urinals for men so that the main seat-riser or slab does not have to be used by those who prefer to urinate standing.

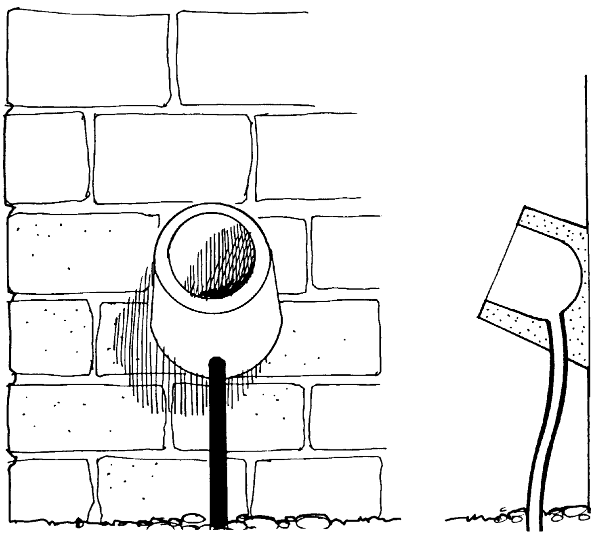

Figure 4.1 *Lasf toilets in Central America are often provided with a separate urinal.*

The large size of seats and slabs, however, sometimes poses special problems for small children, and some options are designed so that a smaller seat can be pulled down over the larger basic seat-riser.

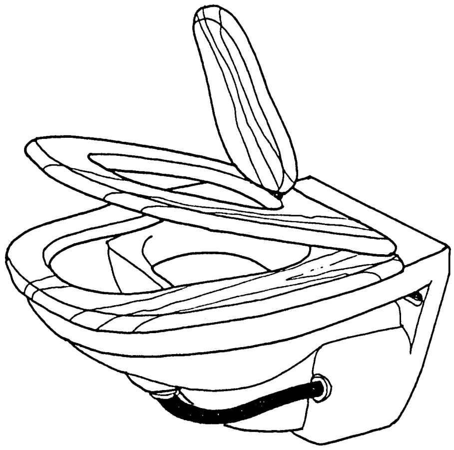

Figure 4.2 *A Swedish toilet with urine diversion, 'Dubbletten', has a lid with a smaller hole for children.*

Sceptics often claim that eco-san is an inferior alternative: it will be smelly, fly-producing and incompatible with modern living. In many cultures the toilet is placed far away from the house, at the back of the garden, near the pig-pen. It has a rough finish, is dark and not kept very clean. This low-standard toilet has given eco-san systems a poor image. This is a valid concern, for as mentioned many times elsewhere in this book, eco-san systems are more sensitive to bad design and management than other on-site options such as pit toilets. If they are not designed and managed properly, taking into account nature, culture and process, they can be unpleasant and not achieve the health and environment protection features for which they were intended. However, once newcomers gain familiarity with the options and see them in practice when designed, built and managed properly, they realize that eco-san can be a high-standard, modern option. Upscale versions for non-poor households have been developed in Europe and North America. These are very attractive and situated inside a modern bathroom, so the image changes completely. Such systems, rather than being inferior, should be viewed as superior: they protect the environment as no other existing toilet option can.

A concern is often expressed that some of these systems are simply too expensive for low income households in developing countries. Eco-san systems need not cost more than conventional systems. In most cases it is possible to find or develop an eco-san option to fit the budget. Some eco-san systems are sophisticated and expensive, while others are relatively simple and low-cost. There is often a trade-off between cost and operation: lower cost solutions mean more manipulation and care of the sanitation system – with higher cost solutions manipulation and care can be reduced.

Eco-san systems need not be expensive to build because:

- the entire device is built above ground – there is thus no need for expensive digging and lining of pits;
- urine is diverted, no water is used for flushing and the volume of the processing vault(s) is fairly small (as they are emptied periodically);
- the contents of the processing vault(s) are dry which means that there is no need for expensive water-tight constructions.

Finally, people unfamiliar with these options cannot imagine how they can be used in multistorey buildings. However, this has been successfully achieved in Sweden and is not so mysterious after all, see Figure 4.3.

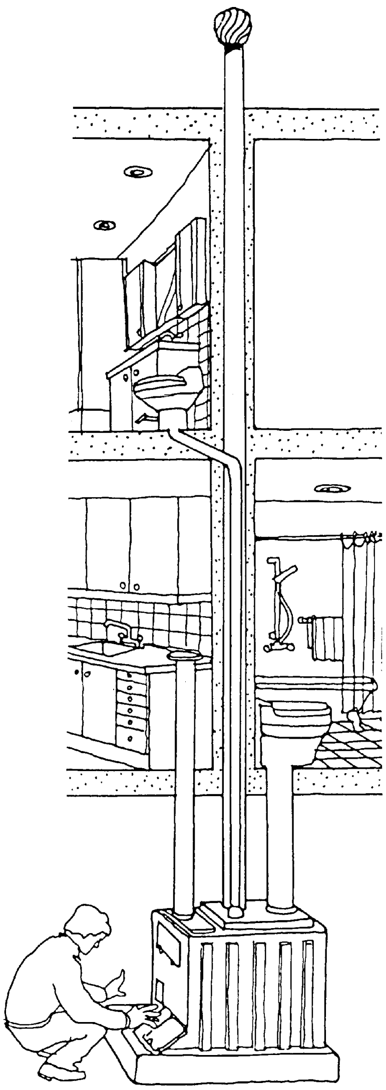

Figure 4.3 *A Clivus Multrum system in a multi-storey building. The lower bathroom has a dry toilet with a chute straight down to the processing chamber. The kitchen has a another chute for organic household refuse. The upper bathroom has a minimum-flush toilet.*

4.1.2 Sensitivity of these systems

Eco-san options are more complex than drop-and-store systems but infinitely less complex than flush-and-discharge. The potential advantages of ecological sanitation can only be realized as long as the system functions properly. There is, particularly with a new concept, the risk that those who plan, design and build do not fully understand the basic principles involved and how they relate to local conditions. This may lead to the selection of a system or options within the system that fit neither climate nor socio-economic conditions. With the right system in place the most common reasons for failure are lack of participation from the user, lack of understanding of how the system works, defective materials and workmanship and improper maintenance.

Lack of participation

A sure recipe for failure of an ecological sanitation programme is to put it in place without the participation of the intended users and without proper instruction. This is clearly illustrated by the following example.

In 1992–94, in a project financed by IDB through the Social Investment Fund, the government of El Salvador built 50,263 so called Lasf toilets. The total investment was USD 12.5 million. The toilets were built by contractors without community participation and little or no community training.

A sample survey of 6,380 families carried out in 1994 showed that 39% of the toilets were used adequately, 25% were used inadequately and 36% were not used at all[1].

These findings led to the development of a hygiene education strategy that focused on personalized education for all family members through home visits, participation of organized women in the implementation of the whole educational process, education materials and user-friendly monitoring and evaluation. The impact of this hygiene education model was significant. After the completion of the first education module, the percentage of proper use increased to 72%, and the toilets that were being used improperly or were not being used at all decreased to 18% and 10%, respectively[2].

The lesson learnt from this whole process was that the problems of non-use or improper management are not because of the technology itself but because of 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. The need for behavioural changes, proper use and maintenance should be stressed.

The case of northern Vietnam (see Section 3.1.1) poses a special problem because of a relatively high prevalence of intestinal parasites. In southern Vietnam double-vault toilets are not very common and the prevalence of intestinal parasites is much lower. From these facts some observers have drawn the conclusion that a high level of parasite infestation is caused by the use of double-vault toilets. A more likely explanation is that in the north there is a long tradition of using fresh faeces as fertilizer, much more so than in the south, and while many families use their double-vault toilets properly, others do not. Improper use often means that fresh faeces are removed from toilets whenever they are needed on the fields. Parasite eggs are also spread by infested children defecating in the open and by less than careful handwashing and food handling practices. This problem is recognized in Vietnam where the original health education campaign associated with these toilets needs to be revived. The lesson from Vietnam is that health education needs to be continuous and probably combined with a massive deworming of the rural population. With long-term follow-up and education, including an emphasis on other routes of contamination such as hands, food and the handling of the faeces of small children, this problem should eventually disappear.

Lack of understanding

Sanitation is a complex matter. The raw material we are dealing with is potentially lethal and will, if not managed properly, cause considerable nuisance. Sanitation is also a topic that in many cultures is surrounded by taboos. Over the years we have come across a number of cases where eco-san systems have failed due to ignorance and lack of experience.

When a properly selected and well built eco-system fails, the most common fault is that the process has turned wet. In a system based on dehydration the humidity of the contents of the processing vault should quickly be reduced to less than 20%. If this is achieved there is no smell, no fly-breeding and very rapid pathogen destruction. If the contents, for various reasons, remain damp, they will smell, flies and other insects will breed in the pile and pathogenic organisms will survive longer.

In a system based on decomposition the corresponding humidity should ideally be between 50% and 60%. If the contents of the processing vault become too wet the decomposition process will slow down, the compost pile will smell, there will be flies, and pathogenic organisms will survive longer.

Fly breeding in toilets is basically related to the wetness of the contents of the processing vault. In a properly functioning dehydration system there would be no fly breeding, but if something goes wrong and the contents turn wet, fly breeding is likely to occur. The risk of fly breeding is greater in a composting system for two reasons: it operates with a much higher process humidity and fly eggs may be introduced into the processing vault together with kitchen scraps.

Pathogen destruction is a key issue in eco-san. In a malfunctioning or wrongly used eco-san system pathogenic organisms may survive and, through recycling of inadequately processed faeces, be released into the environment.

Defective materials and workmanship

Eco-san systems are no more sensitive to poor workmanship and defective materials than any other sanitation system. In some ways they are less sensitive because the processes involved are dry and the volumes handled comparatively small. Common faults include seepage of water into the processing vault, leaking urine conduits and blocked ventpipes[3].

In a squatter settlement on the outskirts of Cuernavaca in Morelos, Mexico, a neighbourhood group asked for credit from the state public works department in order to build dry toilets. Although the petition was eventually approved, the department 'under-delivered' materials (i.e. they stole them), and they replaced the skilled masons with their 'own' unskilled, lower paid bricklayers (skimming the excess pay for themselves). As a result, the toilets were left unfinished and incorrectly built with the residents disgusted and doubtful of the toilets[4].

Improper maintenance

Many eco-san systems have failed because they received improper maintenance. Usually this has been because they were viewed simply as new types of devices rather than as whole systems that also include the interacting elements of nature, society, process and device (see Chapter 1.3). Often, new devices have been installed without adequate attention to the education and ongoing technical assistance that may be necessary to ensure that users understand and accept to do what is required to make them work.

All sanitation technologies require maintenance to function properly. Large water-borne sewerage systems with centralized treatment plants, for example, must receive constant maintenance from a professional staff. However, since in eco-san systems more of the processing occurs on site and because sanitizing and recycling human excreta is inevitably more complex than simply disposing of them as wastes, eco-san devices generally require a higher level of maintenance by users than conventional flush toilets or pit toilets.

The amount of maintenance required by users of eco-san systems varies a great deal, depending upon the design strategy, climate and other local conditions. Good system design can minimize the need for intensive maintenance, and the tasks required need not be onerous. For example, systems that rely on composting often require the regular addition of bulking agents and periodic checking to ensure that ventilation pipes are not blocked. Some systems may require the transfer of partially processed solids to a secondary processing area. Many systems require that the toilet seat-riser or squatting hole be in some way closed-off when not in use. All systems require periodic inspection and removal of the end products. The major common element in the maintenance of eco-san systems is that the user must ensure that the system is working properly. However, it is important to note that many operation and maintenance functions, such as emptying of toilet vaults, transport and secondary treatment, can be carried out by special service providers, either as a **public service** or through **private enterprise**. Service contracts will minimize the burden on households and also enable municipal administrations to guarantee a satisfactory standard of operation and maintenance.

Non-use

The alternative to the use of a sanitary device is often open defecation. Non-use is therefore a potential public health risk. There could be a number of reasons for non-use: the eco-san concept may not be accepted by the users, it may be poorly understood or it is rejected because the system does not function properly or is difficult to use. Important factors in acceptance are traditional attitudes, habits and taboos related to defecation and human excreta.

4.2 Design and management features of eco-san

The examples in Chapter 3 show that within the overall concept of eco-san there is a range of choices. The purpose of this section is first to provide an overview of possibilities in dealing with liquids and in sanitizing solids and second to discuss a number of design options.

4.2.1 Dealing with liquids

A basic question when designing an eco-san system is whether to divert urine or to receive combined urine and faeces in a single receptacle. If the latter approach is used, effective processing will with few exceptions require later separation of urine and other liquids. Thus we start with three options: urine diversion, liquid separation and combined processing.

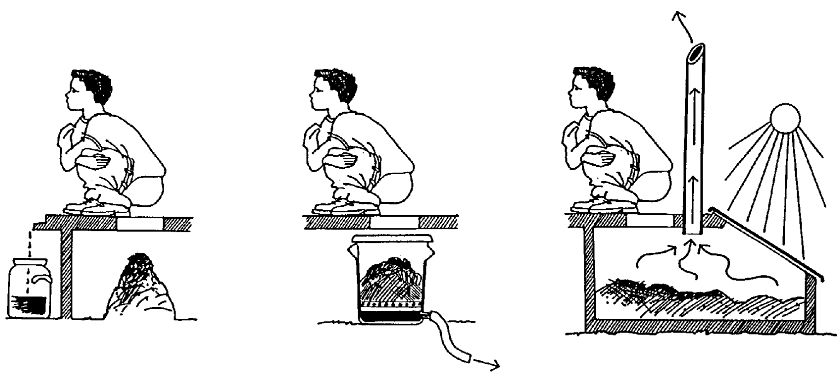

Figure 4.4 *Ecological sanitation systems have three options for dealing with liquids: urine diversion, liquid separation and combined processing.*

Urine diversion

There are at least three good reasons for not mixing urine and faeces: it is easier to avoid excess humidity/wetness in the processing vault, the urine remains relatively free from pathogenic organisms, and the uncontaminated urine is an excellent fertilizer. The problem is that urine diversion requires a specially designed seat-riser or squatting slab that is functionally reliable and socially acceptable.

The basic idea of how to avoid mixing urine and faeces is simple: the defecating person should sit or squat over some kind of dividing wall so that faeces drop down behind the wall and urine passes in front of the wall. The idea of not mixing urine and faeces is not new. In parts of China, simple toilets with urine diversion have been in use for centuries (Figure 4.5) and in more recent years a factory near Beijing has started producing porcelain squatting pans with urine diversion (Figure 2.4).

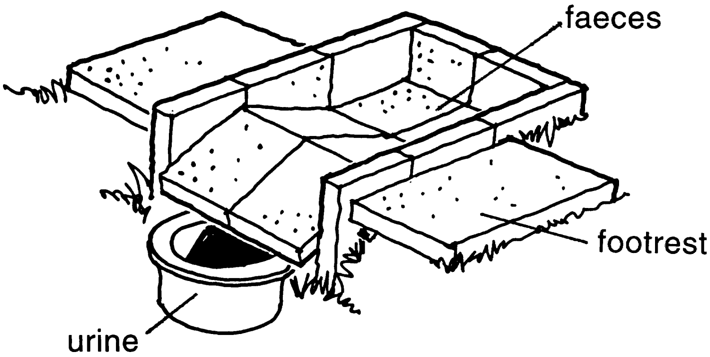

Figure 4.5 *A traditional toilet with urine diversion in China. Urine is collected in a jar and used as a liquid fertilizer for vegetables. (Faeces are scooped up daily and taken to a compost pile.)*

In Latin America and Scandinavia the same approach has been adapted to various toilets with seat-risers in private households as well as in institutions and public toilets[5].

Once collected the urine can either be infiltrated into a soakpit or an evapo-transpiration bed, used the same day for irrigation or stored on site for later collection, see Chapter 4.3 and Figure 2.6.

Liquid separation

Systems based on liquid separation do not require a special design of the seat-riser or squatting plate. Urine, faeces, and in some systems a small amount of water, go down the same hole. Liquids and solids are then separated, for example in an 'Aquatron', fixed on top of the processing vault (see Figure 4.6). This device, developed in Sweden, has no moving parts and simply uses the velocity of the flush to send the liquid around the inner wall of a doughnut-like arrangement while the solids fall through a hole in the middle.

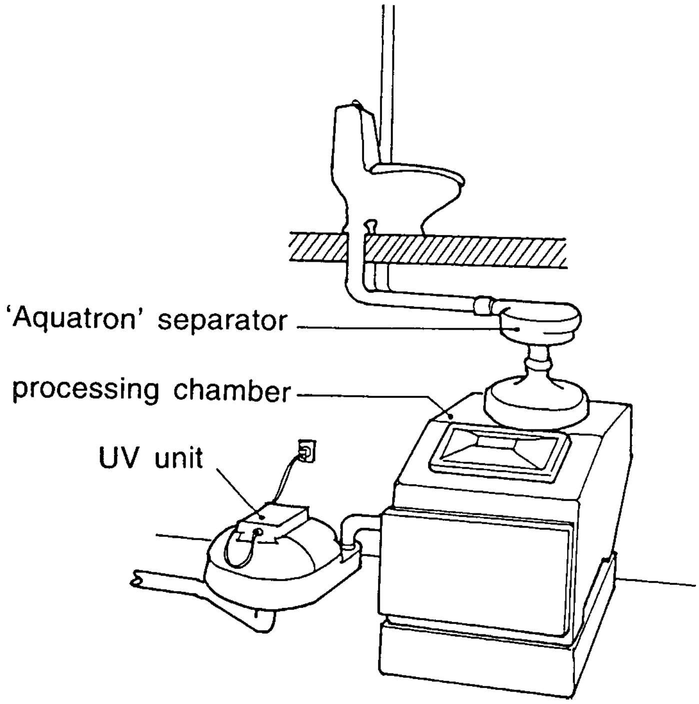

Figure 4.6 *An 'Aquatron' device for separation of liquids and solids from a minimum-flush toilet. The separator is placed on top of a processing (composting) chamber. The liquids are sanitized with ultraviolet radiation.*

Another possibility is to drain the vault through a net or a false floor of wire mesh (see Figure 3.17).

As the liquids have been in contact with faeces they must be sterilized or otherwise treated before they can be recycled as fertilizer.

Combined processing

Under extremely dry climatic conditions or where large amounts of absorbent material are added it may be possible to process liquids and solids together. Also in this case urine, faeces, and in some systems a small amount of water, go down the same hole. Normally we would not recommend this approach as there is a great risk that the contents of the processing chamber turn wet and malodorous.

4.2.2 Dehydration versus decomposition

The primary processing in an eco-san system is either through dehydration or decomposition, or a combination of both. The purpose of the primary processing is to destroy pathogenic organisms, to prevent nuisance and to facilitate subsequent transport, secondary processing and end use.

Dehydration

Dehydration means lowering the humidity of the contents of the processing vault to less than 25% through evaporation and addition of dry material (ash, sawdust, husks). No water or moist plant material must be added to the processing vault. There is little reduction in volume because of the added dry material and minimal decomposition of organic material. The crumbly cake that remains when faeces dry out is not compost but rather a kind of mulch which is rich in nutrients, carbon and fibrous material.

Dehydration is an effective way of destroying pathogenic organisms, particularly helminth eggs, because it deprives them them of the moisture they need to survive (see Section 2.1.2). At this low humidity there is little odour and no fly-breeding. As there is so little breakdown of organic material, toilet paper or other things placed in the processing vault will not disintegrate regardless of storage time. Toilet paper must therefore either be handled separately or be composted in a secondary treatment process.

Sanitation systems based on dehydration require diversion of urine and water for anal cleaning. These systems are particularly suitable for dry climates but with simple solar heaters (see Section 3.1.4) they can also work in a humid climate.

Decomposition

Decomposition ('composting') is a complex biological process in which organic substances are mineralized and turned into humus. Decomposition ideally requires a humidity of around 60% in the compost heap. If much lower, the process comes to a standstill because the organisms involved in the process are deprived of water. If much higher, the process slows down because the organisms are deprived of oxygen. It also ideally needs a carbon to nitrogen ratio of about 30:1 which means that we must add carbonaceous material (sawdust, kitchen refuse, toilet paper, weeds, grass clippings).

High-temperature composting (with temperatures reaching >60°C) will effectively destroy most pathogenic organisms but such process temperatures are in practice difficult to reach in a composting toilet. The volume of material is too small, it tends to be too compact and it is difficult and unpleasant to turn the pile to aerate the central part. Fortunately other factors in the compost environment help destroy pathogens including time, unfavourable pH value, competition for food, antibiotic action and the toxic by-products of decomposing organisms. Most composting toilets are designed for a retention time of 8–12 months.

4.2.3 Other technical options

Solar heaters

Solar heaters are fitted to the processing vaults of toilet to increase evaporation. This is more important in humid climates and where urine and water are mixed with the faeces. It is also more important in a system based on dehydration than in one based on composting.

The solar heaters used in some of the systems described in chapter 3 consist of a black-painted metal sheet covering the part of the processing chamber exposed to the sun. This metal sheet usually also acts as an access lid to the processing chamber(s). (See Figures 3.8, 3.9, 3.10 and 3.16.)

The solar heater must be fitted so that it prevents water as well as flies from entering the processing chamber(s).

Single or double vault

Most composting or dehydrating toilets marketed in the Scandinavian countries and North America are of single-vault type. The primary concern with a single-vault device is pathogen in fresh faeces. Although the amount of fresh faecal material at any one time is relatively small, the amount which has gone through enough processing to kill pathogens may not be small, and even the addition of a small amount of pathogens can serve to contaminate the entire pile. One way or the other, the system must ensure isolation of faeces until pathogens have been reduced to acceptable levels. With single-vault systems the faecal material is usually transferred to another pile/bin/container for further processing before being recycled.

Toilets for developing countries have often been designed with two vaults, each with its own seat-riser or squatting slab. In these systems each vault is used alternately for a certain period. When the switch is made from one vault to the other, the contents of the vault which has been dormant are emptied, the assumption being that after several months without new faecal material the contents of the dormant vault should be safe to handle.

When urine and water are excluded from the vaults (or rapidly drained or evaporated) the process of dehydration might be so rapid that acceptably hygienic systems with only one vault can be developed.

Trials (associated with the Sanres project) have recently been run in El Salvador, Mexico, South Africa, Vietnam and China with prototype single-vault dehydration toilets. These toilets require careful maintenance from the users and a good understanding of basic hygiene since partially processed solids have to be shifted to a secondary processing location. However, the benefits are not only the reduced smells and good fertilizer of the double-vault toilet but also the reduced costs and space requirements of a single, small vault.

These prototypes are still being tested and improved. It remains to be seen whether the potential benefits to the users of the single-vault designs will be a sufficiently strong motivating force to bring about the behavioural change necessary for their safe use and whether the savings in construction costs will be greater than the additional costs of promotion, education, and follow-up which this approach will require.

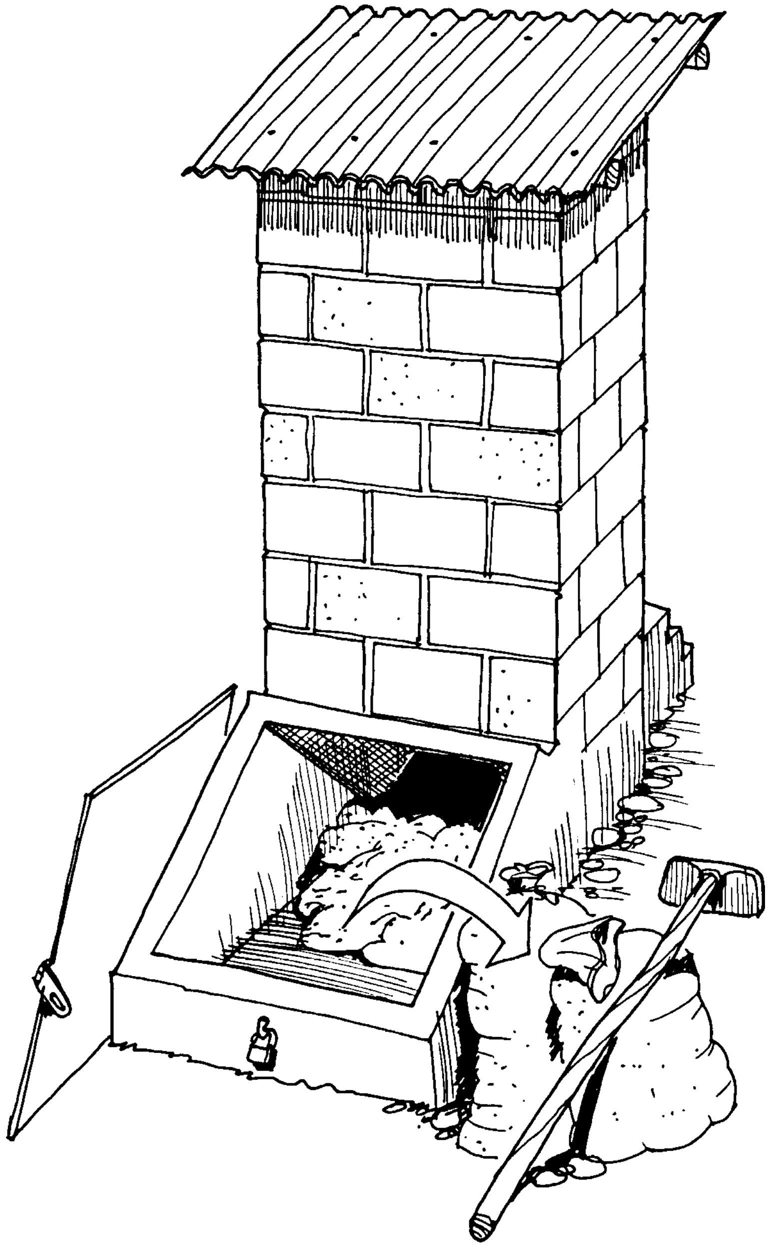

Figure 4.7 *A single-vault dehydrating toilet in El Salvador. The pile building up below the toilet seat is periodically shifted to the processing chamber under the solar heater. When this space is full the material is taken out and placed in bags for further storage until ready for use as fertilizer.*

Anal cleaning material

Cultures differ in their use of cleaning materials after defecation. Some use paper, some use vegetable material or stones, and others, as mentioned above, use water. The inappropriate disposal of cleaning material in a toilet can cause problems. In some parts of the world the drainage system for WCs cannot cope with toilet paper so it has to be collected separately in a bin for later disposal by burning. Elsewhere WCs have rapidly been rendered useless by people trying to dispose of stones or maize cobs in the toilet. In addition to anal cleaning materials other things such as tampons, sanitary towels and condoms are frequently disposed of in toilets.

Dry systems can handle all kinds of paper and solid objects. The examples from Yemen (3.1.7) and India (3.2.6) show that a dry system can even be adapted to cope with the use of water for anal cleaning.

A composting toilet can handle paper but in a dehydrating toilet the paper does not decompose. There are three solutions to the problem of paper in a dehydrating toilet:

- compost the output from the processing chamber,
- burn the output from the chamber, or
- place the toilet paper in a special container and burn it periodically.

Absorbents and bulking agents

Absorbents like ash, lime, sawdust, husks, crushed dry leaves, peat moss and dry soil are used to reduce smells, absorb excess moisture, and make the pile less compact as well as less unsightly for the next user. They should be added immediately after defecation in order to cover the fresh faeces. They are used in both dehydrating and in composting toilets.

Bulking agents like dry grass, twigs, coconut fibre and wood shavings are used in composting toilets to make the pile less compact and allow air to enter and filter through the heap.

In the nineteenth century there were a number of designs for 'earth closets', which when 'flushed', automatically sprinkled earth and/or ash on to the faeces (see Box 4.1).

Ventilation and aeration

Ventilation serves several purposes: it removes odours, it dries out the contents and, in composting toilets, provides oxygen for the decomposition process. A ventpipe is not always necessary: the Vietnamese double-vault toilet (3.1.1) and its variations in Central America and Mexico (3.1.2) are usually built without a ventpipe. All indoor models in Scandinavia (3.1.3, 3.2.1 and 3.2.2) are provided with ventpipe. The need for a ventpipe is determined by climate, wetness of the input into the processing chamber and standard desired. (With a well-functioning ventpipe from the processing chamber, the toilet/bathroom can be completely odour free, as air from the room is evacuated via the seat-riser/squatting-pan.)

Box 4.1 Nineteenth century earth closets

During the second half of the nineteenth century there was a fierce contest in Britain between those who favoured water closets and those who favoured earth closets. The first patent for an earth closet was taken out in 1838 by Thomas Swinburne but his device was not widely adopted. The breakthrough came quarter of a century later with the work of Henry Moule. He experimented by burying the contents of his own household bucket toilet in the garden. He discovered that in 3–4 weeks there was no trace of the buried material. Moule went on to design a toilet that deposited a controlled amount of earth on the fresh faeces from a hopper behind the seat-riser. He went on to establish the Moule Patent Earth-Closet Company Ltd. and developed luxury models as well as ones designed for barracks, schools and hospitals. Various other inventors patented semi-automatic devices to flush the toilet with earth when the pressure on the seat was released or when a foot pedal was pressed.

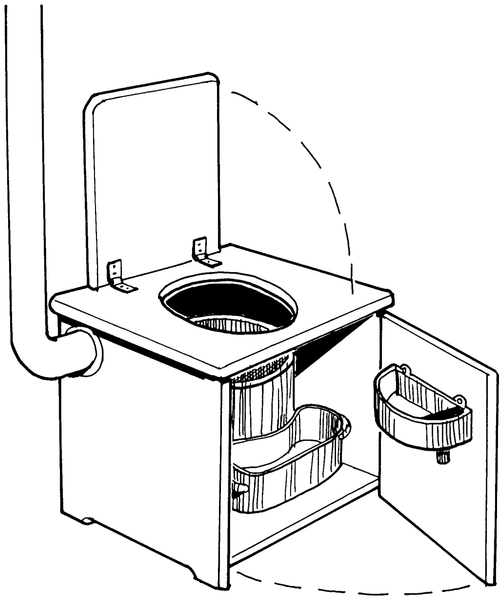

Figure 4.8 *Henry Moule's earth closet.*

Henry Moule was an effective publicist and used pamphlets to promote the advantages of earth-based sanitation and the insanity of water-borne sanitation. In 1861 he published a pamphlet called 'National Health and Wealth' which generated widespread support. The Lancet of 1st August 1868 reported that 148 of his toilets were used by a military encampment in Wimbledon, London. Forty of them were used daily by 2,000 men without any annoyance of odour. In 1860 a number of schools switched from water closets to earth-closets because they were considered more reliable and cheaper to maintain.

➔

In the 1870s Moule and others moved on to look at how heat could be used to treat pathogens and remove smells. Designs were developed in which a drying pan was integrated into the domestic fire grate. Other designers developed devices with larger hoppers which could cope with up to a thousand uses before being refilled. Some included vent pipes and self-closing flaps.

Moule H (1875): National health and wealth, W Macintosh, London, UK, and Poore GV (1894): Essays on rural hygiene, London, UK.

A ventpipe should have a diameter of 10–15 cm. In humid climates with large amount of liquid to be evaporated (3.2.5) the diameter could be larger – up to 25 cm. The pipe should be as straight as possible and reach 30–90 cm above the roof.

Composting is basically an aerobic process. Many of the microbes responsible for the decomposition need oxygen. Air must therefore be brought into the pile. This can be done by stirring, digging or shifting the pile. The worms, insects and other organisms living in a compost pile play a major role in mixing, aerating and tearing apart the contents of the processing chamber. In some cases the processing chamber is provided with perforated pipes that bring air into the centre of the pile (3.2.1). Another method is to use a hanging net with a compostable lining (3.2.5). Aeration can also be accomplished with the addition of a bulking agent as described above.

4.3 Greywater

The water generated from food preparation, bathing and washing is known as greywater. Dry sanitation systems do not handle greywater and therefore a separate system must be devised to take care of this potential resource.

Many public health authorities regard greywater as a health hazard although it is usually as clean or cleaner than the sewage effluents which those same authorities consider safe enough to discharge into the environment. For example, data from Sweden indicate that greywater contains less than half the concentration of nitrogen and phosphorus compared with farm run-off, and roughly a quarter of the nitrogen concentration of purified sewage effluent legally discharged into water resources[6]. It has about half the biochemical oxygen demand (BOD) and suspended solids of combined wastewater (greywater together with urine, faeces and flushing water)[7].

Both the quantity and the quality of greywater can be controlled at the household level. Any strategy for managing greywater can be made easier by water conservation measures as well as attention to the soaps, cleansers and other household chemicals used. The amount of greywater generated can be significantly reduced through behavioural changes, good maintenance of pipe and water taps, and the use of water-saving devices. To the extent that

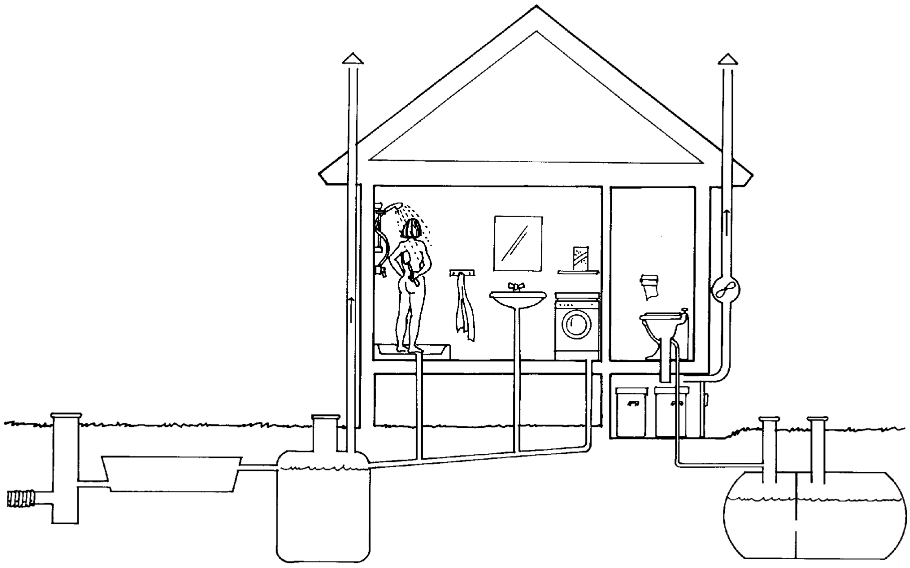

Figure 4.9 *A house in Sweden with a dehydrating toilet, urine diversion and storage in an underground tank (see Section 3.1.3) and on-site greywater treatment.*

pollutants in greywater are a problem, it makes sense to prevent them at source by selecting non-polluting household products. Such solutions tend to be ignored because they are not the province of engineers, but they are likely to be much more feasible than separating the pollutants later.

Often the easiest way to recycle greywater is for plant irrigation. In many parts of the world where water is scarce, this is done as a matter of course. Greywater irrigation can be as simple as pouring it on garden areas by hand. Even where there are few gardens, greywater can be put to use, such as in the peri-urban areas of Guatemala City, where households routinely apply it on the road in front of their houses to keep dust down. However, recent studies confirm that there is a considerable amount of gardening practised in urban and peri-urban areas[8], so greywater irrigation is often feasible.

Although greywater does not generally present health concerns and will not pose significant pollution hazards if toxic products are not used, it is best to design a greywater system that prevents human contact and the potential for environmental contamination. A number of commercial systems are available in industrialized countries which accomplish this through subsurface irrigation with greywater.

In areas where water is not piped to individual households, simple solutions for the return of greywater can suffice, since much less greywater is generated in the first place. Even where management consists of using it to water plants, to hold down dusts on roads, or simply allowing it to infiltrate the soil, the hazards posed by greywater are far less than those posed by human excreta or the lack of good hygiene.

4.4 Choosing an eco-san system

Ideally, an eco-san system will prevent pollution, sanitize excretal nutrients and return them to the soil and require no water for transport or processing. For the sake of brevity we have called this arrangement 'sanitize and recycle'. This book has presented a number of examples of different design strategies for eco-san systems, along with a discussion of important design features. Some of the examples included in this book come closer to truly achieving this ideal than others. However, each of these systems was developed to address those issues that were of greatest concern in the place where they are used. This discussion provides a framework for thinking about applying the eco-san approach in response to local circumstances.

Many local variables influence the choice of an appropriate sanitation system:

- **Climate** – temperature, humidity and precipitation.
- **Topography and soil type** – the relative ease or difficulty of placing systems in the ground, how quickly and the direction in which water and pollutants move through soils.
- **Abundance/scarcity of water** – the relative importance of water conservation.
- **Proximity/sensitivity of water resources and aquatic ecosystems** – groundwater level and availability, closeness to lakes, rivers and streams, or coastal waters.
- **Energy** – the availability of local energy inputs, such as solar radiation.
- **Social/cultural** – the customs, beliefs, values and practices that influence the design of the 'social' components of a sanitation system, its acceptability or 'fit' within a community. (It should be noted, however, that these things are not static, and that new practices are constantly evolving in most societies.)
- **Economic** – the financial resources of both individuals and the community as a whole to support a sanitation system.
- **Technical capacity** – the level of technology that can be supported by local skills and tools.
- **Infrastructure** – the existing level of both physical infrastructure and existing services that might help support a sanitation system (i.e. extent of existing water supply, transport, public health network, educational system etc.).
- **Population density and settlement pattern** – the availability of space for on-site processing and storage and local recycling.
- **Agriculture** – the characteristics of local agriculture and home gardening.

The nature of these factors will determine both the relative importance of preventing pollution, recycling excretal nutrients, conserving water and other design objectives, and also design constraints. For some communities, the need for a source of plant nutrients may be the driving force behind a move toward eco-san and they will give special care to developing a system that ensures recovery of urine for use as a fertilizer. For others, the need to protect sensitive water resources is paramount and they may be willing to sacrifice complete recovery of excretal nutrients if design strategies that favour composting and the atmospheric loss of nitrogen are easier to implement. In dry areas it will be easiest to sanitize faeces through dehydration, whereas composting may be more successful in very humid places.

4.5 Promotion and support to families and communities

Eco-san systems are more complex than most conventional sanitation systems, and usually place more responsibility for appropriate functioning on individual families and local communities. Users must become aware that, despite potential health benefits, improper use of any toilet may turn it into a nuisance, threaten public health, and pollute the environment. These problems can best be avoided by adopting the appropriate behaviours from the outset. In addition special care is required to take full advantage of the significant resource potential of the recycled plant nutrients.

At the household level individuals and families must understand how the eco-san system works, what can go wrong, and have the commitment and skills to manage it correctly. For large-scale application it is also essential that a significant part of the local community shares this understanding and commitment.

In urban areas the fundamental issue of eco-san is how to establish a full-scale operation. It is one thing to operate scattered eco-san devices spread over a large territory; it is another very different matter to make thousands of eco-san devices work properly in densely populated squatter areas. In devising urban eco-san systems a number of critical issues surface. These relate to the safe handling, transportation and recycling of the output of eco-san devices.

This section will examine some of the critical issues related to promoting and supporting eco-san systems on a larger scale. The first two parts discuss the key elements of a participatory user-oriented promotion, education and training strategy. The last two parts cover the essential institutional and financial arrangements required to develop and back up the community-based system. It is important to move away from manipulation of public opinion towards citizen control by sharing knowledge, delegating responsibility and building partnerships.

4.5.1 Community empowerment and promotion

Eco-san toilets should not be promoted for their own sake, but rather as part of a deeper process of empowering poor people, in particular, to take charge of their own development. Greater awareness and transformation at individual, group and community levels are more important than improved sanitation – which, in fact, will only be sustainable if more profound changes have also taken place.

In order to be sustainable, eco-san systems must be based on an understanding of its basic elements and how they are interconnected. These elements were outlined in Section 1.3:

- the **nature** that influences and is affected by the system, such as the climate and seasonal variations, the possible impact on water availability and resources and risk of pollution;
- the cultural and behavioural implications of the **society** in which it operates;
- the basic characteristics and limits of the **process** selected, and how to maintain the appropriate conditions in order to make it work; and
- the principal characteristics of the **device** and how to design, build, use and care for it properly.

Where eco-san is an entirely new and unfamiliar concept or technology, a substantial amount of promotion and instruction will be required. Promoting eco-san will be easiest when the system does not represent a radical break from accepted cultural practices. For example, the long-standing tradition of urine-diverting systems in the old towns and dwellings in Yemen, and the use of night-soil as fertilizer in China and Vietnam provide strong precedents for improving or expanding eco-san in these countries. Similarly, in the Scandinavian countries the tradition of maintaining rural weekend/summer homes with decentralized sanitary systems has favoured the spread of a large number of eco-san systems (see 3.1.3, 3.2.1 and 3.2.2).

It is particularly important that women are included in the empowerment and promotion process right from the beginning. Women are the ones responsible for the households' water supply, sanitation, hygiene and food preparation. Their views and concerns must be expressed and integrated into the programme design as well as in detailed design decisions[9].

Needs based approach

Sanitation programmes should be designed to meet the needs defined by communities and households, rather than promote specific solutions as defined by outsiders. Needs can vary tremendously. For example, the remarkably rapid spread of dehydrating toilets in El Salvador has been primarily due to environmental factors. An acute and now chronic water shortage in much of the country has made conventional water-borne sewerage unrealistic, while the high water-table characteristic of the coastal areas makes traditional pit toilets infeasible. Conversely, poverty alleviation through the use of urine for food production has been a primary motivating factor for the Anadeges project in Mexico City. Water saving has been considered an important secondary benefit.

If potential users have not identified alternative sanitation as a necessity, and have limited knowledge of how facilities are to be constructed and maintained, the project often fails. The new toilet might end up being used as a storage space or a pig pen; or, in a more serious scenario, a badly-managed toilet can become a serious health hazard. When new toilets don't 'work', word spreads very quickly and overcoming the negative reputation of an unfamiliar technology or system can be extremely difficult.

Promotion strategies

No matter how effective the eco-san system may seem, its long-term success will depend on the credibility it enjoys with potential users. For the system to become an integral part of local culture, it must first be shown to work and it must be acceptable to respected local leaders and opinion makers. A visit to a well functioning eco-san toilet in a neighbour's home is one of the best ways to convert 'non-believers'.

Key families can be a valuable mechanism for introducing eco-san concepts into a community. If these key families are pleased with the toilet, word always spreads quickly. These families should be encouraged to work together and learn from each other by sharing experiences, successes and failures. Initially this mutual support can reduce the risk of ridicule and rejection from other community members.

It is generally best to work through local **grassroots organizations** that are successful and well known within the community. Such organizations are usually committed to transforming their communities for the benefit of all the people, as well as the environment. They might also have begun to analyse problems on a local (and broader) level and to develop ways to overcome them collectively; and they are likely to have the necessary social and political skills to cope with resistance to change within the community.

Technology selection and adaptation

When promoting eco-san it is important to **offer alternative approaches** and encourage the users to select the option most appropriate for their community. To do so they must have access to full information regarding advantages and disadvantages of each – including the long-term implications for health and the environment.

Dehydrating and composting eco-san toilets systems be promoted as viable long-term alternatives to conventional water-borne systems, not as ‘intermediate’ technology. For example, in parts of Latin America, dry ‘latrines’ have been offered as a rural solution, (*sanitarios rurales*) with the unfortunate implication that they are a ‘poor man’s toilet’ somehow inferior to a flush-and-discharge toilet.

Particularly when technologies are being borrowed from other cultural and physical settings, it is important to involve local users in a pilot phase through which the new system is tested and modified to fit local cultural practices and environmental conditions. Long-term success and sustainability of the program will depend upon the effectiveness of this stage.

The Vietnamese double-vault toilet has gone through a series of adaptations to suit cultural circumstances in Latin America. For example, the urine-diverting toilet seat-riser was first developed in Guatemala to meet the expectations of the local culture that preferred sitting rather than squatting toilets. The Sirdo Seco project in Mexico (Section 3.2.3) has drawn ideas from a number of sources including the Clivus Multrum, the Vietnamese double-vault toilet and Uno Winblad’s experiments with solar-heated toilets in Tanzania in 1974–1977[10].

Finally, setting up demonstration toilets in public spaces, such as at a school or near a clinic, frequently leads to failure, as generally no one takes clear responsibility for public toilets. This risk is further magnified in the case of eco-san toilets, which require even more user awareness and maintenance than conventional pit toilets.

Phasing the programme

The history of technology transfer has many examples of programmes that went wrong when planners or politicians tried to go too fast without adequate attention to user participation and understanding. Eco-san is no exception.

It is advisable to begin with experimental small-scale **pilot** projects through which different eco-san devices may be assessed. During the **demonstration** phase the social aspects of the approach can be refined while demonstrating to a broader audience that the technology works. Finally, as César Añorve in Mexico has shown, broad **dissemination** requires an attractive and accessible product, strategic alliances for promoting a holistic change of vision, and regulatory reform. Finally there needs to be regular follow-up to monitor experimental aspects and to ensure that the necessary adjustments and modifications are made.

4.5.2 Education and training of eco-san facilitators and communities

To ensure that the people involved acquire the necessary commitment and capacity to set up, operate and maintain an eco-san system, it is usually necessary to recruit and prepare a cadre of *eco-san facilitators* or promoters. These people can be either community or institution based and voluntary or paid. Frequently they will be attached to programmes that are primarily oriented towards other areas, such as water, health, agriculture or environment. In fact,

Box 4.2 San Luis Beltrán

San Luis Beltrán is a peri-urban barrio in the northern part of the city of Oaxaca, Mexico. The inhabitants of San Luis had hoped for a full water-borne sewerage system but the resources required were far in excess of what they or the municipal budget could afford.

In the late 1980s, a technician from Espacios Culturales de Innovación Tecnológica, a national NGO, succeeded in convincing a small number of families to install dry toilets with urine diversion. To start with 35 units were constructed with the support of the Ministry of Public Works. – 'At first we doubted that they would work' said Don Jeronimo, president of the local committee. 'But when people began to see for themselves that they were working well, don't smell and don't produce flies, they were interested in having a dry toilet.'

Motivated by the success of the first stage, the citizens were able to get the support of the Municipal President to build an additional 140 toilets. In just over two years, San Luis became the first community in the state of Oaxaca, and perhaps all of Mexico, to solve, once and for all, its excreta disposal problem. Five years later, an offer from the municipal authorities to install a conventional sewerage system in San Luis Beltrán was rejected by the community, now firmly convinced of the benefits of their dry system.

It was not simply an environmental concern that motivated people in San Beltrán to adopt a dry sanitation option. They were mainly interested in avoiding a confrontation with their downstream neighbours. They were well aware of the serious conflicts that had arisen in similar cases, where one community was receiving the untreated sewage from an upstream neighbour.

Since the dry toilets were introduced to San Luis, the river is noticeably less contaminated; and the water is safer. People's attitudes have also changed: no one is interested in sewerage now. People are pleased with the effectiveness of the dry toilets and are improving them all the time – they are really pleasant to use.

The ecological sanitation system adopted by San Luis Beltrán caught the eye of Clara Sherer, the wife to the governor of the state of Oaxaca and president of the state social welfare agency (DIF – Dirrección Integral de la Familia). She began to promote dry toilets through both official and NGO channels and there are now more than 27,000 ecological toilets registered in the state.

César Añorve (1998): personal communication.

multidisciplinary and interministerial teams can be most effective for establishing sustainable eco-san programs and should be encouraged. (See 'Integrated strategies and partnerships' below.)

To equip the team of eco-san facilitators adequately, a balance of three complementary educational strategies should be considered: participatory learning, sharing information and skills training. The degree of emphasis towards one approach or another will depend upon the specific culture or circumstances. For example, the use of participatory learning methods will be essential where urine diversion and the concept of recycling are unfamiliar or unacceptable. On the other hand, highly motivated cultures, with few or no basic resistances or taboos related to urine diversion or recycling of human excreta, may simply require information on the options available and specific skills training on how to construct the units and monitor their operation. Whatever the combination, it is especially important to maintain a holistic, interdisciplinary approach which will permit the users to integrate eco-san into their local culture and lifestyle.

Participatory learning

The effective use of participatory methods can be vitally important to the success of eco-san programmes, as well as to hygiene and sanitation programs in general. These methods involve users in the overall identification of problems and needs, in planning and finding solutions, and in monitoring health and environmental impact. User participation is essential to make necessary adjustments to the system.

Participatory methods can also improve communication both within and between the community and support agencies. Individuals and communities have unique identities and ways of functioning, which change agents must listen to, understand and respect. Effective implementation requires a balance between local, traditional knowledge and outside expertise.

Another advantage of participatory approaches is their potential for stimulating the self-confidence and creativity of the community members.

Technical and field staff of the eco-san program in El Salvador have been trained in Sarar (Self-esteem, Associative strengths, Resourcefulness, Action planning, Responsibility) participatory methodology[11]. The comprehensive educational strategy, which has emerged, integrates the construction, use and management of dry toilets with personal hygiene and ecological sanitation. It is proving to be vital for promoting the acceptance and sustainability of alternative sanitation approaches. An important output of this participatory learning process has been the formation of an inter-institutional team of trainers, who take the lead in promoting participatory methods; train staff from other institutions, as well as other sectors; and adapt and produce innovative, participatory learning materials.

Sharing information

Informed, knowledgeable people adopt and sustain behavioural change. Also, access to relevant information leads to sound community decisions. The exchange of this relevant information is accelerated through participatory processes and social networks. Mass communication (e.g. radio) and social marketing methods can add to the information contained in traditional knowledge systems. Public endorsement by respected leaders is useful, as are information campaigns by government institutions, NGOs and private entrepreneurs.

Language can play a critical role in any promotional or educational strategy. The name given to a device or system will influence its perception as desirable or undesirable. For example, it is important to use the word 'toilet' in referring to eco-san devices, since common usage equates 'latrine' with a smelly outhouse at the back of the garden. For similar reasons, the term 'waste' should also be avoided. The wise promoter will avoid using such negatively loaded words.

Skills training

The successful implementation of an eco-san programme requires changes in users' sanitation-related beliefs and practices, as well as in public officials' way of thinking. Large-scale eco-san urban systems, in particular, require appropriate training at various levels:

- Key local authorities and field staff must be properly trained in the principles, technical solutions, comparative advantages and limitations of eco-san systems.
- Field workers will require practical training concerning the construction and management of the eco-san system, as well as empowerment methods.
- Household and community members must acquire skills in building, operating and maintaining eco-san devices.

The **learning-by-doing** approach should include participatory seminars, workshops and meetings, as well as broader hands-on training.

The promotion of eco-san systems provides a unique opportunity to increase hygiene awareness. Operation and maintenance of dehydrating toilets, in Central America, has been remarkable in communities where sanitation programmes combine information on healthy practices with demonstration projects, user participation in choosing sanitary devices, and targeted actions to reinforce new habits. In communities where training of household members in the management of their sanitation facilities has been neglected, sanitation continues to be poor.

4.5.3 Institutional framework

Various types of institutions need to be involved in promoting and supporting eco-san systems. The specific arrangements vary a great deal depending upon the local and national context. In some countries, the programmes evolve almost entirely through the official government structures; in others, the commercial sector and/or NGOs tend to take the lead.

Local and non-governmental organizations

Decentralized eco-san systems frequently rely on **local organizations** to promote, build, monitor and evaluate facilities. Their knowledge of local conditions, particularly household habits, is essential for promotion and management. Moreover, these organizations have the power to bring in new practices, survey household performance, mobilize local resources and influence the conduct of community members.

Incentives and sanctions exerted by local **religious or political organizations** can be vital assets in promoting and managing eco-san systems. If a large number of people belong to one particular religious sect, as in Hermosa Provincia (a low-income neighbourhood in San Salvador, see Section 3.1.2) the group's endorsement of a new approach to sanitation can lead to a high level of acceptance and sustainable maintenance.

Trusted local organizations can help to encourage communities to adopt non-conventional approaches – even when those choices do not fit the households' initial aspirations. Appropriate long-term operation and maintenance of facilities require active involvement of community organizations. At Hermosa Provincia, community leaders monitor adequate operation and maintenance of eco-san toilets and levy fines against households that do not take proper care.

Local and international NGOs are often ideal for promoting eco-san approaches, particularly during the early experimental and pilot phases. NGOs often enjoy ample contact and confidence with communities and have the flexibility to adapt their approaches and technologies to user needs.

Government and official bodies

Strong government commitment to eco-san is necessary in any effort to go to scale, particularly in urban areas where the legal regulatory framework can be a decisive factor in the construction of sanitary systems. Although effective introduction and use of eco-san systems depend to a great extent on community-based initiatives, central and local government involvement is needed to expand and sustain the approach. For example, a recent study of community based solid waste management programmes found that the prospects of sustainability and replicability will be greater if there is a high political will and government regulation clearly support community based efforts. The study also indicated that the organization of secondary transport and disposal of solid waste is usually beyond the resources of the community, even when they have been successful in organizing a primary collection programme.

On the other hand, in cases where the government agencies are highly bureaucratized or corrupt, it can be necessary initially to develop mechanisms to bypass them.

Commercial and private sector

Independent **contractors** and **consulting groups** have a straightforward economic incentive to see that their products or services are accepted and in demand. In fact, going a step further, César Añorve in Mexico has suggested that one of the keys to longer term sustainability of eco-san systems is to strengthen the link that exists between the small scale community oriented workshops that construct the urine-diverting toilet seats and the masons who build the toilets. The strategic role of locally based builders as promoters has also been observed in numerous sanitation projects around the world.

International development organizations and donors

In addition to their role as potential founders of innovative pilot sanitation programmes, international organizations can help to influence government officials and to formulate a favourable policy framework. Unicef, for example, has played an important role in El Salvador as a channel for external funds and in aiding co-ordination between institutions, training and technical assistance. Similarly, Greenpeace has helped to bring about change in Micronesia, and the Sida-funded Sanres programme has worked globally – particularly in starting and supporting technical research and development, and networking.

Technical schools, research institutions and professional associations

Research institutions and technology centres can be vital in testing, adapting and monitoring the quality of new technologies and their operation. For example, Cemat in Guatemala played a central role in introducing and adapting the Vietnamese double-vault composting toilet to Central America.

As projects mature, more attention tends to be given to influencing sector policies and standards through training technical personnel and gaining support from professional associations, e.g. architects, engineers, public health officials and agriculturalists. In urban programmes, in particular, it is advisable to think out a strategy for involving these institutions early on. In Cuernavaca, Mexico, it was considered an important victory, recently, when the local architects association successfully lobbied the municipal government to issue a construction permit for a middle-income urban dwelling that included a domestic eco-san system. This established an important precedent for future strategies which may include reduced utility bills for families that use water conserving eco-san systems.

Integrated strategies and partnerships

Some of the strongest eco-san programmes have developed strategies for involving several levels of institutions simultaneously. One of the best examples is in El Salvador:

- Local and international NGOs work at the municipal and grassroots levels.
- The Ministry of Health has been at the forefront of research and development, training and promotion.

- Unicef, with funding from Sida, has helped to bring about a change.
- Sanres has provided technical guidance and co-funded international seminars and training courses.

In urban settings, in particular, responsibilities must be clearly defined. For example, the community or the local government will be responsible for the establishment of operational guidelines and for monitoring the safe functioning of the system at household level. If necessary a system of incentives and sanctions will have to be agreed upon and enforced.

The municipality, a community organization or a private contractor could be responsible for collection, further treatment, distribution and sale of the sanitized faeces and the urine. The collection staff might also be given the task of monitoring the household units.

Whatever the particular arrangement, the combining of community initiative and official sanction is essential over the long term.

4.5.4 Financial considerations

The introduction of eco-san systems is bound to lower the total costs of urban sanitation. Sewers and treatment plants and sludge disposal arrangements will cost several times as much as an eco-san system. This is particularly important for Third World countries, where public institutions face stringent financial limits. Eco-san systems require much less investment as they need neither water for flushing nor pipelines for the transport of sewage, nor treatment plants and arrangements for the disposal of toxic sludge.

However, eco-san systems will involve costs for information, training, monitoring and follow-up that are greater than corresponding costs for conventional sanitation systems. Furthermore, an urban eco-san system will generate additional costs that are not usually present in small rural eco-san projects, such as the safe handling, transportation, storage of urine and

Box 4.3 'The financial problem'

Inadequacy of financial resources is not the only problem that requires a new model of water and sanitation services. Very often 'the financial problem' is not really one of scarcity of funds but one of misallocation of financial resources, of inappropriate technology, and of disregard of the environment. The use of a model developed for different environmental conditions, different climates, and different socio-economic situations leads to expensive and often ineffective solutions. The future promises more of these problems. Money alone will not solve water scarcity problems; what is required is a different approach to water supply and sanitation.

Kalbermatten, JM & Middleton RN (1992): Future directions in water supply and waste disposal, mimeo, Washington DC.

dehydrated or composted material from many devices. On the other hand, the economic (and ecological) value of the fertilizers produced could be significant.

Successful sanitation relies on sound finances. In principle, households should fully repay investment and operational and maintenance costs to ensure the sustainability of a local eco-san system. In practice, pilot peri-urban sanitation programmes involving free or highly-subsidized demonstration models are likely to fail in the long run when false expectations have been raised regarding the cost of the system.

Initial subsidies should not vary significantly from the long-term pricing structures. Many families may accept a free toilet only to abandon it. Users' willingness to contribute their own resources, rather than relying on external financing, is a strong indicator of acceptance and enduring success.

In urban programmes that require large scale support services, payment collection becomes a crucial issue. In order to improve collection, payments can be collected by financial institutions (bank, or co-operatives) or a local non-governmental organization might inspire more confidence from the users.

Some of the funds should be held by community organizations, for promotion, training and monitoring activities. Another portion could be transferred, for example, to a trust fund, aimed at financing new eco-san projects or improving existing ones. If possible some funds should be reserved for further research and development, as there has been little independent funding for quality scientific research.

5. A VISION FOR THE FUTURE

In the foregoing sections of this book, we have explained what is currently known about eco-san systems, their strengths and weaknesses. We have given advice on how to make ecological sanitation systems work with regard to the selection, design and management of devices and systems for households and shared our knowledge about the promotion and support aspects so necessary to their success. But how could eco-san work on a large scale, such as an entire town or city, and how would cities deal with the excreta products in a safe and hygienic manner that would be a benefit to society and the larger environment?

There are few large-scale examples from which to draw conclusions. For large scale urban applications, we are compelled instead to draw upon our own vision of how it might work.

5.1 A vision

Typically, cities in developing countries have affluent areas with all modern amenities, poorer areas, fast growing squatter areas, and surrounding rural areas with farms and market gardens. Typically also, many such cities are critically short of fresh water, and are, or ought to be, deeply concerned about preserving the quality of their groundwater and surface water resources. Municipal governments in developing countries, as well as most of the people living in cities and the surrounding countryside are short of money. In addition, many parts of cities are crowded. Many of the poorer sections of cities are unplanned developments and thus have narrow roads and pathways between houses and a difficult terrain.

Our imaginary city thus has these fairly typical characteristics. In this city the municipal government is progressive. The city government is truly concerned about the welfare of all of its citizens and tries to balance the interests of all. The city leaders have taken to heart the Rio Declaration and have tried to make rational decisions based upon the principles of equity and sustainability and maintaining the quality of the environment. They searched for a solution to their problem of poor sanitation and rejected centralized sewerage, as they have neither the water required for flushing nor the funds for investments in sewers, pumping stations and treatment plants. Owing to their concerns about groundwater quality, they also decided against pit or pour-flush toilets. They are also concerned about utilizing local resources and building local capacity, both of which are important for sustainability. They do not want to become dependent upon any outside assistance in the form of materials or parts or funding.

The city leaders realized that they needed a sanitation system to serve all citizens, thus it could not be too expensive. They had to consider climatic conditions, topography, groundwater conditions, population density, settlement pattern, taboos, and existing defecation habits in selecting their system.

They chose a sanitation system based upon decentralized management of human excreta and household refuse. The maintenance burden on homeowners was to be minimized with service contracts and communal collection. Recycling stations would be set up in each neighbourhood for metal, paper, plastics, glass, organic refuse from kitchens and gardens, and human excreta. They selected, on the basis of these decisions, an eco-san system that would allow them safely to recycle organic kitchen wastes and sanitized human urine and faeces back to small horticultural plots within the city and to rural farms. The system they chose for the recycling of human wastes involved a urine diversion feature, so that urine was collected separately from the sanitized faeces.

Recycling stations were set up in neighbourhoods, and today its workers collect urine and organic kitchen wastes from the households on a regular schedule decided upon by the community. Sanitized faecal products are collected every 6 months from the toilets and brought to the recycling station. After the primary treatment (dehydration) on site the weight of the partly sanitized faeces is greatly reduced and they are safe and inoffensive enough for the workers to handle. This makes collection easier, especially since many roads are narrow and bicycle and donkey carts have to be used for collection in some neighbourhoods.

At the recycling station the partly sanitized faeces go through a secondary treatment of high temperature composting for complete pathogen destruction.

The urine is temporarily stored near the toilet and used for the household's own garden or rooftop container garden (see Box 2.1).

Excess urine, and urine from households not wanting to use it on-site, is collected weekly, stored in tanks at the recycling stations until sanitized and then sold as a liquid fertilizer to market gardeners and farmers in and around the city. During the cold season there is still a demand for urine fertilizer from farmers who produce vegetables in greenhouses.

The sanitized faeces are sold as a soil conditioner. These products are found to be as good as commercial fertilizers but are much cheaper. The price paid by farmers and urban horticulturalists funds the wages of the workers at the recycling station, so that households have to pay nothing for collection. Each recycling station has created a large number of jobs for local residents.

The entire system is supported by an education and training programme for both households and workers at recycling centres. Collection workers are trained in instructing and following up households. If at the time of collection they see a problem in the household's sanitation unit, it is their job to discuss the problem with the owner and try to correct it on the spot. In addition, the municipal government has instituted regular monitoring of the neighbourhood

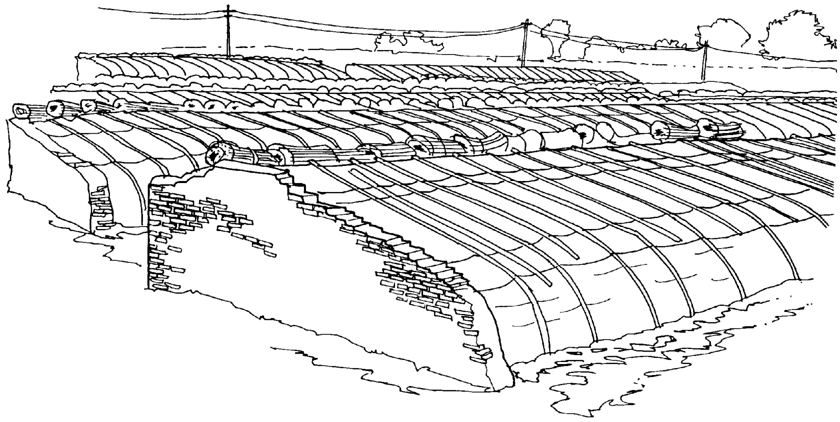

Figure 5.1 *With greenhouse production of vegetables there is also a demand for urine fertilizer during the cold season.*

recycling centres and the fertilizers being produced. There is periodic testing of both urine and sanitized faeces for public health safety.

A bonus of the new sanitation system's educational programme is that a range of hygiene behaviours are addressed as never before. Hand washing, food hygiene and the care of infants and toddlers to prevent diarrhoeal diseases receive greater attention. Another benefit is that participatory methods were used with communities to plan their recycling centres. These methods are now used by community groups to address other development issues.

5.2 Advantages of ecological sanitation

If this vision of ecological sanitation could be realized, then it would confer a great many advantages to the environment, households and families and to municipalities. To close our book we summarize these advantages below.

5.2.1 Advantages to the environment

If ecological sanitation could be adopted on a large scale, it would protect our groundwater, streams, lakes and the sea from faecal contamination. Less water would be consumed. Farmers would require less amount of expensive commercial fertilizers, much of which today washes out of the soil into water, thereby contributing to environmental degradation.

Eco-san allows us to make use of the high fertilizer value of urine. The 400–500 litres of urine produced by each person during a year contains enough plant nutrients to grow 250 kilograms of grain, enough to feed one person for one year. Urine is rich in nitrogen, phosphorus and potassium. As much as 90% of the fertilizer value of human excreta is in the urine[1]. This important resource is much easier and safer to handle in the form of pure urine than it is in a mix of urine and faeces. Urine can be diluted with water and put directly on vegetable gardens and agricultural fields or saved in underground tanks for later use.

Eco-san also allows us to recover the resource value of faeces. Human faeces can be turned into a valuable soil conditioner. But faeces may also contain dangerous micro-organisms. Before we can recycle faeces back to the soil, these pathogens must be destroyed. Pathogen destruction as well as handling is safer, easier and less costly if the faeces are not mixed with urine and water.

Large scale recycling would rejuvenate rural and urban agriculture. Returning human urine and sanitized faeces to rural areas on a regular basis has the potential to replenish soil nutrients to levels at which productivity will rise dramatically. A Swedish study found that the nutrient content of compost removed from composting toilets compared well with that of farmyard manure, and in some ways was superior[2].

Large scale recycling would reduce the greenhouse effect. The recycling of human excreta could help to reduce the greenhouse effect if practised on a large scale as part of a comprehensive programme to increase the carbon content of soils. Most efforts to address the atmospheric build-up of carbon dioxide (CO_2), which is believed to be causing climate change, have focused on reducing the CO_2 emissions from fossil fuel burning and the clearing of rain forests. However, scientists have recently begun to focus on the ability of soils to serve as a sink for excess atmospheric carbon. (In soils carbon is stored in the form of humus and decaying organic matter.) A number of factors influence the accumulation of carbon in soils. Returning sanitized human excreta to degraded lands would play a significant role in this process by enhancing soil fertility, increasing plant growth and hence the amount of CO_2 pulled from the atmosphere through photosynthesis. A modest doubling of the amount of carbon in non-forest soils, from the current low level of 1% (as a result of erosion) to 2% over the course of 100 years would balance the net annual increase of atmospheric carbon over that time[3].

5.2.2 Advantages to households and neighbourhoods

Eco-san systems, if properly managed and maintained do not smell or produce flies and other insects. This is a great advantage over ordinary pit toilets. Urine and faeces do not come into contact to produce smell. Moisture levels are too low for fly breeding.

A frequently heard objection to ordinary pit toilets is that small children may fall into them and die. Eco-san systems pose no such risk because they are neither deep nor wet and usually built entirely above ground.

No matter how unpleasant the immediate environment may be, individual households can improve their conditions considerably by adopting an eco-san system. There is no need to wait for the authorities to come and install piped water and a sewerage system. The device itself can be relatively inexpensive and is not difficult to build. Households can immediately have the privacy, convenience and aesthetic advantages of an odourless and flyless toilet, attached to or even built right into their homes, however small. This is of course particularly important for women. Where groups of households do not have toilets and open defecation is practised, these householders can improve their part of a neighbourhood dramatically.

The health benefits of toilets are usually not an important selling point for consumer acceptance. However, some consumers may find it attractive to know that if a large area of their community can be made more sanitary, the likelihood of diarrhoea and worm infections will decrease, leading to overall better health and better study results for school children[4].

The nutrition of families would also improve if urine and faeces were recycled to grow additional vegetables in garden plots, on rooftops and balconies (see Box 2.1) or even on walls (see Box 2.2). The fertilizer value of recycled urine and the soil-improving properties of decomposed faeces should produce excellent crops even from poor soil or soil-less horticulture[5]. This again is particularly important for women as they normally are the ones responsible for the household's food production.

Some designs of eco-san toilets are lightweight and movable. The urban poor usually do not own the land on which they live and do not wish to invest money in structures they cannot take with them. With the eco-san approach it is possible for them to have a prefabricated toilet unit that can be moved. This has proved to be an important selling point for the prefabricated toilets produced by Tecnologia Alternativa SA in Mexico City (see Section 3.2.3).

The emptying of ordinary pit toilets and the sludge removal from septic tanks is both messy, expensive and technically difficult. In many informal settlements, the vacuum trucks needed for the process cannot negotiate the narrow streets and the steep slopes. If contents are removed by hand, the sludge is smelly, wet and dangerous to the workers. Eco-san systems based on dehydration or decomposition reduce the volume of material to be handled and transported and result in a dry, soil-like, completely inoffensive and easy-to-handle product. As the toilet is built completely above ground there is easy access to the sanitized faeces for recycling and easier management of contents for pathogen destruction.

A great problem of building toilets in some areas is the subsoil and groundwater conditions. In some areas the ground is too hard for digging. In other areas the water-table is close to the surface. Both conditions prevent or make difficult the construction of pit toilets, VIP toilets or pour-flush toilets.

As eco-san systems can be built entirely above ground, they allow construction anywhere a house can be built, they do not collapse, they do not destabilize the foundations of nearby buildings and they do not pollute the groundwater.

It is often said that one cannot have good toilets without water. This is because some sanitation systems depend on water for transport of faeces and urine to an off-site location. Most eco-san toilets need no water – in fact, for many designs, water is harmful to their proper functioning.

Figure 5.2 A neighbourhood with an ecological sanitation system. Each household has its own dehydrating or composting toilet attached to the house. There is urine diversion and the processing chamber is solar heated. Municipal workers collect urine, primary processed faeces and kitchen wastes and take them to the neighbourhood's own recycling station.

Over half the population of the developing world has no sanitary system of excreta disposal. The market for appropriate sanitation devices is enormous and the demand is there. Also over half of poor people are unemployed. The majority of eco-san toilets do not require expensive or high-tech equipment. Jobs can be created for builders and for collectors of urine and sanitized faeces. These products can be sold to farmers or households could use them to grow food. An entire mini-economy could potentially develop around ecological sanitation systems, especially in urban areas.

5.2.3 Advantages to municipalities

Municipalities all over the world are experiencing greater and greater difficulty in supplying water to households and neighbourhoods. In many cities water is rationed and supplied only a few hours a week. Wealthier households collect this water in large tanks while the poor queue up at public taps to receive their daily ration. Eco-san systems do not use these scarce water resources and may result therefore in a more equitable allocation of water to rich and poor households.

A major advantage of eco-san systems is that they have the potential to increase sanitation coverage of the unserved more quickly than any other method. Municipal governments are under increasing pressure to provide sanitation coverage for the entire urban population. Even if there is political will, the options available are severely limited owing to lack of water and/or money (for flush-and-discharge systems) and lack of space and/or difficult ground or groundwater conditions (for drop-and-store systems). The eco-san options, outlined in Chapter 3 are in general affordable to the poor and have almost no recurrent costs for operation and maintenance. In most cases they require no excavation, do not depend on water and pipe networks, and, as the units have no odour and can be placed anywhere (even inside a house and on upper floors), they can be used even in congested areas. Eco-san could be an inexpensive and attractive alternative to expansion of sewerage systems.

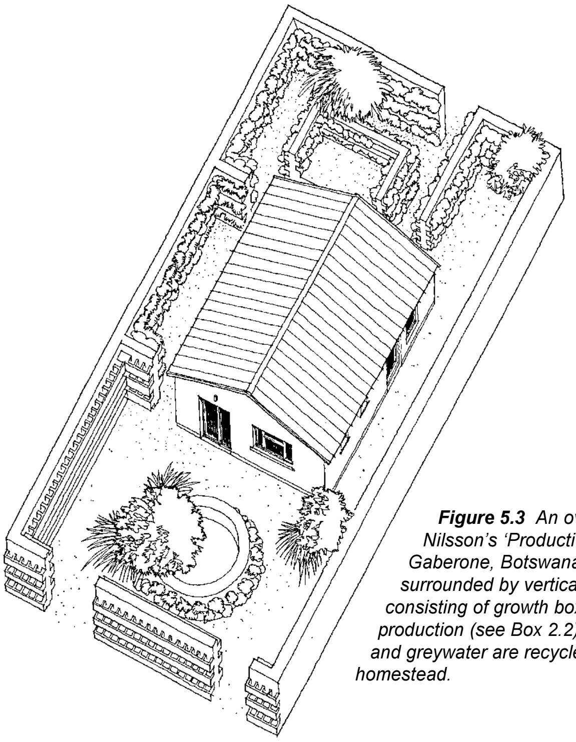

***Figure 5.3** An overview of Dr Gus Nilsson's 'Productive Homestead' in Gaberone, Botswana. The house is surrounded by vertical gardens consisting of growth boxes for vegetable production (see Box 2.2). Urine, faeces and greywater are recycled on the homestead.*

Finally, eco-san systems allow, even favour, decentralized urban waste-to-resource management. The burden for guaranteeing a well functioning urban sanitation system is taken from the municipal government and transferred to neighbourhood level where citizens can monitor conditions and take direct action when necessary. The role of municipal government then becomes regulatory with the goal of safeguarding public health.

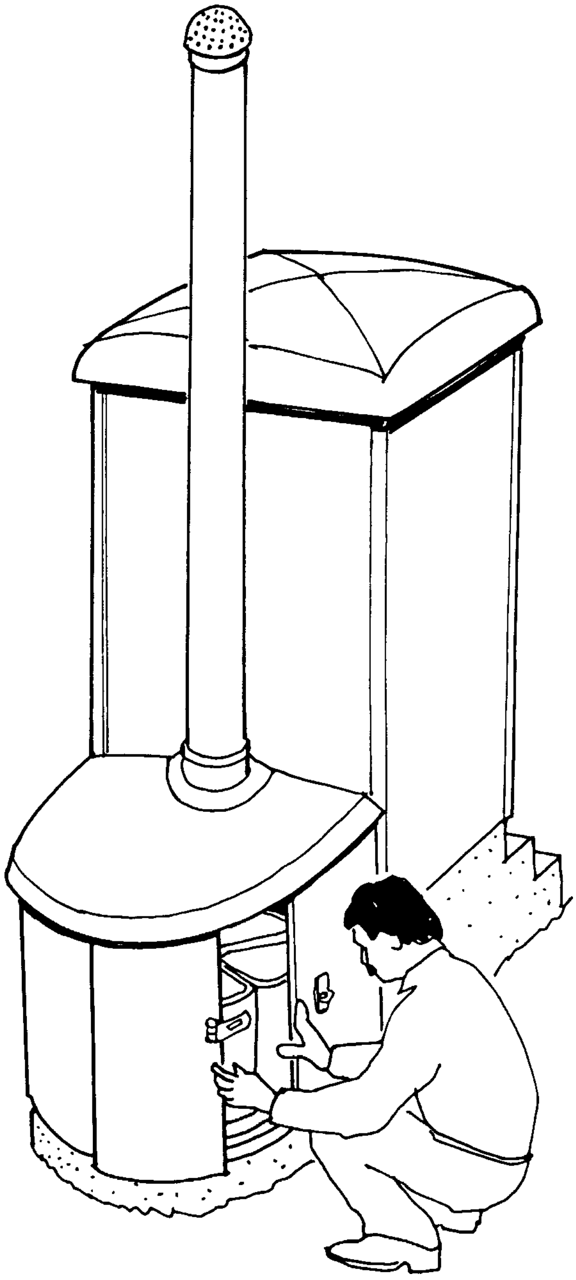

Figure 5.4 *Eco-san toilets are built entirely above ground. This example of a prefabricated unit has a solar heated processing chamber with buckets on a rotating floor.*

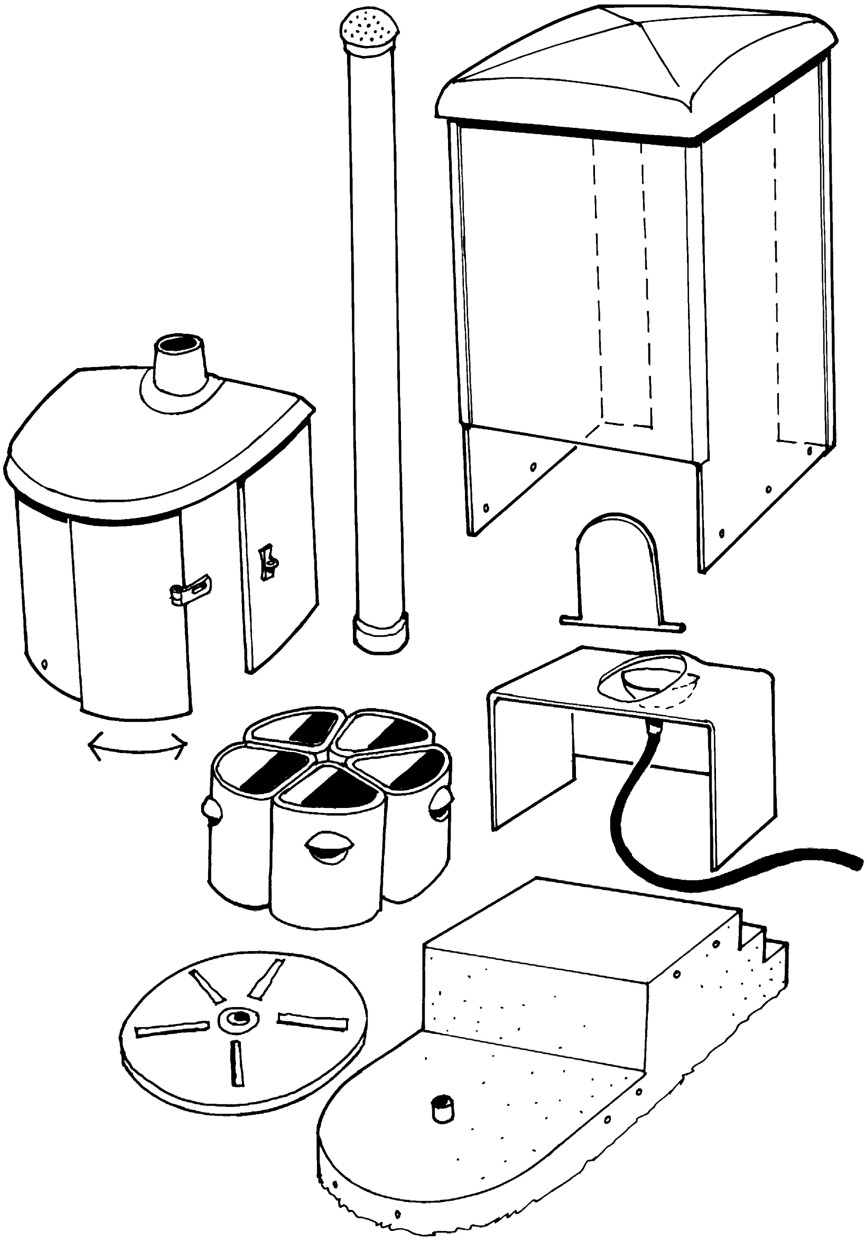

Figure 5.5 *Exploded view of the toilet in Figure 5.4.*

NOTES AND REFERENCES

Chapter 1: INTRODUCTION

(1) Union of Concerned Scientists (1992): *World scientists' warning to humanity*, issued in Washington, DC, USA, on 18 November 1992. UNCHS (1996): Water crisis to strike most developing world cities by 2010. *Habitat Press Release*, Nairobi, Kenya. UNDP (1996): Habitat II, Dialogue III: *Water for thirsty cities*, Report of the Dialogue, UN Conference on Human Settlements, June 1996, Istanbul, Turkey.

(2) Niu Mao Sheng, China's Minister of Water Resources, quoted in Brown LR (1997): *Who will feed China? Wake-up call for a small planet*. WW Norton & Co, New York, USA.

(3) UNCSD (1997): *Comprehensive assessment of the freshwater resources of the world.* Economic and Social Council, fifth session, 5–25 April. E/CN.171997/9/. New York, USA.

(4) Costner P and Thornton J (1989): *We all live downstream – the Mississippi River and the national toxics crisis*, Greenpeace, Washington DC, USA. Platte, AE (1995): Dying seas. *World Watch*, 8 (1), Worldwatch Institute, Washington, DC, USA. Smayda T (1990): Novel and nuisance phytoplankton in the sea – evidence for a global epidemic, in Graneli E *et al.* (eds): *Toxic marine phytoplankton*. Elsevier Science Publishing House, New York, USA.

(5) Briscoe J and Steer A (1993): New approaches to sanitation – a process of structural learning. *Ambio*, 22 (7): 456. Stockholm, Sweden. WHO (1997): *Environmental Health Newsletter*, No 27 – Supplement, Geneva, Switzerland.

(6) For a recent study of groundwater pollution from pit toilets, see Stenström TA (1996): Water microbiology for the 21st century, paper presented at Workshop 3, Stockholm Water Symposium, 7 August 1996, Stockholm, Sweden. – 'Poor siting of latrines or wells may create extensive groundwater pollution of micro-organisms. Old rules of thumb are applied without taking relevant factors into consideration. A safety distance of 10–30 m between latrines and wells has at the best been adhered to in many developing countries, but without considering factors that may affect the actual risk of pollution. To assess and exemplify this as a transmission route, we conducted a number of simple experiments where bacteriophages where introduced as biotracers into different latrines in two peri-urban African settings. It was shown that a transmission occurred within days under the prevailing conditions from the latrines to wells up to distances of between 50–100 meters. This shows that, although parasites and bacteria may be held back effectively, some viruses where not.'

Chapter 2: SANITIZE-AND-RECYCLE

(1) The major pathogens (and associated diseases) found in urine include: *Salmonella typhi* (typhoid), *Salmonella paratyphi* (paratyphoid fever), *Schistosoma haematobium* (bilharzia). *Salmonella typhi* and *paratyphi* are excreted in urine and faeces, and in most parts of the world, short-term faecal carriers are more common than urinary carriers. *S. haematobium* eggs leave the body mainly in the urine, but enter through the skin after a development period outside of the body. – For a more complete description of each of the above pathogens and diseases see for example Beneson AS (ed) (1995): *Control of communicable diseases manual.* American Public Health Association, Washington DC, USA. See also Höglund C (1998): Hygienisk kvalitet på källsorterad urin (Hygienic quality of diverted urine). Paper presented at the National VAV Conference, Linköping 2–3 March 1998.

(2) Less than 5% of domestic wastewater is treated in urban areas of developing countries. See World Resources Institute (1996): *The urban environment*, 1996–1997. Oxford University Press, New York, USA, p 109.

(3) For a review the evolution of resistance to *Shigella*, see Tuttle J and Tauxe R (1995): *Antimicrobial-resistant Shigella – the growing need for preventive strategies.* CDC/NCID Report. Infectious diseases in clinical practice, 2(1):55–59. Pathogens are also becoming resistant to disinfection in environmental media. For example, chlorine is not effective against helminths and protozoa.

(4) A more thorough discussion of these factors and pathogen die-off can be found in several documents: Strauss M & Blumenthal UJ (1990): *Use of human wastes in agriculture and aquaculture – utilization practices and health perspectives.* International Reference Centre for Waste Disposal (IRCWD), Duebendorf, Switzerland. Feachem RG *et al.* (1983): *Sanitation and disease – health aspects of excreta and wastewater management.* John Wiley and Sons, Chichester, New York. Jenkins JC (1994): *The humanure handbook – a guide to composting human manure emphasizing minimum technology and maximum hygienic safety.* Jenkins Publishing, Grove City, PA, USA.

(5) For a description of each pathogen, including their epidemiology, survivability and disease characteristics, see Feachem RG *et al.* (1983): *Sanitation and disease – health aspects of excreta and wastewater management* John Wiley & Sons, Chichester, NY, USA.

(6) Markell EK, Voge M and John DTT (1986): *Medical parasitology.* WB Saunders Company, Philadelphia, USA.

(7) Beneson AS (ed) (1995): *Control of communicable diseases manual.* American Public Health Association, Washington DC, USA.

(8) Robertson LJ, Campbell AT, and Smith HV (1992): Survival of *Cryptosporidium parvum* oocysts under various environmental pressures. *Applied and Environmental Microbiology*, 58(11): 3494–3500.

(9) Fayer R (1985): Effect of high temperature on infectivity of *Cryptosporidium parvum* oocysts in water. *Applied Environmental Microbiology*, 60(8): 2732–2735. Andersson BC (1985): Moist heat inactivation of *Cryptosporidium* sp. *American Journal of Public Health*, 75 (12): 1433-1434.

(10) Armando Caceres, CEMAT: Personal communication.

(11) A series of studies were carried out by Reimers RS *et al.* on survivability of *Ascaris* under differing conditions in wastewater. They are: *Parasites in southern sludges and disinfection by standard sludge treatment* (EPA-600/S2-81-166, Oct 1981); *Investigation of parasites in sludges and disinfection techniques* (EPA-600/S1-85/022, Jan 1986), and *Persistence of pathogens in lagoon-stored sludge* (EPA/6000/S@-89/015, Jan 1990).

(12) King FH (1973): *Farmers of Forty Centuries: permanent agriculture in China, Korea and Japan.* Rodale Press, Emmaus, PA. (originally published in 1909). See also Winblad U and Kilama W (1985): *Sanitation without water.* Revised and enlarged edition, Macmillan, London, UK.

(13) Matsui S, (1997): Nightsoil collection and treatment in Japan. *Ecological alternatives in sanitation*, Publications on Water Resources No 9, Sida, Stockholm, Sweden.

(14) UNDP (1996): *Urban Agriculture.* New York, USA.

(15) Jönsson H (1997): Assessment of sanitation systems and reuse of urine. *Ecological alternatives in sanitation*, Publications on Water Resources No 9, Sida, Stockholm, Sweden.

(16) Jönsson H, Olsson A, Stenström TA and Dalhammar G (1996): Källsorterad humanurin i kretslopp – en förstudie i tre delar (Recycling source separated human urine – pilot study in three parts), *VA-Forsk Report* 96-03, Stockholm, Sweden. (In Swedish, English summary.)

(17) Olsson A (1995): *Källsorterad humanurin – förekomst och överlevnad av fekala mikroorganismer samt kemisk sammansättning* (Source separated human urine – occurrence and survival of faecal micro-organisms and chemical composition). Report 208, Department of Agricultural Engineering Research, Swedish University of Agricultural Sciences, Uppsala, Sweden.

(18) Jönsson H, Stenström TA, Svensson J and Sundin A (1997): Source separated urine – nutrient and heavy metal content, water saving and faecal contamination. *Water Science and Technology*, 35 (9): 145–152. Other researchers have found that the addition of acid inhibits the initiation of the decomposition of urea. The acid should be added before the decomposition starts, see Hanaeus Å *et al.* (1996): Conversion of urea during storage of human urine. *Vatten* 52: 263–270, Lund, Sweden. A Vietnamese researcher recommends the addition of superphosphate to prevent the evaporation of ammonia, see Polprasert C (ed) (1981): *Human faeces, urine and their utilization.* ENSIC, Bangkok, Thailand.

(19) Jönsson H (1997): Assessment of sanitation systems and reuse of urine. *Ecological alternatives in sanitation*, Publications on Water Resources No 9, Sida, Stockholm, Sweden.

Elmuist H, Rodhe L, Blomberg M, Lindén B, and Steineck S (1998): Human urine and effluents from digestion of food refuse as a fertilizer to barley – crop yields, ammonia emission and nitrate leakage. Paper presented at the 8th International RAMIRAN Conference Management Strategies for Organic Waste in Agriculture, 26–29 May 1998, Rennes, Brittany, France.

Chapter 3: ECOLOGICAL SANITATION – ANCIENT PRACTICES AND NEW IDEAS

(1) Pathogens are destroyed by the sanitation system through the four-step process outlined in Section 2.1.3. Ideally all pathogens are destroyed in the on-site primary processing chamber. If this treatment fails to produce a sufficiently pathogen-free product, the output from the processing chamber must go through a secondary treatment on/off site.

(2) McMichael JK (ed) (1976): *Health in the Third World – studies from Vietnam*, Spokesman Books, Nottingham, UK. Polprasert C (ed) (1981): *Human faeces, urine and their utilization*. ENSIC, Bangkok, Thailand.

(3) A testing programme was initiated in 1998 by Sanres in cooperation with the Swedish Institute for Infectious Disease Control. Results will be published in 1999–2000.

(4) Solar heated first prototypes in Tanzania and Mexico, see Winblad U and Kilama W (1985): *Sanitation without water*. Revised and enlarged edition. Macmillan, London, UK. Solar heated toilets in Vietnam, see Winblad U and Stenström TA (1997): Pilot project in Cam Duc commune, Kan Hoa province – rapid assessment. Report to Sida, Stockholm, Sweden.

(5) Gough J (1997): El Salvador experience with dry sanitation. *Ecological alternatives in sanitation*, Publications on Water Resources No 9, Sida, Stockholm, Sweden. The contents of the processing chamber of some of the Tecpan toilets was analysed for a number of conditions in 1996 and 1997. In 17 out of 19 the texture was powder, with one pasty and one semi-pasty. Faecal coliforms, as measured by MPN/g had a median value of 4. The pasty toilet had a MPN of 2,400, the highest number reported. Only one of the toilets had ascaris eggs, but under microscopic examination, none was viable. It is possible that ascaris was not widely prevalent in this community. (A special study of ascaris survival is under way.) The pH ranged from 7 to 12, with a median value of 10. The moisture content was generally low, ranging from 8% to 38%. The median value was 13%, and only 4 samples were above 20% humidity.

(6) Kirkman J (1976): *City of Sanaa*. World of Islam Publishing Co Ltd, London, UK. Lewcock R (1976): Towns and buildings in Arabia – N. Yemen, *Architectural Association Quarterly* 8(1).

(7) Irma De Cal: Personal communication.

(8) At Salsbury Beach in Massachusetts there is a Clivus Multrum installation (33 toilets and 6 urinals in three buildings) serving up to 20,000 persons per day. It was completed and has been in use since 1996. Another one in Rhode Island, Misquamicut Beach, has had a Clivus Multrum installation (consisting of 12 processing chambers) for 6 years and is now being extended. The installations are owned by the respective states and are managed by Clivus New England Inc. The two beaches were previously closed down because of pollution but could reopen after installation of the composting systems. At present there are negotiations with farmers about recycling the liquid. The solid part stays in the tanks for about 10 years before it is taken out. There are now a few thousand public composting toilets in use in the US, in national parks, highway service areas and military camps. Regulations about reuse vary from state to state. – Carl Lindström (1998): Personal communication.

(9) Dudley E and Winblad U (1994): *Dry latrines for urban areas – the findings of the 2nd Sanres Workshop*. Mexico City, Mexico.

(10) Berry G and Crennan L (1996): Paper presented at the Sanres Workshop on Eco-sustainable Sanitation, San Salvador, El Salvador.

(11) Rapaport D (1995): *Sewage pollution in Pacific island countries and how to prevent it*. Centre for Clean Development, Eugene, Oregon, USA.

(12) Calvert P (1997): Seeing (but not smelling) is believing – Kerala's compost toilet. *Waterlines* 15 (3): 30–32. Calvert P (1998): A positive experience with composting toilets in India – Kerala case study, paper presented at the CSE Conference on Health and Environment, New Delhi, July 1998. Paul Calvert (1998): Personal communication.

Chapter 4: MAKING ECOLOGICAL SANITATION WORK

(1) Fondo de Inversion Social (1994): Diagnostico y recomendaciones proyecto letrinas aboneras, operaciones BID I y II, San Salvador, El Salvador.

(2) Fis, Unicef and Ministry of Health (1995): Unpublished evaluation of the pilot project on the hygiene education module, San Salvador, El Salvador.

(3) Fittschen I (1995) *Water management in the Ecovillage Toarp*, Department of Water Resources Engineering, Lunds University, Lund, Sweden and Janusz Niemczynowicz: Personal communication.

(4) Clark GA (1997): Dry sanitation in Morelos, Mexico. *Ecological alternatives in sanitation*, Publications on Water Resources No 9, Sida, Stockholm, Sweden.

(5) Two recent examples from Sweden: The new (1997) science building for the University of Kalmar is equipped with an ecological sanitation system: urine diversion, worm composting and on-site greywater treatment for 500 students and 50 staff. The Bergianska Botanical Garden in Stockholm has a staff and guest toilet with urine diversion and a carousel-type processing chamber for faeces.

(6) Günther F (1992): *Simplifying waste water treatment by source separation.* Dept of Systems Ecology, University of Stockholm, Sweden.

(7) Clivus Multrum (1998): *Greywater – facts about greywater: what it is and how to treat it.* http://www.clivusmultrum.com/greywater.html

(8) See reference 14, Chapter 2.

(9) Haden A (1997): Gender checklist for planning sanitation programmes. *Sanitation promotion kit.* Simpson-Hébert M and Wood S (eds), WHO and Water Supply & Sanitation Collaborative Council, Geneva, Switzerland.

(10) Winblad U and Kilama W (1985): *Sanitation without water.* Revised and enlarged edition. Macmillan, London, UK.

(11) Wood S, Sawyer R and Simpson-Hébert M (1998): *Phast step-by-step guide – a participatory approach for the control of diarrhoeal disease.* WHO, Geneva, Switzerland.

Chapter 5: A VISION FOR THE FUTURE

(1) Sundblad K and Johansson M (1997): *Ecological engineering in sewage management.* Coalition Clean Baltic, Stockholm, Sweden,

(2) Valdmaa K (1975): *Functioning of the 'Ecolet' biological compost toilet.* The Royal Agricultural College, Uppsala, Sweden.

(3) Strong M and Arrhenius E (1993): Closing linear flows of carbon through a sectoral society – diagnosis and implementation. *Ambio* 22 (7): 414–416.

(4) WHO (1997): *Strengthening interventions to reduce helminth infections.* World Health Organization, Geneva, Switzerland.

(5) See for example Brown LR *et al.* (1998): *State of the world 1998.* Earthscan Publications Ltd, London, UK: 'For the urban poor, compost is a virtually free fertilizer and soil builder, whose production requires little space, virtually no equipment, and a modest amount of labour. Such a valuable and affordable resource, available without reliance on outside suppliers, can make an economic and nutritional difference to people living on the economic margins.'

GLOSSARY

Anadeges Autonomia, Descentralismo y Gestion, AC; an NGO in Mexico

barrio a district of a city or town in Spanish-speaking countries

blackwater
water that contains human excreta

BOD biochemical oxygen demand

CCD Centre for Clean Development; an NGO in USA

Cedicar Centro de Investigation y Capacitacion Rural AC; an NGO in Mexico

Cemat Centro Mesoamericano de Estudios sobre Tecnologia Apropriada; an NGO in Guatemala

composting a biological process by which various living things (e.g. bacteria, fungi, earthworms and so on) break down organic matter to make humus

defecation the act of discharging faeces from the body

dehydration removal of water; drying

diarrhoea a condition of frequent and loose defecation

Ecit Espacios Culturales de Innovación Technológica; an NGO in Mexico

eco-san
ecological sanitation

evapo-transpiration the process by which water is lost to the air through plant leaves and from soil and water surfaces

faeces undigested material discharged from the anus

faecophilic cultures cultures with no taboos against handling and talking about human faeces

faecophobic cultures cultures with strong taboos against handling and talking about human faeces

Fis Social Investment Fund

greywater
water that has been used for washing

groundwater water contained in the soil and deep underground

helminths parasitic worms

humus organic matter present in the soil, which has decomposed so far that it has lost all signs of its original structure

IDB Inter-American Development Bank

Lasf Letrina abonera seca familiar (the Central American version of the Vietnamese double-vault toilet

MPN most probable number

NGO non-governmental organization

night-soil fresh human excreta collected (traditionally at night) for use as fertilizer

nutrients any substance that provides nourishment

parasite an organism living in or on another and benefiting at the expense of the other, e.g. intestinal worms

pathogen an agent that causes disease

permeability the ability of soil to let liquids pass through

Phast An approach to promoting hygiene behaviour change: Participatory Hygiene and Sanitation Transformation

protozoa single-cell microscopic animals (singular: protozoon)

sanitation the disposal of human excreta and household refuse: 'Good sanitation is a state of cleanliness and a healthy environment, free from contamination. Sanitation is the process of creating and maintaining these conditions.' (WHO/Collaborative Council Working Group on Sanitation Promotion, 1995)

sanitize to make clean/hygienic so as not to be capable of causing disease

Sanres the acronym for an international sanitation research programme funded by Sida

Sarar a participatory non-formal education methodology promoting Self-esteem, Associative strength, Resourcefulness, Action planning and Responsibility

seat-riser the base on which the seat is put in a sitting toilet

Sida Swedish International Development Cooperation Agency

Sirdo Sistema Integral de Reciclamiento de Desechos Organicos

surface water rivers, lakes, ponds and streams

UNDP United Nations Development Programme

Unicef United Nations (International) Children's (Emergency) Fund

urination the act of discharging urine

urine a fluid produced by the kidneys and periodically discharged

USD United States dollars

VIP toilet ventilated, improved pit toilet

washer a person who uses water for anal cleaning

water conservation
saving (i.e. not wasting) water

WC water closet = flush toilet

WHO World Health Organization

wiper a person who uses paper or other solid materials (e.g. wooden sticks, stones or maize cobs) for anal cleaning

INDEX

THE AUTHORS

STEVEN A. ESREY
nutritional epidemiologist
Comparative studies of global health impacts of water and sanitation measures.
Currently with Unicef, New York, USA.
<sesrey@igc.apc.org>

JEAN GOUGH
sanitary engineer
Implementation of water and sanitation programmes in Central America.
Currently with Unicef, El Salvador.
<jgough@hqfaus01.unicef.org>

DAVE RAPAPORT
environmentalist-activist
Implementation of sanitation projects in the South Pacific for Greenpeace and the Centre for Clean Development.
Currently with VPIRG, an environmental NGO in Vermont, USA.
<vpirg@together.net>

RON SAWYER
social scientist
Development of the UNDP/Prowess project and the WHO/UNDP/World Bank PHAST initiative. Currently with the international consulting group SARAR Transformacion SC, Tepoztlan, Mexico.
<rsawyer@laneta.apc.org>

MAYLING SIMPSON-HÉBERT
medical anthropologist
Sanitation promotion worldwide, including editing the WHO/WSSCC/Sida book Sanitation Promotion.
Currently an international consultant on health and hygiene promotion, Colorado, USA.
<phebert@cmn.net>

JORGE VARGAS
economist-sociologist
Implementation of housing programmes in Costa Rica.
Currently a PhD student, Costa Rica and USA.
<jvcaam@sol.racsa.co.cr>

UNO WINBLAD
architect-planner
R&D on innovative sanitation systems for third world urban areas.
Currently with the international consulting group WKAB, Stockholm, Sweden.
<uno.win@wkab.se>

Urban and peri-urban areas in developing countries are among the worst polluted and disease ridden habitats of the world. Much of this pollution is caused by inadequate sanitation services. As cities expand and populations increase, the situation will grow worse and the need for safe, sustainable and affordable sanitation systems will be even more critical. Existing approaches to sanitation are neither viable nor affordable to the vast majority of people.

This book is about seeking new solutions in the form of 'ecological sanitation'. The book discusses what is currently known about ecological sanitation systems, their strengths and weaknesses. It gives advice on how to make such systems work with regard to the selection, design and management of devices as well as about the promotion and support aspects so necessary to their success.

The book is intended for all who share the will to explore new ways of tackling urban sanitation systems.