HEALTH ASPECTS OF DRY SANITATION WITH WASTE REUSE

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Health Aspects of Dry Sanitation with Waste Reuse

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EXECUTIVE SUMMARY

BACKGROUND

Dry sanitation is defined in this report as the on-site disposal of human urine and faeces without the use of water as a carrier. This definition includes many of the most popular options for low-cost sanitation including pit latrines, Ventilated Improved Pits, SanPlats, etc. There has always been an interest in the reuse of human waste as a fertiliser, and there has been much recent work on the development of composting and other processes to permit human waste reuse.

This report examines the practice of dry sanitation with reuse in Mexico, with a particular focus on health issues and the lessons to be learned from case studies and experience.

DRY SANITATION WITH REUSE

There are two distinct technical approaches to dry sanitation with reuse;

- **Dehydration**. Urine and faeces are managed separately. The deposited faecal matter may be dried by the addition of lime, ash, or earth, and the contents are simply isolated from human contact for a specified period of time to reduce the presence of pathogens.
- **Decomposition (composting)** In this process, bacteria, worms, or other organisms are used to break organic matter down to produce compost. The temperature and airflow are carefully controlled to optimise conditions for composting.

Toilets working on the dehydration principle, such as the Vietnamese double bin toilet, the Mexican Dry Ecological Toilet, the Guatemalan DAFF, the South African urine diversion dry toilet, the Ethiopian ECOSAN toilet, and other models from Yemen, El Salvador, Ecuador and Mexico are described in Section 2.3. Toilets working on the composting principle include the Mexican SIRDO, the Pacific Island Carousel toilet, and the Clivus Multrum. The first two models are described in Section 2.4.

Mexico is something of a “centre” or “focus” for work on dry sanitation with reuse. Mexican NGOs (e.g. Centro de Innovación Tecnológica, Espacio de Saluc A.C., and Grupo de Technologia Alternativa S.C) and government (e.g. the National Water Commission, and parts of both local and federal government) have actively promoted dry sanitation with reuse with mixed degrees of success.

PATHOGEN REDUCTION

The isolation, reduction and/or elimination of pathogens (disease-causing organisms) are the primary objectives of any sanitation system. There are, unfortunately, a limited number of documented studies of pathogen die-off within dehydrating toilets, but these indicate consistent findings. The two most influential factors appear to be pH and residence time. Assuming appropriate addition of absorbent material, the reported storage time required prior to reuse of the faeces pile varies in the literature from 3-12 months.

The Engelberg guidelines (<1 nematode egg per kilogram wet weight and <1000 faecal coliforms/litre) are appropriate limits to consider for compost applied to topsoil. Studies indicate that the contents of neither the Guatemalan DAFF nor the South African urine separation toilet meet these standards. Other studies, however, show that the Vietnamese double bin toilet can meet these criteria if contents are left undisturbed for 6 months. The single microbiological study of a composting toilet (the SIRDO model) indicates that its contents would meet the Engelberg guidelines.

Unfortunately most of the studies do not assess the health status of the families using the toilet; the absence of worm eggs in faeces from families uninfected by worms is hardly surprising, and says nothing about the efficacy of the process in destroying worm eggs!

CASE STUDIES

Dry sanitation systems designed for excreta reuse were visited in Ixtlico el Chico (Morelos State) and San Juan Amecac (Puebla State). In Ixtlico el Chico, the more recently constructed toilets seem to fare better than the earliest models. Some problems with urine separation seemed universal, including blocked separators, difficulties for children in use of the urine separation devices, and inadequate urine absorption into ground during heavy rainfall. In San Juan Amecac, residents seemed able to manage the toilets well, apparently in no small part due to the frequent visits of sanitation extension workers.

CONCLUSIONS

- **Reuse of the contents of dry sanitation systems offers both advantages and risks.** There has been much recent publicity about the ecological advantages of composting and dehydrating toilets. There has been less attention to the demands these systems place upon the population for their safe adoption, and the risks of disease transmission that will result from inappropriate use.
- **Safe adoption of dry sanitation with reuse is a slow process**. This is the over-riding message from NGOs and governmental organisations involved in promotion of dry sanitation with reuse in Mexico.
- **The risk to health from a given sanitation facility depends not only upon its technology, but also upon the health status of the family using the toilet.** This fact is often forgotten in a number of the studies establishing the “safety” of a given technology by establishing the absence of parasite eggs.

- **A greater understanding of pathogen die-off during the ordinary use of these technologies is required.** While this report reviews the available evidence, a great deal more is required, especially given the current impetus behind the movement for ecological sanitation.

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1. INTRODUCTION

In the world today, 3 billion people are without proper sanitation and over one million tons of human faeces are produced each day, 50% of which remain uncollected (WHO, 1997). Sanitation of any kind is promoted and adopted for a variety of reasons, but the two most commonly cited objectives are human health and environmental protection. A recent meeting of the Environmental Sanitation Working Group of the Water Supply and Sanitation Collaborative Council agreed that current waste management policies and practices are abusive to human well-being, economically unaffordable and environmentally unsustainable (Bellagio, 2000).

Dry sanitation incorporating human waste reuse has been described as a valid alternative to water-borne sanitation (Stockholm International Water Institute, 1999). Such an option has an intuitive appeal as it appears to satisfy both objectives of human health and environmental protection. There is however, substantial controversy in the sector about the technology. Some quarters actively promote various forms of "eco-sanitation" and the reuse of human waste products from dry sanitation. Others are concerned about the widespread promotion of these technologies with what they believe to be inadequate testing under field conditions. Both proponents and critics of composting toilets and similar waste reuse technologies agree that human health is always the primary objective of any sanitation system; it must minimise the risk of disease and be capable of destroying or isolating pathogens. Both proponents and critics also agree that well-functioning sanitation together with effective hygiene education will break the cycle of disease (Wood & Simpson-Herbert, 1998). The disagreement is about the evidence establishing the safety and practicability of dry sanitation with reuse as an everyday practice.

Dry sanitation with reuse is promoted as an appropriate technology for community settings without sewerage or plentiful water. It has been heralded as solving many of the problems encountered with other sanitation systems. These include fly breeding, smell, groundwater contamination, short pit life and pit collapse. It is also claimed to achieve sufficient destruction of disease-causing organisms (pathogens) to enable safe handling of compost. Reviews in the literature have reported on the variety of technologies adopted around the world according to local conditions (del Porto & Steinfeld, 1999; Esrey *et al.*, 1998). Few however, have addressed the problems that can be associated with using such technologies in community settings or have documented the pathogen die-off. The enthusiasm which this sanitation technology has generated seems sometimes to have overshadowed the most important issue, of whether the end-products from dry sanitation toilets *per se* in community settings are safe to handle and use as soil conditioners and plant fertilisers. Correct usage of some types of dry sanitation with reuse sometimes seems to require an almost regimented control of the system and some understanding of dehydration or decomposition processes. How easy is it to use these toilets correctly? For example, to ensure maintenance of a certain moisture content, users must ensure the correct ratio of human to organic waste or absorbent is maintained. It is essential that an assessment be made of the efficiency of dry sanitation in community settings. Different technologies recommend different storage periods to ensure pathogen die-off and safe handling of the compost. There is a need for documentary evidence to support these claims.

This review attempts to collate current knowledge of

- health risks that may be associated with these technologies, through handling of the end-products and
- the problems associated with their use and maintenance.

Considering the difficulties that confront the prospective dry sanitation user, it is important to identify under what circumstances dry sanitation technologies are functioning safely and efficiently in communities on a long-term basis. Also, where there are problems, it is important to consider how these can be addressed. Taking these steps will ensure that users of dry will benefit long after the initial construction of the system.

This review focuses largely on dry sanitation technologies being promoted in Mexico. Mexico has been described as the dry sanitation capital of the world. Over 200,000 dry sanitation toilets have been installed in Mexico. Many regions of the country are inaccessible and conventional drainage inappropriate. There is much governmental interest in the different dry sanitation technologies available.

A small survey of dry sanitation technologies in-situ in Central Mexico assesses local perceptions and attitudes to these technologies and the problems that could affect their sustainability. To find an appropriate technology is only the first step, one must also convince people to accept it (McMichael, 1978).

2. DEFINING DRY SANITATION WITH REUSE

Dry sanitation is the disposal of human urine and faeces without the use of water as a carrier. Defined this way, dry sanitation includes some of the most popular forms of low cost onsite sanitation, such as pit latrines, Ventilated Improved Pit (VIP) latrines, etc. This report does not focus on all such forms of sanitation, but looks at the subset of dry sanitation technologies specifically designed to permit agricultural reuse of the products of urine and faeces. These are frequently referred to simply as “composting toilets” but in fact the word “composting” has a specific technical meaning that is not necessarily satisfied by all the dry sanitation technologies which reuse human waste.

2.1 EVOLUTION OF DRY SANITATION WITH REUSE

The practice of reusing human wastes is not new. Although the relationship between human faeces and disease was not yet understood, the value of human faeces as a fertiliser was known in Syria over 1000 years ago. Urine was evaporated and faeces sun dried, collected and sold. n China, farmers built roadside privies to attract travellers and collect the resulting fertiliser. In the 1930s in India, aerobic biological decomposition of human faeces was practised and in the 1940s, the Gopuri double-chamber dry toilet system was invented (del Porto & Steinfeld, 1999). Since 1954, a double chamber dry toilet has been used in Vietnam (Pacey, 1978). Ventilation pipes were added to both the Vietnamese and the Gopuri systems to remove odours.

The Clivus Multrum was developed in the 1930s by the Swedish engineer, Rickard Lindstrom. It consisted of a concrete sloped-bottom single chamber with two baffles and air ducts. In 1964 it was fabricated in fibre glass and patented, then in the 1970s it was licensed for use in the United States. The Clivus multrum is probably the best-known composting toilet. Such composting toilet systems have clearly been shown to be cost-effective and resource efficient when correctly operated.

Several authors have reviewed the now wide range of dry sanitation technologies available (del Porto & Steinfeld, 1999; Esrey *et al.*, 1998). This document concentrates on designs that are appropriate for low-income families in less developed countries.

2.2 TECHNICAL PRINCIPLES AND DEFINITIONS

There are two main processes employed in dry sanitation with reuse:

(i) **Dehydration**. Toilets based on the process of dehydration do not generally mix the faeces and urine. The urine is diverted and either collected or flows into a soak-pit. The faeces are collected in one of two chambers below the toilet seat and are dried by the addition of lime, ash or earth to the chamber after each defecation. Addition of these absorbents is also reported to reduce flies and eliminate bad odours. Once the chamber is full, it is sealed and the other chamber used. When the second chamber is full, the first chamber is opened. The contents of the first chamber are removed and used as a soil conditioner, buried or composted (by home composting or at a local composting centre) depending on the recommendations of the toilet designer.

(ii) **Decomposition (composting)**. Toilets based on the process of biological decomposition use bacteria, worms or other organisms to break down the faeces, producing compost. Many designs permit (or recommend) the addition of other organic matter such as vegetable scraps, straw, wood shaving or coconut husks. The temperature and airflow are carefully controlled in such designs to optimise conditions favourable for composting. It is important that airflow is sufficient to maintain aerobic conditions in the faeces pile. Urine is not usually diverted. The end-product is a fine compost that can be used as a soil conditioner. The additional liquid produced is either evaporated or allowed to flow into a soak-pit.

Dehydrating toilets either are built by the community with local materials or are prefabricated. Toilets based on the process of decomposition are usually prefabricated
Note that both systems involve construction of an all enveloping chamber which isolates the faecal pile from the environment. Such construction offers greater protection against groundwater contamination than a conventional unlined pit latrine, presumably at greater cost.

2.3 DEHYDRATION TOILETS

2.3.1 *Vietnamese dry toilet*

The Vietnamese dry toilet has two chambers built above the ground, which are constructed of concrete, stone or unbaked brick. There is a squatting slab with two holes on top of the chambers. The toilet cubicle over the two chambers is reached by two or three steps. Before a chamber is used, the floor of the chamber is covered with a layer of ash, soil or lime. The faeces drop into one of the chambers. The urine is piped into a vessel or soakpit. Paper used for anal cleaning is put in a metal bucket and burnt. After each use, additional ash, soil or lime is added to the chamber and the hole is covered with a wooden lid. When the chamber is nearly full, it is topped up with soil and the drop hole sealed with mud. A process of anaerobic dehydration then probably begins. The second chamber is then used by the family as a toilet in the same way as the first. When the second chamber is full, the first chamber is open and emptied. This usually occurs at least 2 months later. The resulting humus is used as a fertiliser.

During the anaerobic dehydration process, the temperature in the chamber is usually 2-6ºC higher than the ambient temperature, but has been reported to reach 50ºC in summer when the ambient temperature is 28-32ºC (McMichael,1978). Reports suggest that 85% of helminth eggs are destroyed after 7-8 weeks.

Modifications of this design have been adopted in several countries, due to its simple and low-cost construction.

2.3.2 *Dry Ecological Toilet (Mexico)*

A modified version of the Vietnamese double chamber dry toilet is promoted by the Mexican NGO, Espacio de Salud AC (ESAC). This modified version of the Vietnamese double chamber dry toilet was designed by Cesar Anorve in Mexico (Sawyer, 1998). The squatting slab is replace by two toilet risers. A conventional-looking urine separating toilet seat is placed on the toilet riser and the toilet is painted in attractive colours. Both these factors increased acceptance of the toilet in rural areas. The urine-separating toilet seat has been modified as a result of feed-back from users and a domestic urinal has also been designed. The design has also been adapted for use within
homes. The total building cost is about US$150 including labour and materials.

ESAC report that the dry ecological toilet has been successfully built in communities in a variety of climates from humid and temperate to dry and tropical.

2.3.3 *DAFF (Guatemala)*

The DAFF is a dry compost family latrine developed in Guatemala at CEMAT, (Centro Mesoamericano de Estudios sobre Technologia Apropriado) (Chavez, 1987). It is a modified version of the Vietnamese double chamber dry toilet. There are two concrete lined chambers, each with a hole in the top, on which the toilet seats are placed (rather than a squatting slab with two holes). The excreta and urine are collected separately. The excreta are deposited into one of two chambers. Ash, chalk or earth is added after each defecation to keep the excreta dry. The urine flows down a pipe into a pot. At the back of each chamber is a door through which the compost can be removed after 10-12 months. The compost is stored in sacks until used on the field. The urine, a source of nitrogen, is diluted and used to water plants.

This latrine can be built in the community by unskilled local labour using basic building materials. Total cost including labour is US$40-100 depending on the materials used for the superstructure. It is being promoted by the National Sanitation Program in Guatemala. Although it was possible to transfer the construction techniques, follow-up to ensure correct usage and maintenance of latrines was often inadequate, resulting in low levels of usage (Strauss & Blumenthal, 1990).

The DAFF has also been used in El Salvador, in such high density urban squatter areas as Hermosa Provincia, in the centre of San Salvador The fact that the DAFF units were functioning well after 6 years, with no odours or flies, was largely credited to the high level of community participation. (Winblad, 1996).

2.3.4 *Urine diversion dry toilet (South Africa)*

The urine diversion "dry box" toilet is another modification of the Vietnamese double chamber dry toilet. The Council for Scientific and Industrial Research (CSIR) in South Africa saw urine diversion as a possible solution to many problems that had been confronted with the VIP toilets (Holden, 1999).

A pilot project was carried out in 1997 with a blow moulded plastic toilet seat. The chambers and the superstructure were constructed with locally available materials. The toilet is raised above the ground. There is a chamber below the seat with two containers. The faeces are collected in one container, then when this container is full it is sealed and the other container is used. The urine flows into a soak-pit (communities were not keen to collect the urine and use it as a fertiliser), with the option of converting to collection, should people be willing to try later (Austin & van Vuuren, 1999). After defecation, ash was sprinkled in the chamber. Most families in the pilot were enthusiastic about the new technology and toilets had no odours or flies, although there was no vent pipe (Austin & van Vuuren, 1999). It was concluded that if properly implemented, urine diversion sanitation works well (Austin & van Vuuren, 1999). Further pilot studies are now under way using the urine separating toilet seat designed by Cesar Anorve in Mexico. This uses a fibre glass mould and a cement mortar mix, which substantially reduced the cost of each toilet seat from US$42 to US$10 (Holden, 1999).

2.3.5 *ECOSAN toilet (Ethiopia)*

The ECOSAN toilet was developed by the Society for Urban Development in East Africa (SUDEA). It is a urine diverting or non-mixing toilet that enables separate handling of faeces and urine (Terrefe & Edström, 1999a). The urine is collected in a special container. The faeces are also collected in special container and mixed with ashes, soil, leaves, grass or sawdust. The urine and the composted faeces can be used as a fertiliser. It is recommended that neither urine nor composted faeces should be spread on the top of the soil, but should be used under the topsoil. The toilet is constructed from locally available and appropriate materials . The total cost is about US$100 per toilet. SUDEA stresses the importance of a systematic approach to toilet installation and use, from the initial contact, construction and up keep, through to the re-cycling process for urban or household agriculture.(Terrefe & Edström, 1999b).

2.3.6 *One-chamber dehydrating toilet (Yemen)*

A one-chamber dehydrating toilet with urine diversion is used in city of Sanaa, Yemen. The toilet is placed in a bathroom several floors above the street level. The faeces drop down a vertical shaft inside the building, while the urine and water from anal cleaning drain down a vertical pipe on the outside of the building. Sanaa has a hot dry climate. The faeces quickly dry out, are collected and used as fuel. Most of the urine evaporates on the way down, and the rest drains into a soakpit. (Winblad, 1985).

2.3.7 *Tecpan solar heated toilet prototype (El Salvador)*

This design was developed in El Salvador (Gough, 1997). The basic toilet design is the same as a DAFF, but the toilet has a single chamber and solar heating to minimise wetness. As with the DAFF design, after each use, wood ash, soil or lime is added. The urine is piped away to a soak-pit near the toilet. Every 1-2 weeks the pile is pushed to the back of the vault with a rake. Then every 2 or 3 months, the dry and odour-free humus at the rear of the vault is removed and stored in a sack until used in the garden. The toilet costs US$164 including the chamber, the superstructure and the solar heater.

2.3.8 *Two-chambered solar-heated composting toilet (Ecuador)*

A two-chambered solar-heated composting toilet has been built in the Andes in Ecuador. At this altitude, urine diversion is not necessary since natural evaporation eliminates any excess humidity. After defecation, a handful of sawdust and/or ash is added. Each chamber has a diagonally sloping lid, made of a wooden frame covered with thin galvanised iron painted black. The chambers each have a ventilation pipe and the chamber lids have vents; both are covered with metal mesh. The toilet chambers and superstructure are built from locally-made sun-dried bricks, while the toilet seat, lid for the toilet hole, ventilation pipe and door are prefabricated from wood (Esrey *et al.*, 1998). It is unclear though whether this functions as a dehydration or composting toilet (Dudley, 1993).

2.3.9 *Ecological Sanitary Unit (Mexico)*

The Ecological Sanitary Unit is a prefabricated toilet constructed from high-impact recycled polyethylene and based on the double chamber Vietnamese dry toilet. It is promoted by GTA (see section 3.1.3).There are two versions available, the CA2 and the CA3. The CA2 consists of a pair of conical chambers of recycled polyethylene. The CA3 also consists of two conical chambers, but each chamber comprises of two conical pieces of recycled polyethylene which are joined by screws on-site, to form the chamber. This version is designed for areas where donkeys are the only available transportation. In both the CA2 and the CA3, each chamber is covered with a polyethylene lid and a toilet seat, which separates the urine and faecal material. The design ideally requires the addition of 0.5kg per user per day of ash, lime and soil (in equal proportions) to the main chamber containing the faecal material. A mix of three parts soil to 1 part lime is also reported to be effective. The urine drains away to a soak-pit of gravel or tezontle (a Mexican porous stone). Toilet paper must not be added to the chamber. The lime raises the pH of the faecal material, which is reported to assist in the removal of pathogens. Due to the high lime content, the humus produced is highly alkaline, making it unsuitable for use with many crops. When the ecological sanitary unit is correctly operated, the humus has <100 total coliforms per 100ml (Personal communication, Josefina Mena Abraham).

2.4 DECOMPOSITION TOILETS

2.4.1 *SIRDO (Mexico)*

The SIRDO (translated as the acronym for Integrated System to Recycle Organic Waste) is a prefabricated solar-heated toilet developed over 15 years ago in Mexico by the Alternative Technology Group (GTA). The SIRDO is promoted as a radical change from the traditional pit latrine transforming faecal material into a biofertiliser free from pathogens (laboratory studies are cited, see section 4.2).

There is an initial anaerobic decomposition of the faecal sludge with rapid sedimentation (24-48 hours). After 48 hours, the sludge passes into the biological chamber, mixing with the organic waste from the house. The moisture content of the compost must be maintained between 40-60%; excess water is removed by evaporation using a solar collector to generate heat. The solar collector is a black metal sheet in the roof of the biological chambers, inclined at 20° and facing south. Ducts in the roof ensure sufficient air flow. Temperatures up to 70°C can be reached in the SIRDO. The process of decomposition is carried out over a period of 6 months to guarantee pathogen die-off. The humus produced is reported to be high quality compost, a fact that owners of the SIRDOs are not slow in picking up. As well as acting as a composter, the SIRDO can also treat "gray water", by passing it through a slow sand filter, after which it can be used to irrigate plants.

There are now six designs available, which reflect combinations of a dehydrating or composting unit, with or without urine diversion and with one or two chambers. The basic design (SIRDO SECO 6M) is based on a combination of the Vietnamese technology and the Mexican *chinampa*. The polyethylene inclined chamber is divided into two vaults, with a baffle above the dividing wall. There is a window at the rear to collect solar heat. The design is based on a process of biological decomposition and is for use by a family. The SIRDO SECO "La Oruga" (the caterpillar) is a modified version of the 6M. The design is more efficient and cheaper and is for use by children in nursery, primary and secondary schools.

Cost-benefit analyses indicate that although some of the SIRDO models are more expensive than the basic dehydrating double chamber dry toilet, the fertiliser value more than pays for the cost of system after several years (Internal document, GTASC).

2.4.2 *Carousel toilet (Pacific Islands)*

A carousel toilet has a four-chambered fibreglass waste collection tank for batch. This tank rotates on a pivot inside an outer chamber. An electric fan ensures adequate ventilation and aids evaporation. One chamber is used until full, and then the tank is rotated and the next chamber filled. With the recommended usage, the four chambers will be filled after about 2 years, by which time the humus from the first chamber can be removed and applied to the garden soil (del Porto, 1996).

At the start, a bed of small stone gravel (3/4"), coconut husks and a scoop of garden soil is placed in the bottom of the chamber to allow drainage and provide soil bacteria to digest the waste. According to del Porto (1996), the minimum routine maintenance of adding a small handful of organic matter after each use (e.g. leaves or coconut husks), ensures aerobic digestion.

The climate in the Pacific Islands enhanced the performance of the composting process. During cooler and wetter periods humidity increased and an auxiliary heater was turned on until the excess liquid had evaporated (del Porto, 1996).

3. PROMOTION OF DRY SANITATION WITH REUSE IN MEXICO

The Water Supply and Sanitation Collaborative Council Working Group on Sanitation emphasised the importance of sanitation promotion and hygiene education in their Sanitation Promotion Kit, and linked the value of excreta with ecology (Simpson-Herbert & Wood, 1998). Dry sanitation practices in Mexico are given as innovative approaches to sanitation, although WSSCC and WHO emphasise that these technologies are not necessarily endorsed by them, but are discussed by them to stimulate thinking and debate in the sanitation sector. UNICEF is a supporter of projects of dry sanitation with reuse and has jointly financed several such initiatives in Mexico. SIDA (Swedish International Development Co-operation Agency) has given ecological sanitation prominence on its development agenda. The Sanres program funded by SIDA supports a variety of projects from no-mix toilets to sanitised urine for urban agriculture. It currently supports ecological sanitation projects in Mexico, China, Vietnam, South Africa, Bolivia and El Salvador.

There is much interest among NGOs, governmental organisations and commercial companies in dry sanitation with reuse in Mexico. Many regions of the country are inaccessible and a combination of the inaccessibility and the topography prohibit the installation of both waterborne or conventional latrine sanitation. There is also a slow realism of the disadvantages of conventional excreta management systems. Initially governmental sanitation programs promoted pit latrines, providing the community with the materials for self help construction (CNA, 1996). Many latrines were poorly constructed, or never built and the materials were used for other ends. In addition, the pit just added to the contamination of the aquifers. The combination of all these problems caused many organisations to turn to dry sanitation with reuse technologies as a possible solution.

3.1 NON-GOVERNMENTAL ORGANISATIONS IN MEXICO

3.1.1 *Centro de Innovación Tecnológica (CITA)*

CITA promotes the urine separating dry toilet designed by Cesar Anorve, by providing training in construction, use and maintenance of the toilet (Clark, 1997). Training is financed through the sale of the urine separating toilet seat.

Anorve places an emphasis on the importance of training future users. He feels that outsiders cannot just install toilets and leave. He argues that, as with any program of assistance, there is always an element of risk. Sanitation is not a high priority for all people. Some families will make the effort while others will not be interested. There will never be 100% success. Problems do occur, however Anorve argues that when appropriate training has been given, these problems can be solved. However, it is the responsibility of the user to alter their habits and correctly use the dry sanitation toilets. Since there is a need for close supervision, such programs of installation only work when toilets are installed a few at a time. Large scale sanitation programs are doomed to fail from the beginning, since it is difficult to set up large-scale programs to convince populations to assume responsibility for the correct usage of their newly installed dry toilets. Programs must slowly install dry toilets in households keen to adopt this technology. When neighbours see the benefits of the technology, they too will be enthusiastic to install dry toilets. By this means the initiative comes from the householder and is thus not an imposed technology.

CITA feel that one of their most important achievements is that they do not offer their services, but rather respond to requests by individuals, whether farmer or wealthy householder, organisation or government department. A good example of this is the community of Cienega in the State of Morelos, Mexico. Here the groundwater table is only 50 cm below the surface. Many households were concerned about the risk of faecal pollution of the water table, since most obtained their drinking water from wells. A woman from Cienega took a course that mentioned dry toilets and CITA. She contacted CITA and dry toilets have now gradually been installed by householders with technical support and guidance from CITA.

At federal level, the Secretary of Health and the Mexican Institute of Social Security (IMSS) have contracted Cesar Anovre to train around 300 extension workers each year. IMSS have built 1,337 dry toilets in 17 states in the past year.

3.1.2 *Espacio de Salud A.C. (ESAC)*

Espacio de Salud (ESAC) is a non-profit making organisation that provides training and development programs in appropriate technologies and sustainable agriculture (Sawyer, 1998). ESAC promotes the urine separating dry toilet designed by Cesar Anorve (see section 2.3.2 for details). ESAC complements Anorve's design by providing education and technical assistance to communities that contact ESAC. The importance of follow-up over a period of time is stressed by ESAC, (i) to build-up the confidence in the dry toilet technology and encourage other members of the community to request a dry toilet and (ii) to ensure correct usage and maintenance of the toilet.

ESAC's objective is to promote the use of dry sanitation and strengthen local economies by creating jobs, using local materials, requiring minimal investment and using simple technology. Fifteen local independent workshops have been set up across Mexico. ESAC aims to ensure environmental sustainability through the empowerment of local communities and economies

3.1.3 *Grupo de Technologia Alternativa S.C. (GTASC)*

GTA is a 'for-profit' organisation whose objective is to develop alternative technologies for the recycling of domestic liquids and solids. GTA designed and now promotes the decomposting toilet system, the SIRDO (Integrated System to Recycle Organic Waste) (see section 2.4.1 for details). Unlike many other dry sanitation technologies, GTA has worked not only with rural communities, but also in semi-urban and urban areas. Numerous sanitation projects have been undertaken and hundreds of SIRDOs have now been installed in Mexico since the inception of GTA in 1978.

Near the Guadalupe lake, on the north-east side of the metropolitan area of Mexico City, more than 70% of households tip their domestic waste into ravines and rivers. There was a thick layer of irises covering the lake. In 1994, GTA was contracted to address this problem. It was established that most of the wastewater discharges, which were feeding the irises in the lake, came from an area where most households had no drainage. In these areas, residents practised open defecation or had improvised latrines so that the human waste was going directly into the ravines and rivers and then entering the lake. GTA (with the financial support of SIDA) installed 24 dry toilet units made from local materials and 2 SIRDO SECO units prefabricated from fibre glass to transform the human waste into biofertiliser (BF). All units without urine separation had solar collectors to control moisture content of the compost. After 1 year, 16 of the 24 dry toilets were functioning adequately, 6 families had chosen to connect to a discharge pipe into the ravine, and 2 families had moved away. The two prefabricated units were in use and the families had produced and sold biofertiliser. Urine separation, solar collection and the process employed (chemical or biological) were assessed for the effect on pathogen die-off (see section 4.2). In 1996, with the aid of private donations, a further 19 SIRDO SECO prefabricated units were installed. All had a solar collector, did not separate the urine and had a layer of earth containing the SIRDO innoculant. Two years later, all units were still in use.

As well as promoting the SIRDO, GTA are currently installing 1000 double vault latrines per month through the Mexican government program "Fondo para la Paz" in remote communities. After GTA have completed the initial installation and promotion of the SIRDO, follow-up is given by local NGOs, with whom GTA develop defined methodologies.

GTA is currently working in Ciudad Juarez, in the north of Mexico, together with researchers from the Centre for Environmental Resource Management at the University of Texas in El Paso and the National Wildlife Federation. The installation of the prefabricated SIRDO takes just 1½ hours, then the rest of the time is spent explaining how to use the toilet and motivating the family. Over the last 6-9 months, 300 have been installed, and only 6 reported a little flooding. The flooding caused fly problems. Children had been incorrectly using the toilet and urine had passed into the chamber causing excess humidity. In this endeavour, follow-up is high on the list of priorities with weekly visits at the start of the program, reducing to monthly and finally annual visits. Microbiological testing of the biofertiliser, in terms of faecal coliforms, Ascaris, Cryptosporidium and Giardia, will begin in March 2000.

3.2 GOVERNMENTAL ORGANISATIONS IN MEXICO

3.2.1 *National Water Commission*

Since 1996, the Mexican National Water Commission (CNA) has been installing dry sanitation in communities with under 2500 inhabitants, where access is difficult and where the terrain makes the installation of drains inappropriate. Prior to 1996, such communities were offered pit latrines. Dry sanitation has been particularly promoted where water is scarce or lacking. Initially, the municipality applies to the CNA for the provision of drains. The CNA carry out an economic feasibility study. If the application is approved but conditions make mains drainage not possible, then the communities concerned are offered dry sanitation toilets. The logistics involved in the sanitation programs vary slightly between states.

In the State of Hidalgo, a variety of designs have been installed since the start of this dry sanitation program in 1996 (see Table 1). In some communities dry sanitation units have been promoted, where the two chambers and the superstructure are constructed in the community by the community with local materials and only the urine separating toilet seat is bought. Other communities have been offered prefabricated dry toilets constructed from fibre glass or recycled polyethylene, where only a pit to hold the two chambers need be dug by the community. Once a program of dry toilets has been approved for a particular community, whether constructed by the community or prefabricated, the State Water Commission (SWC) then begins the process of "sensitisation" (mobilisation) of the community. The SWC organises meetings with the community, sets up a construction committee, and arranges talks and workshops on topics such as water and handling of faecal material from toilets. After construction is complete, an operation and maintenance committee is established to oversee new users. Initially this sensitisation process was contracted out to commercial companies and supervised by CNA, however it is now done by social workers and extension workers from SWC. The CNA has not yet reached a decision regarding the appropriate length of time between sealing a chamber and removing the contents. CNA recommends using the humus or compost produced as a fertiliser for crops.

In Hidalgo in April and May 2000, there is to be a review of the dry toilets that have been installed. Toilets will be visited, and an assessment made as to whether the toilet is in use and whether it is being correctly used.

Table 1 Dry sanitation programs in Hidalgo State[1]

Year	Municipality	Community	No. Houses[2]	Design	Source	Number installed
1996	Huichapan	El Apartadero	401	Prefabricated	IEPSA[3]	9
		El Astillero	296	Prefabricated	IEPSA	18
		El Carmen	834	Prefabricated	IEPSA	9
		Jonacapa	1027	Prefabricated	IEPSA	9
1997	Chilcuautla	Santa Ana Batha	1539	Self-construction	-	-
	Huasca de Ocampo	Tlaxocoyucan	1397	Self-construction	-	-
	Mineral de Chico	San Jose Capulines	291	Self-construction	-	-
	Xochiatipan	El Zapote	272	Prefabricated	-	-
		Nuevo Coyolar	147	Prefabricated	-	-
		Tenexaco	-	Prefabricated	-	-
		Xilico	248	Prefabricated	-	-
1998	Huehuetla	San Antonio El Grande	2193	Self-construction	CNA-UNICEF	77
		San Esteban	1457	Self-construction	CNA-UNICEF	121
		San Gregorio	1572	Self-construction	CNA-UNICEF	27
1999	No communities that requested sanitation were allocated dry toilets					
2000	Economic feasibility study for Huasteca in progress					

In Chiapas, CNA formulated a Rural Sanitation Program. There are now 20 experimental units being built in each state. Construction is a little expensive ($127) but municipalities now help with cost of materials. NGO's are training around 300 extension workers each year to educate the community, provide technical assistance and negotiate subsidies for construction materials with municipalities.

[1] '-' indicates that no data was available
[2] Source: INEGI 1990
[3] IEPSA (Ingenieria, Ecologicia y Proyectos SA de CV) is an mexican engineering company that produces a prefabricated fibre glass version of the Vietnamese double chamber toilet with urine diversion. A family of 6 is reported to fill a chamber in about 10 months.

3.2.2 *Local and Federal Government*

Interest in the use of composting toilets has grown in recent years. Several NGOs have been contracted to assist in the installation of dry toilets in rural areas. In the state of Morelos, dry toilets have been installed in most municipalities. Support to these initiatives has been given by the Department of Public Works in Cuernavaca and the Minister of Environment in the state of Morelos.

In 1994, the Oaxacan state government and a businessman began large-scale toilet seat production, building 15,000 toilets in the first year. Unfortunately, the project only gave toilets and offered no training or follow-up to potential users (Personal communication, C.Anorve). NGOs were brought in to assist at a late stage in the program. Tens of thousands of dry toilets have now been financed with no community participation, education, training or follow-up (Personal communication, Josefina Mena Abraham). The government has indicated a commitment to build another 30,000 each year.

The current dry sanitation program "Use of the Ecological Dry Toilet" is organised by the Oaxacan state government with the participation of the Ministry of Health, the DIF (Integrated Family Development) and the Ministry of Urban Development, Communication and Public Work (SEDUCOP). The DIF is in charge of administration, social actions and the finances for materials. SEDUCOP provides technical assistance through a local company, Espacios Culturales de Inovacion Technologia SC. The majority of toilets are reported to be working satisfactorily, with problems related to non-compliance of users and lack of training (Personal communication Eng. Garcia, CNA 2000)

There are plans to build many more dry toilets in Mexico. It is unfortunate that early sanitation programs organised by governmental organisations in Mexico provide clear examples of failure. In many cases, householders were just given the materials to construct the dry toilets but offered no training or follow-up. Consequently many dry sanitation units have been built but never used or used for very little time (Anorve, personal communication 2000).

4. REVIEW OF CURRENT KNOWLEDGE OF PATHOGEN DIE-OFF

All reviews of dry sanitation mention, however briefly, the importance of efficient pathogen die-off to enable safe handling and re-use of the end-product. Pathogen survival during thermophilic composting is fairly well documented (Strauss, 1985). There are however surprisingly few studies on pathogen die-off in dehydrated human faeces, despite the large numbers of dehydrating dry toilets in use and the acknowledged health risks associated with the use of human faeces (nightsoil) as a fertiliser (Blum & Feachem, 1985).

There is a general agreement among dry sanitation promoters that a risk to health may exist if such systems are not properly operated. The amount of treatment required is dependent on the health status of users and the intended use of the end-product (Winblad, 1996). It has been suggested that primary treatment either by dehydration or decomposition is usually sufficient to destroy most pathogenic organisms, but secondary treatment (for example high-temperature composting) may be required where intestinal parasites are common, (Winblad, 1996). Unfortunately, over one third of the population in developing countries is infected with intestinal worms, of whom a large proportion are children (Chan, 1997). Therefore, in at least one third of households where dry sanitation is installed, primary treatment by dehydration or decomposition may be insufficient to ensure pathogen die-off.

Anecdotal data from Vietnam, the country with the largest number of dry sanitation toilets, suggest there may be health risks associated with their use. In North Vietnam on the plains, where fertiliser from double chamber composting toilets is widely used, Ascaris prevalence is around 90%. In contrast, in southern Vietnam, where the population defecates over fish ponds, Ascaris prevalence is 45-60% (personal communication Dr Hoang Thi Kim, Vietnam).

A study from Vietnam indicates that women handling 'treated' human faeces had lower intensity hookworm infections than those handling fresh human faeces (Humphries *et al.*, 1997). In this article, 'treatment' was described as the mixing of human faeces with kitchen ash or paper ash until they were dry and crumbly, after which the faeces were placed in a pit and covered with coconut or banana leaves and dirt. Women usually wait less than 4 months before using the 'treated' faeces. (Humphries *et al.*, 1997). This study shows that where human faeces are not treated or treated insufficiently then handling of faeces can pose a threat to health.

4.1 DEHYDRATION TOILETS

4.1.1 *DAFF (Guatemala)*

Alvarez (1987) found faecal coliforms in both the chamber in use and the compost (Table 2) and concluded that both pH and humidity of compost samples were important factors in determining the concentration of faecal coliforms. The small sample size prevented any more detailed assessment. Flores (1987) found a reduction in the number of Ascaris eggs per gram, when comparing the chamber in use (n=152, 308 eggs per gram) and the stored compost (n=20, 59 eggs per gram). While 5% of samples from the chamber in use had viable Ascaris eggs, none of the Ascaris eggs from the compost were viable. Taking the sample size for the compost samples into account, one would have expected less than one sample to have viable eggs. While it can therefore be concluded that the number of Ascaris eggs per gram reduced from the chamber in use to the compost, it is not possible to comment on the impact of the composting process on the viability of those eggs.

Table 2 Concentration of total coliforms and faecal coliforms in DAFF toilets

Source of sample	Number of samples	Total coliforms (MPN/g)		Faecal coliforms (MPN/g)	
		Mean	SD[4]	Mean	SD
Pit latrine	71	2156	663	1965	871
LASF chamber in use	379	1309	1034	827	1954
LASF chamber full	3	2400	0	165	356
LASF compost	20	672	942	160	539

Strauss & Blumenthal (1990) also concluded that pH was an important factor in pathogen die-off in the DAFF. The addition of ash, soil or lime produced an alkaline mix, which increased the pH value and enhanced bacterial pathogen die-off. It was also concluded that the effect of increasing the pH value was lessened when humidity was greater than 60%. pH did not seem to affect die-off of Ascaris eggs. The mean concentration of viable eggs was 300 eggs per gram in faeces stored for one year, compared with several thousand per gram in fresh faeces. In general, the concentration of viable eggs did not fall below 30% of the total concentration of eggs per gram of faeces. However, the practice of sun-drying the compost from the vault prior to storage in sacks, rapidly reduced viability (Strauss & Blumenthal, 1990).

These results indicate that depending on usage, pathogen die-off can vary, but that 10-12 months period of storage in the vault is probably insufficient to achieve low or zero egg viability in these communities where intestinal parasites are endemic. Strauss & Blumenthal (1990) suggested a vault storage time of 10-12 months in lowland tropical regions, and 18 months in cooler highlands. Both these periods of storage would then need to be followed by a period of sun-drying (lowlands 8-10 months, highlands 12 months).

[4] SD=standard deviation

4.1.2 *Urine diversion dry toilet (South Africa)*

Studies of five urine diversion "dry box" toilets (see section 2.3.4 for details of design) indicated that although pathogen die-off occurred, the faeces pile did not heat up as much as was expected (Austin 2000). Therefore, any pathogen die-off that occurred was not the result of heat. Key factors in the reduction of bacteria in the pile were storage time, pH value and humidity. The concentration of faecal coliform (FC) and faecal streptococci was measurec in samples after 6 and 10 months storage. During this 4 month period, the reduction varied from no change to a 2 log reduction (range 0 - 55 x 10^5 FC/g after 10 months). More coliforms remained viable when the pile had a higher moisture content and pH values were not high. It was suggested that the addition of fine ash to the pile while increasing pH might result in the pile being anaerobic rather than aerobic. Turning or mixing the pile may aerate it, increase the heat generated and so enhance pathogen destruction. A sub-study in which the faeces pile from one of the toilets was sun-dried resulted in a further reduction in faecal coliforms (from 55 x 10^5 - 310 FC/g) but no further reduction in faecal streptococci. The author concluded that more research was necessary on methods to increase pathogen destruction if the desiccated faeces were to be handled and if there was any intention to use them as fertiliser for crops. Alternatively storage period greater than 10 months was required (Austin, 2000).

4.1.3 *Dry ecological toilet (Mexico)*

Preliminary studies of pathogen die-off in dry sanitation toilets in Mexico (see section 2.3.2 for details of design) have been carried out by the Centre for Biotechnology Research (CEIB) at the University of Morelos. A wide variety of bacteria and parasites, including Salmonella and *Ascaris lumbricoides* eggs were found in the stored faeces pile of dry sanitation toilets in San Juan Amecac, Puebla State (Personal communication, Dr Laura Ortiz, March 2000). Another study at CEIB, using *Ascaris suum* eggs as a proxy for *A.lumbricoides* eggs, measured the viability of *A.suum* eggs in the dry sanitation toilets in San Juan Amecac, Puebla State. Twelve small "tea bags" made of polyamide cloth (pore size of 20μm) containing *A.suum* eggs were implanted in the middle of the full chamber of 10 dry sanitation toilets at the time the chamber was sealed. Each month, a bag was removed and the viability of the *A.suum* eggs determined. The pH, moisture and temperature were also determined at each sampling. Initially 83% of eggs were viable. Results to date show that after five months, between 12 and 57% of eggs were viable. Unfortunately, only five of the toilets were followed for the full 12 month period. However the authors concluded that pH appeared the most important factor in determining the viability of the eggs, the higher the pH, the lower the percentage viability (Olvera-Velona & Ortiz-Hernandez, 2000).

4.1.4 *Vietnamese double-chamber dry toilet (Vietnam)*

Studies of pathogen die-off in Vietnamese double-chamber dry toilets (see section 2.3.1 for details of design) with solar heaters installed in Cam Duc commune in central Vietnam were carried out (Stenstrom, 1999). Two indicators were employed, *Ascaris suum* eggs and the bacteriophage *Salmonella typhimurium* 28B. The phages mixed with faecal material (1.108 pfu/g) and eggs in "tea-bags" made of polyamide cloth (104 eggs/bag) were placed in stainless steel containers in the centre of the faecal pile of 12 toilets. Faecal material samples were retrieved weekly and "tea-bags" were retrieved every two weeks to determine the percentage of viable phages and eggs. The pH, moisture and temperature were also determined at each sampling (Stenstrom, 1999).

Moisture ranged from 25% to 60% and decreased linearly with time. The average temperature in the pile was 34°C (max. 40°C), while the average ambient temperature was 32°C. The pH was determined by the material added to the chamber (ash pH 11.3, rice-husks pH 10.6). This was the single most influential factor in governing pathogen die-off (Stenstrom, 1999).

The shortest time for total die-off was 51 days for *A.suum* eggs and 23 days for *Sal.typhymurium* phages. The longest time was 169 and 154 days respectively. It was concluded that 6 months retention time was sufficient for the total reduction of the indicator organisms in the test toilets. Ash from wood was the best additive. Solar heaters shortened survival time, but the operation and construction of these toilets was more complicated. Stenstrom (1999) emphasised the importance of proper use for these toilets to function well.

4.1.5 *Dry Sanitation (China)*

Studies of dry sanitation toilets in China within the Sida sponsored Sanres program investigated:

- die-off of implanted *Ascaris suum* eggs and bacteriophages,
- the concentration of faecal coliforms (FC) and Salmonella and
- the role of environmental factors and different absorbents under cold conditions (Stenström, 1999).

Tests were performed on toilets in use for at least 3 months. The moisture content ranged from 15-66%, the FC concentration was between <1 and 107/g and the survival of *A.suum* eggs between 0.3% and 63%. The absorbent material used was an important factor in determining pathogen die-off. The best material was plant ash with a pH of 11. Addition of plant ash resulted in an elevation of the pH of the pile and the greatest reduction in faecal coliforms, test phages and the viability of *Ascaris* eggs (Stenstrom, 1999).

4.1.6 *Health risks from urine*

Urine contains few pathogens, though may contain Ascaris eggs and Schistosoma eggs (Drangert, 1998). Urine may also carry the pathogens responsible for typhoid. Experiences from China and Japan suggest that urine not containing these may be used as a plant fertiliser (urine from individuals using antibiotics is also not recommended) (Drangert, 1998). Faecal contamination of the urine can occasionally occur when the user has diarrhoea, by mistake, or by children who often find it difficult to correctly use the urine-separator. In view of this, Drangert (1998) recommended storing urine for six months prior to use on the family vegetable plot.

Studies in Sweden however found E.coli had a rapid die-off in urine (decimal reduction time or D-value = 0.9 days at 20°C), although when diluted 1:9, persistence increased 5-6 fold (Stenström, 1999). Die-off for other bacteria was more rapid, with a D-value of <1 day for undiluted urine and under 20 days when diluted 1:9. Keeping pH > 6 also increased the die-off. Enterococci had a D-value of 5 days in undiluted urine. Clostridia showed no reduction over a period of 35 days. Cryptosporidium parvum had a rapid die-off at 20°C and pH 9, although at lower pH values, die-off was much slower. Rotavirus slowly reduced over time at 20°C. Viability of Ascaris suum cysts reduced by only 15-20% over 20 days.

There is clearly a potential risk from the re-use of urine. Stored urine has a high pH. Therefore, according to Drangert (1998), storage of urine for 6 months should be sufficient to eliminate all pathogens. Results indicated that at ambient temperatures of 20°C or more, pathogen die-off is more rapid. However the author suggested caution, since the studies did not take into account parasites prevalent in tropical conditions nor vibrios, such as *Vibrio cholera* that may have extended survival at high pH values. Also to eliminate risks from viral pathogens such as rotavirus would require storage for 4-5 months at 20°C, or longer if the ambient temperature is lower.

4.2 DECOMPOSITION TOILETS

In thermophilic composting toilet systems, temperatures of 50-60°C can be reached within the pile. In such cases, the total destruction of all pathogens, including Ascaris eggs will be achieved in a few days. At temperatures of 70°C, the same effect is achieved in 1-2 hours.

Chapman (1995) however reported on heat lost by conduction in an operating compost toilet. He cites several publications that indicate that the principal problems with compost toilets are lost compost temperatures, anaerobic conditions and high humidity. Heat from compost activity was shown to be lost by conduction through the walls or removal with ventilated air. When there was good mixing composting was optimal, but very low humidity and urine removal caused some faeces build-up. A reduction in air flow was shown to improve the composting process, but this had to be reconciled with the build-up of odours caused by low airflow.

It was only possible to obtain data on pathogen die-off for one composting toilet appropriate for use in low-income communities in developing countries, the SIRDO designed and promoted by GTA.

A GTA project in the Guadalupe lake, on the north-east side of Mexico City compared pathogen die-off in the different dry toilets installed after 8 months use. The biofertiliser (BF) from the toilet with urine separation but without a solar collector still had viable pathogens, whereas the BF from toilets with a solar collector (with or without urine separation) had much fewer viable pathogens. The best results came from the prefabricated units, where the BF had very low levels of viable pathogens. In contrast, adult viable pathogens were identified in the BF from the dry toilets where only lime had been added. 19 SIRDO SECO prefabricated units were later installed, with solar collector, without urine separation and with a layer of earth containing the SIRDO inoculant. After 6 months, the BF produced had no pathogens (negative for faecal coliforms, protozoans and nematodes).

4.3 SUMMARY

There are a limited number of documented studies of pathogen die-off within dehydrating toilets. There is however a general consensus of opinion emerging from these studies. Since the temperature of the pile is not raised significantly above the ambient temperature, heat is not a factor in pathogen die-off. The two most influential factors seem to be the pH of the faeces pile and the storage or resting time. The more alkaline the pile and the longer it is stored, the greater the percentage reduction in pathogens. With the regular addition of the appropriate absorbent, for example ash or lime, the recommended storage time prior to re-use of the faeces pile however varies from 3-12 months depending on the study.

Mara & Cairncross (1989) stated that if excreta was not buried, but applied to the topsoil then the Engelberg guidelines for wastewater should be observed and interpreted as <1 nematode egg per kilogram (wet weight) and <1000 faecal coliforms per kilogram (wet weight). In the United States, regulations for the products of dry sanitation vary from state to state. In general, there should be less than 200 FC/g in the end-product and ≤200/100ml in the liquid end-product to receive NSF[5] approval. If either of these guidelines were applied, then the results for the DAFF toilet in Guatemala and the urine diversion dry toilet in South Africa suggest there may still be a health risk associated with handling the 'treated' excreta. Whereas the studies with the Vietnamese double chamber toilet indicate that a retention or storage time of 6 months should be sufficient to achieve this guideline.

The one microbiological study obtained for a composting toilet design indicates that the SIRDO would conform with Engelberg or NSF standards. Further studies, as planned with the University of Texas (see section 3.1.3), would be desirable to establish with greater certainty the percentage of SIRDO units in community settings that are producing biofertiliser that is safe to handle.

[5] NSF International, Inc. is a non-profit organisation that develops standards for a wide range of health related technologies. It works with the American National Institute of Standards.

Many of the studies reported here did not assess the health status of toilet users. This is important when assessing the performance of a dry sanitation toilet. If the toilet users are not infected with Ascaris or Giardia in the first place, there would be no reason to expect Ascaris eggs or Giardia in the faeces pile. Finding Ascaris eggs in the faeces pile of only 20% of dry sanitation toilets does not necessarily imply that 80% of toilets are functioning adequately; it may just indicate that only 20% of households have a user infected with Ascaris. In general, Ascaris eggs have the longest survival time, so where Ascaris infection is endemic, the concentration of viable Ascaris eggs per gram is a good marker of pathogen die-off in the pile. "Before" and "after" results would be required in any event to determine die-off.

It should be noted that no microbiological data could be obtained for the other dry sanitation toilets described in section 2.

5. CASE STUDIES IN MEXICO

5.1 IXTLILCO EL CHICO, MORELOS STATE

Ixtlilco el Chico has a population of 1,241 (INEGI, 1995a). It is located within the municipality of Tepalcingo, on the far eastern side of the state of Morelos. There are 289 houses in the village, of which 99% have electricity, 56% have drinking water piped to the house (many have wells) and 16% are connected to mains drainage. The water table is over 15 metres below the surface. Many houses have deep wells. Over the last 9 years, there have been two dry sanitation programs.

The first program in 1991, under the auspices of the Ministry of Social Development (SEDESOL), installed 84 dry sanitation toilets with urine diversion and double chamber. SEDESOL provided the prefabricated urine separating toilet seat and the materials to build the chambers and the toilet floor. The materials for the superstructure were provided by the household. Extension workers from a local agricultural workers' group provided the training for the new users.

Unfortunately, there were several problems that may explain the high drop-out rate. The toilet seat was made from plaster and painted. Any slight humidity caused for example by a poorly constructed superstructure resulted in a gradual deterioration of the toilet seat. The urine caused the urine separator to become pitted. Households were recommended to sprinkle ash in the chamber after use. Despite following this advice, many households experienced bad smells and problems with flies. When lime was used instead of ash, the problems with smells and flies are reported to have been resolved.

Of the 84 toilets approved, it is estimated that only 50 functioned initially, although it is unclear whether this is as a result of the construction of the toilet seat, other initial problems or possibly a lack of sufficient support to the users. In the remainder of cases, either the construction was never completed or the household never fully adopted the dry sanitation toilet instead of open defecation. To date, it is estimated that only about 10 are now in use (12%). In the remainder of households, it is reported that households either have adopted alternative sanitation or have reverted to open defecation.

In 1997, the second dry sanitation program, also under the auspices of SEDESOL installed 6 dry sanitation toilets with urine diversion and double chamber. Many of the problems encountered in the first program were avoided in this program. Households were provided with the toilet seat and all the materials necessary to build the chambers, the toilet floor and the superstructure (including the roof and door). The toilet seat was made from fibre glass and painted. Although problems still occur, all six toilets are reported to be in use and functioning without smell or problems with flies. This is, however, a much smaller number, and the percentage of success may decrease somewhat with larger numbers and correspondingly less individual attention.

In Ixtlilco el Chico, seven households with dry sanitation toilets were visited, three from the first program and four from the second program. All households defecated openly prior to the installation of the dry toilet. The custom is to build a low standing corral of brick, breeze block or brush and to make a small hole in the ground, defecate and then cover over with earth.

The four dry toilets visited from the second program were in a good general state of repair. The toilet basin and the urine separator were clean in 3 out of 4 of the toilets. In one household, the toilet basin was dusty and used toilet paper had been left in the urine separator, suggesting that it may not have been used recently. All four toilets had somewhere to put the used toilet paper and a pot or bag of lime to hand (although in one household, a hen was roosting on the bag of lime and had laid her eggs there!). In none of the households was the urine pipe buried, in three cases the pipe lay on the surface and the urine gradually seeped away, although a small puddle of urine was visible. In the other toilet, the pipe had been cut off where it came out at the back of the chamber and the urine dripped to the ground. Only in one of the households had both chambers been filled, the contents of the chamber removed with spades, and carried in sacks to the nearby field for disposal. In that house, all four adults used the toilet and passers-by often asked to use the toilet (the family lived in the centre of the village near where dances were regularly held). In two households, all members used the dry toilet, and in the other household of 2 men and 6 women, only 3 younger women used the toilet, the other members of the household continued to practice open defecation in the brick corral.

The superstructure of the three toilets visited from the first program was more basic than those from the second program. Instead of a metal door, the toilets had a curtain. One toilet had a corrugated cardboard roof that was in a poor state of repair. The rain had got in and had pitted the toilet seat. Also, the humidity from the ground in the rainy season had dampened the chamber walls. The toilet was no longer in use and the household had reverted to open defecation. The other two toilets were in use, however the toilet seats were in such a poor state of repair, pitted by humidity and urine, that it was seemed no longer possible to maintain the toilet basin and urine separator clean. There was also used toilet paper strewn on the floor in both toilets, and in one toilet, a turkey had adopted the bag of lime as a roost.

Overall, the toilets and the superstructure from the second program were in a better state of repair than those from the first program. This possibly encouraged householders to keep the toilets generally tidy and clean, with the used toilet paper collected, and the toilet floor, basin and urine separator clean. Several problems seemed universal:

- the urine separator blocked from time to time, through incorrect use of the toilet or children putting toilet paper or stones down the tube,
- small children found it difficult to use the urine separating toilet seat correctly, and
- if the urine tube was buried, then when it rained, the soil became saturated and the urine was not absorbed into the ground.

The information presented in this section is the result of key informant interviews with Mr Amador Palma and Mr Isabel Palma, who live in Ixtlilco el Chico and co-ordinated the two sanitation programs and with householders from Ixtlilco el Chico that have dry sanitation toilets in their homes.

5.2 SAN JUAN AMECAC, PUEBLA STATE

San Juan Amecac has a population of 3,619 (INEGI, 1995b). It is located within the municipality of Atzitzihuacan, on the western side of the state of Puebla. There are 734 houses in the village, of which 99% have electricity, 78% have drinking water piped to the house and 3% are connected to mains drainage. The water table in places is only 3-4 metres below the surface. Many houses have wells.

There was concern in the community that installation of traditional pit latrines may pollute the aquifer, upon which many households depend for drinking water. The community heard about the initiatives of a local NGO, Espacio de Salud (ESAC) and contacted them. The first dry sanitation toilet with urine diversion and double chamber was installed 3 years ago by ESAC in a local amaranto (Amaranthus cruentus) workshop. ESAC provided training and the workshop bought all the materials required for the construction of the toilet and the superstructure. The prefabricated urine separating toilet seat was bought from ESAC. Following the installation of one dry sanitation toilet, more toilets were gradually installed. Today there are over 50 dry sanitation toilets now installed in homes in San Juan Amecac.

ESAC, despite initial requests for many toilets opted for a gradual introduction of the dry sanitation toilets in San Juan Amecac. This enabled close contact between householders and trained extension workers, so ensuring that correct usage and maintenance was fully understood and complied with. All households are periodically visited. Households that have only recently acquired a dry sanitation toilet or where problems are identified by the extension worker are visited more frequently.

Seven households with dry sanitation toilets were visited. The results of these visits are summarised in Table 3. The materials for each toilet were paid for by the household, who also paid a local builder to construct the toilet. The toilets were constructed of breeze block and had a curtain as a door. Five toilets had corrugated metal roofs, one had tiles and the other had a reinforced corrugated cardboard roof. All households reported that adults and children over 7 years old used the dry toilet when at home. Only one household had small children. In that house, two or the three children openly defecated. All households reported stirring the pile in the chamber in use, although the frequency of stirring varied considerably from once a week to every couple of months. In several households, the interviewee did not know how often the pile was stirred, because it was the man that stirred the pile. Most households had a bucket or bag for used toilet paper, although in several cases there was toilet paper strewn on the floor. Despite several toilets being over 12 months old, the toilet seat was in good general repair and there was no pitting of the toilet basin or the urine separator. The time to fill the chamber varied enormously, from about 6 months to over a year. Clearly, the time the chamber rests must be taken into account when the contents are removed.

Overall, the toilets visited were functioning without smell or flies, users seemed aware of the importance of correct usage and maintenance. Many of the problems that had occurred were the result of visitors incorrectly using the toilet or children pushing stones or toilet paper down the urine pipe. The periodic visits by the ESAC extension worker appeared to ensure that problems were promptly identified and a solution found.

Table 3 Characteristics of dry sanitation toilets visited in San Juan Amecac, Puebla State[6]

Variable	Dry Sanitation Toilet						
	1	2	3	4	5	6	7
REPORTED							
No. of months using toilet	12+	10	6	4	6	22	19
Previous habits	Open defecation	Pit latrine	Open defecation	Open defecation	Bucket latrine	Pit latrine	Open defecation
Substance added to chamber	LAE	LAE	LE	LAE	LA	LA	AE
Stir chamber	Not known	Not known	Every 2 weeks	Once a week	Every 2 months	Not known	Not known
<6 yr olds use toilet	-	-	-	-	-	N	-
Previous problems							
- flies	N	N	N	Some times	When dirty	N	N
- smell	N	N	N	N	N	N	N
- urine pipe blocked	N	Some times	Some times	N	N	N	Some times
OBSERVATIONS							
-flies	Few	N	N	N	Few	Few	N
-smell	N	N	Slight	N	N	N	N
-toilet basin clean	Y	N	Y	Y	N	Y	Y
-urine sep. clean	Y	N	Y	Y	Y	N	Y
-urine pipe to ..	Plastic pot	Ground	Ground	Plastic pot	Ground	Plastic pot	Plastic pot
-2nd chamber	Full	Empty	Empty	Empty	Empty	Full	Full
-lid on 2nd chamber	Stone	Wood	None	None	Wood	Wood	Wood

The information presented in this section is the result of key informant interviews with Mr Fortino Arrellano, the Mayor of San Juan Amecac and the first promoter of the dry sanitation initiative with ESAC; Miss Valentina Carrillo Cazales, the nursing auxiliary at the local health centre and the extension worker currently working with ESAC; and with householders from San Juan Amecac that have dry sanitation toilets in their homes.

[6] Y=yes, N=no, L=lime, A=ash, E=earth

6. SUMMARY OF THE ADVANTAGES AND DISADVANTAGES OF DRY SANITATION WITH REUSE

Dry sanitation toilets with reuse are more susceptible to misuse than other sanitation systems. The advantages of well-functioning dry sanitation toilets are summarised below,

(i) Water requirements

- no water is required to flush away the human waste, although basic cleaning of the toilet is necessary

(ii) Construction

- when constructed from local materials, the construction is simple and does not require skilled labour. When prefabricated, installation is quick and simple and upkeep is minimal
- hard rock near the surface does not affect construction

(iii) Spread of disease

- the excreta and urine are not accessible to animals
- unlike conventional pit latrines, faecal material is isolated from the groundwater table by the walls of the composting or dehydration chamber
- the end-products have minimal concentrations of faecal pathogens
- no smells
- does not encourage fly breeding

(iv) Environmental contamination

- raised chambers with concrete bases for storing the excreta avoids contamination of soil, rivers and groundwater, especially where the water table is high

(v) Environmental sustainability

- end-product from the faeces pile can be used as a soil conditioner
- the urine can be diluted and used as a source of nitrogen for plants

(vi) Community acceptance

- if the introduction of dry sanitation is gradual and the donor spends sufficient time and energy on training and supporting users, dry sanitation is accepted by communities
- women when defecating often preferred sitting (on the toilet) rather than squatting (open defecation)

- less distrust among children than with the pit latrine

The disadvantages of dry sanitation are summarised below,

(i) Usage

- successful use require the operator to understand the basic principles of dehydration or decomposition involved
- more sensitive to misuse than other forms of sanitation
- can be difficult to keep the toilet basin above the chamber clean (which can encourage flies), since it is desirable to use only limited amounts of water for cleaning
- keeping the urine separator and pipe clean to avoid odour may be a problem. It is difficult to produce very smooth urine separators from cement mortar. Also it is slightly absorbent, leading to the retention of liquids and the risk of odours

(ii) **Spread of disease** - incorrect usage and maintenance can result in pathogens surviving in the end-product from the faeces pile

- if storage time of the pile is too short, pathogens may still be viable
- the addition of insufficient ash, soil or lime will affect moisture and pH of the pile and can result in problems with odour, fly breeding and reduced pathogen die-off
- seasonal lows in ambient temperature and increased humidity can result in reduced temperature and increased moisture in the storage vault and consequently a reduction in pathogen die-off
- many designs recommend storage for 1 year. Where storage is less than 1 year, then sun drying is sometimes suggested, which requires handling of potentially infectious material
- there is a small risk to health from the use of the urine, through contamination of the urine with faeces or if the excretor has Ascaris or schistosomiasis

(iii) Community acceptance

- for urine diversion to work, men must sit to urinate, which is often unpopular
- in cultures where water is used for anal cleansing, separate arrangements are required to maintain the chamber dry
- the constant addition of ash, earth or lime and the periodic mixing of the pile may be considered onerous tasks by the user
- users must acquire certain habits, which is only possible over a long period of time
- trial periods in a community of several years are necessary to demonstrate the advantages of dry sanitation

7. CONCLUSIONS

Reports in the literature and visits to dry sanitation programs in Mexico have demonstrated that dry sanitation programs can be accepted by communities, when sufficient time and energy is committed to the program. The over-riding message from NGOs and governmental organisations in Mexico, however, is that learning is slow. Programs must be flexible to local conditions and must react to a need and not impose ideas. There are benefits from initially installing just one or two toilets in the houses of the more important members of the community. Once neighbours and others in the community realise the benefits, then they too will be eager to adopt the technology. In Morelos, in communities with no history of dry sanitation, toilets have been installed in schools for the use of teachers. This has given the children an opportunity to view the technology in use at close hand, before installing dry sanitation toilets in the community.

It must not be forgotten however, that the primary aim of sanitation is to prevent the transmission of excreta-related diseases (Simpson-Herbert & Wood, 1998). Studies reported here have indicated that, while some dry sanitation systems based on dehydration or decomposition produce an end-product free of pathogens, other, supposedly well-functioning systems, still contained viable pathogens in the faeces pile (see section 4). In such dry sanitation systems, there is a risk of disease transmission related to the handling of the end-product. Dry sanitation toilets are more sensitive to misuse than other forms of sanitation. Therefore, even in a well-functioning system producing a pathogen-free humus or compost, any misuse, accidental or otherwise, could enhance pathogen survival and lead to an increased risk of disease transmission for those handling the compost or consuming crops fertilised with the end-products from dry sanitation.

The level of risk to health related to a particular dry sanitation technology will depend on the health status of the users, the extent of exposure with the humus or compost produced and the form in which the end-products are re-used. Unfortunately, communities most likely to be offered dry sanitation are often the most marginalised sectors of the population. These communities often have the highest incidence of diarrhoea and the highest prevalence of intestinal and protozoan infection. Winblad (1996) suggested that primary treatment either by dehydration or decomposition may be insufficient to destroy intestinal parasites and that secondary treatment may be necessary, for example high-temperature composting.

WHO estimate that human excreta and solid waste are responsible for nearly 3.3 million deaths from diarrhoeal diseases and for 1.5 thousand million suffering, at any one time, from parasitic worm infections. A substantial effort on the part of planners is required, to ensure access to safe sanitation for all. If pathogen die-off were guaranteed, then dry sanitation with reuse could be one possible solution to the problems of sanitation, by providing a socially, economically and ecologically sustainable system.

A greater understanding of pathogen die-off in dry sanitation toilets based on dehydration or decomposition is required. Assessment of the stability of such systems to withstand a certain degree of misuse and still produce a pathogen-free end-product is needed. Several groups are currently engaged in small studies of pathogen die-off, focusing on a particular dry sanitation technology, however further research is urgently required. There is also a need to assess current microbiological guidelines for excreta re-use in agriculture (Mara & Cairncross, 1989), which are currently stricter than USA guidelines.

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This report examines both the literature and field experience of the health aspects of reuse of dry toilet contents in Mexico. The author concludes that not enough is known about the reduction of disease-causing organisms in such systems, and that successful adoption of reuse is, at best, a slow process.

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