A Review of Dry Toilet Systems

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Preface

Several regions, particularly those with low population densities and with no water supply and sewage systems, commonly store and treat their wastes where they are produced. Nowadays, there are a number of technical options for an on-site organic waste management. As regards the human excreta (urine and faeces); several systems have been based on the concept of not using water in the process, being known as Dry sanitation systems. Dry sanitation may be defined as the on-site system developed for the disposal and respective treatment of human excreta (urine and faeces) without the use of water as a carrier

When correctly planned and implemented, they can provide an environmental, ecological and economical friendly solution to current sanitation problems in both developed and undeveloped countries. However, differently than it looks, the planning process and implementation of such systems are not simple. Reasonably, it must follow specific requirements in order to achieve a desirable technical function and efficiency and consequently to be considered as truthfully viable economically, environmentally and hygienically.

At the same time that several options can be observed and obtained in the market, neither of them have been under a reliable simultaneous evaluation and comparison in such a manner that could bring information regarding their characteristics as well as the possibility to identify under which circumstances these different systems may perform efficiently. There is a lack of information addressed to these subjects.

This present report is focused on the availability of different models of dry system in the market, in order to fill the gaps and gather in a unique document the principal and most used systems. It presents their principal characteristics, advantages and limitations.

Summary

In current days, a broad variety of dry sanitation technologies has been available (del Porto & Steinfeld, 1999; Esrey *et al*., 1998) for different purposes, such as residential use, ships, trains, airplanes and public areas. Different types and models have been developed and widely implemented throughout different regions in the world principally those that suffer of either water scarcity, lack of sewage systems or both. Different areas with a varied socio-cultural and educational contexts such as India, China, Vietnam, Central and South America (Bolivia, Chile, Guatemala, El Salvador, Mexico, Ecuador and Peru), Eastern and Southern Africa (Ethiopia, Kenya, Mozambique and South Africa), Europe (Norway, Sweden, Denmark, Finland), Australia, United States and others (Winblad, 2004) are those where such systems may be easily found and observed in function.

This report has the principal objective to present a literature survey over different dry sanitation systems describing their principal characteristics, advantages as well as their technical limitations. The presented information's were obtained through a deep investigation of literature data.

As principal conclusions, it is evident that though dry toilet systems predominantly follow the same basic concept of storage and sanitization of human excreta, there are some aspects inherent to their design, implementation, function, maintenance, efficiency, capacity and costs that makes each model unique. Besides, it can be emphasized that affordability of dry systems is relative and while some of the existing systems are high-tech and expensive, suitable only for developed countries, others are simple and extremely affordable. As regards the range of application, dry systems could either be implemented for small scale and low density areas (rural areas) or even for medium to high density areas (urban areas).

Finally, it can be observed and highlighted that there is a lack of data regarding public health aspects and microbiological quality of final products in order to evaluate the sanitization process, once this is one of the most important aspects concerning human excreta management in an environmental and hygienic friendly way.

Sammanfatning

Nu för tiden har ett brett spektrum av torra sanitetsteknologier blivit tillgängliga för olika ändamål såsom för hushållsändamål, för fartyg, tåg, flygplan och offentligt bruk m.m. Olika typer och modeller har utvecklats och vitt implementerats i olika regioner i hela världen under varierande socio-kulturella och utbildningsmässiga sammanhang. Primärt avser detta regioner som vidkänns begränsningar av antingen vattentillgångar, brist på avloppssystem eller bäggedera. De regioner där dylika system ofta förekommer och kan ses i fungerande skick är som följer: Indien, Kina, Vietnam, Central- och Sydamerika (Bolivia, Chile, Guatemala, El Salvador, Mexico, Ecuador och Peru), östra och södra Afrika (Etiopien, Kenya, Mocambique och Sydafrika), Europa (Norge, Sverige, Danmark, Finland), Australien, Amerikas Förenta Stater och andra.

Denna rapport har som huvudsyfte att tillhandahålla resultaten från en litteraturstudie över olika torra sanitetssystem. Därvid beskrivs dessa systems främsta särdrag och fördelar liksom deras begränsningar. Den förelagda informationen har anskaffats genom djupgående studier av sekundärdata.

Den huvudsakliga slutsatsen är att det är uppenbart att man vid implementering av torra toalettsystem bör använda samma grundläggande koncept som för lagring och sanitetsarbete med humanexkrementer. Speciella egenskaper för systemens utformning, implementering, funktion, underhåll, effektivitet, kapacitet och kostnadsbild gör dock varje modell unik, medförande att vissa modeller uppvisar bättre prestanda än andra. Därutöver kan betonas att prisbilden för torra system är relativ. Medan vissa av de existerande systemen kan betecknas som *hi tech* och kostsamma och bara passar i utvecklade länder, så är andra system enkla och mycket prisvärda. Beträffande användbarheten kan torra system implementeras både i liten skala i glest befolkade (rurala) områden och i mellantätt befolkade samt i tätbefolkade (urbana) områden.

Slutligen kan anföras och betonas att brist råder på data beträffande offentliga hälsoaspekter och mikrobiologisk kvalitet för slutliga produkter. Syftet är därvid att utvärdera processen för sanitetsarbetet eftersom detta är en av de viktigaste aspekterna beträffande omhändertagande av humanexkrementer på ett miljövänligt och hygieniskt sätt.

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1- Introduction

On-site disposal

In several regions, particularly those with low population densities with no water and wastewater sewage system, it is common to store and treat wastes where they are produced. There are a number of technical options for on-site waste management and if designed, constructed, operated and maintained in a proper way, it certainly will provide adequate sanitation services and health benefits. Building and operating these systems is often much less expensive than off-site alternatives.

Most of them do not use water as carrier material, reason why this kind of process is well known as dry systems (dry toilets, composting toilets), being possible to be also called as ecological sanitation according to some authors. Dry sanitation approaches usually require the separation of urine and faeces; however there are several systems that are collecting both materials together as it can be seen in other topics in the present report.

Urine which generally poses little threat to human health also contains the most part of useful nutrients (88% of the nitrogen, 67% of the phosphorus, and 71% of the potassium) (Wolgast, 1993; Swedish Environmental Protection Agency, 1995). Urine Source Separated Toilet if managed properly, allows the simply treated and stored urine to be further used safely as a fertilizer. Similarly, faeces which contain most of the pathogens also can be safely used as a fertilizer after storage either at ambient temperatures for two years or composting at high-temperatures for six months (WHO, 1996; Mara & Cairncross, 1989).

Even though in some countries this option was largely abandoned as conventional systems became more convenient, there is a clear realization nowadays that conventional systems are unsustainable and a revival of these non conventional approaches to sanitation can be seen (Winblad, 2004).

Different models were developed and may be found in the market to be implemented. It is important to highlight that this concept of on site dry sanitation is particularly relevant to cities where water supply, sanitation systems and financial resources are

scarce, being not only a solution for poor countries, but available for a broad range of socio-economical scenarios.

2 – Objectives

The objective of this report is to present a literature survey over different dry sanitation systems describing their principal characteristics, advantages as well as their limitations.

3 – Methods

This report followed basically secondary information made through a profound investigation addressed to different companies that have been producing sanitation systems and their products. Several data were obtained, screened and further compiled in such a way to put the most reasonable and meaningful information in the report.
Besides, a literature review was carried out in order to obtain knowledge and data inherent to dry sanitation systems, their implementation, operation as well as maintenance.

4 - Results

4.1 - Dry Sanitation Systems

According to the carried out literature review, it can be observed that technically, dry sanitation may be approached in three distinct processes: **Dehydration, Composting toilets** and **Soil Composting toilets**.

Dehydration (Urine Diversion Systems): This system consists in urine and faeces being managed separately using special collectors' devices and allowing the solid matter to be dehydrated easily. Concerning the solid phase, it generally becomes dried by the addition of lime, ash or earth into the storage chamber after each defecation.

Composting Toilets (Non Urine-Diversion): This second method is the composting process of human faeces. Typically, composting toilets do not divert

urine, but they may work better if they did (Peasey, 2000), once an appropriate moisture level, temperature and airflow must be carefully maintained in the defecation chamber, and high urine content shall bring constraints for the maintenance of these desirable conditions. Many designs permit (or recommend) the addition of other types of organic matter such as vegetable scraps, straw, wood shaving or coconut husks in order to assist the control of moisture content. Urine is not usually diverted and the additional produced liquid is either evaporated or allowed to flow into a soak-pit.

Soil Composting: This kind of system deals with either faeces, or in some cases faeces and urine that generally are deposited in a processing chamber together with a liberal amount of soil (Figure 1 and Figure 2). There are two main sub-types with slightly different processes: with a shallow pit or a raised processing chamber. Ordinary soil is added after each defecation, often with wood ash as well. A period of 12 months of composting in shallow pits is recommended before its final disposal. The pathogen die-off takes place in consequence of UV radiation, dryness and competition with other soil organisms.

Figure 1: Banana growing on a soil composting toilet after its period of usage. The structure presented beside alternates as an *Arborloo* and *Fossa alterna*. (Morgan, 2004)

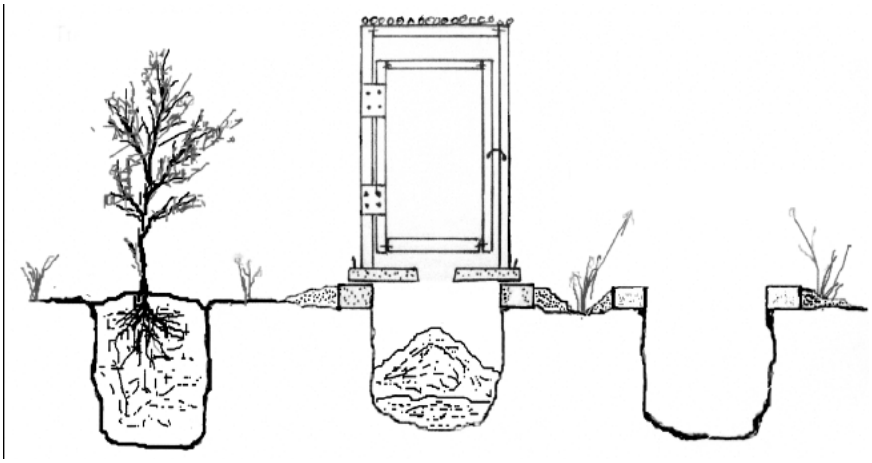

Figure 2: Soil Composting in a shallow pit. (Winblad, 2004)

Currently, according to Winblad, (2004) dry Toilets by theirselves are not suitable to achieve desirable final quality of the organic content (chemical and microbiological) and in face of this fact, the treatment process towards desirable quality is recommended to be done in two steps classified as: **Primary processing** and **secondary processing**, both explained as follows.

Primary Processing

The principal purpose of primary processing is to reduce the volume and weight of faecal material to facilitate storage, transport and further necessary treatment. Primary processing takes place in excreta chambers or containers underneath the toilet where the faeces are kept (‘contained’) for a certain period. During this containment, the number of pathogens should be reduced as a result of storage time (usually is required about 6–12 months); natural decay; dehydration; increased pH, and the presence of other predator organisms (Winblad, 2004).

Secondary Processing

The principal purpose of the secondary treatment is to provide a final polishment for the human excreta in order to reach specifics characteristics that meet public health requirements. This final step could be done principally through thermal decomposition (increase of temperature), alkalinisation (raised pH with lime, urea or

ash addition), and even an additional period of storage. Depending on the final objective and final disposal, completely sterilization shall be preferably done through thermal treatment.

4.2 - Dry Sanitation throughout the World: Different systems and Characteristics

4.2.1- Dehydration Toilets (Urine Diversion Toilets)

4.2.1.1- Low Income Countries

Vietnamese dry toilet

The classical example is the Vietnamese Double-vault toilet (Figure 3). It is widely used in Northern Vietnam and over the past 25 years its concept has been introduced in a number of countries around the world, for example China, Mexico, and even in Sweden (Winblad, 2004).

Characteristics: The Vietnamese dry toilet works as a batch process. It consists of two chambers of 0.3 cubic metres each, built above the ground with a squatting slab with two holes on top of the chambers. This system is constructed with concrete, stone or unbaked brick.

Operation and Maintenance: Before start to use the chamber, its floor is covered with a layer of ash, soil or lime.

The faeces drop into one of the chambers, whereas the urine drains away being collected in a jar behind the toilet. Paper used for anal cleaning is not thrown down into the chamber being collected in a separated container and further burnt. It is recommended that to keep desirable conditions it is necessary to add ash, soil or lime into the chamber to absorb moisture, neutralize bad odours and make the faeces less attractive to flies. When the chamber is nearly full (about three-quarters), it is topped up with soil and the drop hole sealed with mud. Reasonably an anaerobic dehydration begins and meanwhile the second chamber starts to be used. It is recommended to store at least for two months after using the container, however the Nha Trang Pasteur

Institute recommends a retention time of 6 months and in cold climates for 10 months (Trong Phi *et al*, 2004). Reports suggest that 85% of helminth eggs are destroyed after 7-8 weeks (Winblad, 2004; Peasey, 2000).

Modifications of this design have been adopted in several countries, due to its simple and low cost construction, being presented some of them as follows.

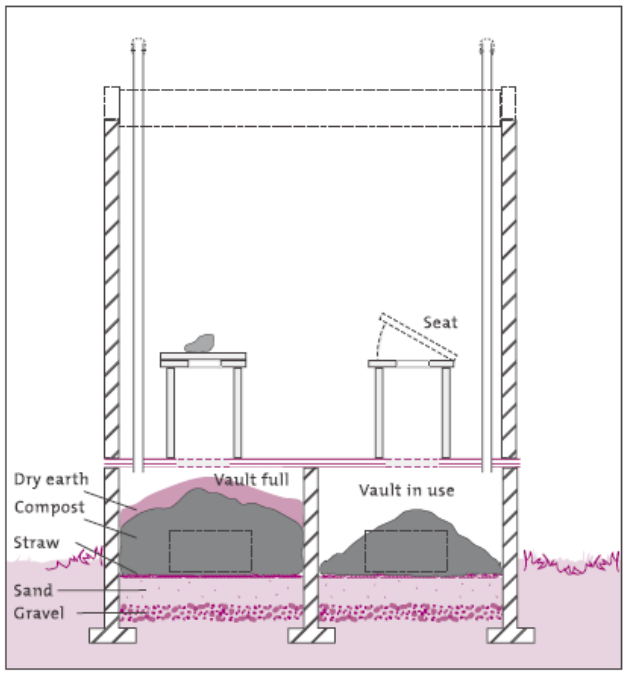

Figure 3: Double Vault Compost Latrine (www.who.int)

China (Modified Version of Vietnamese Dry Toilet)

In 1997–1999 modified versions of the Vietnamese double-vault dehydrating toilet were introduced in several provinces in China by the Sida (Swedish International Development Agency)-funded SanRes programme in cooperation with UNICEF and the Chinese Ministry of Health (Winblad, 2002).

Characteristics: The toilets were placed indoors in several households. Faeces are collected through a 20 cm wide PVC chute down to a ground level double-vault processing chamber (Jiang, 2001 *in Winblad*, 2004).

Material Costs: US$ 35 (Jiang, 2004 *in* Winblad, 2004).

Aesthetic Conditions: Aesthetically this toilet is equivalent of moderns urban bathrooms and this province in China have about 100,000 families with installed double vault toilets inside their houses (Jiang, 2004 *in* Winblad, 2004). Along 17 provinces, the total number of dry toilets installed in China is estimated to 685,000 (NPHCC *in* Winblad, 2004).

Mexico- Dry Ecological Toilet (Modified Version of Vietnamese System)

This modified version of the Vietnamese toilet designed by Cesar Anorve in Mexico (Sawyer, 1998) is widespread throughout the country (Peasey, 2000). This model has been already built successfully in communities in a variety of climates from humid and temperate to dry and tropical (Peasey, 2000).

Characteristics - Conventional-looking urine diversion toilet seat is placed on the toilet riser being aesthetically attractive, increasing considerably the public 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.

Building Cost: about US$150 including labour and materials.

Mexico-LASF (Letrina Arbonera Seca Familiar)

LASF is also a modified version of the Vietnamese toilet, introduced not only in Mexico, but it was also spread throughout the Central America, and over the past 25 years many thousands of units have been built. It was introduced in Guatemala in 1978 (Van Buren, *et al*. 1984 *in* Winblad, 2004).

Characteristics and Capacity: The Lasf toilet (in Mexico called Sanitario Ecologico Seco) consists of two chambers built above ground, each with a volume of about 0.6 cubic metres. A household of 5–6 persons will produce almost 0.5 cubic metres of dehydrated completely odourless material per year.

Advantages: The experience of 25 years of use of the Vietnamese double-vault system in Central America and Mexico is 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.

Guatemala DAFF (Modified Version of the Vietnamese System)

The DAFF is a dry compost family latrine developed in Guatemala at CEMAT, (Centro Mesoamericano de Estudios sobre Technologia Apropriado) (Chavez, 1987). This system was being promoted by the National Sanitation Program in Guatemala and, although it was possible to transfer the construction techniques, follow-up to ensure correct usage and maintenance of latrines was showing to be often inadequate, in which resulted in low levels of usage (Strauss & Blumenthal, 1990).
The DAFF has also been implemented in El Salvador, in such a high density urban squatter area, such as Hermosa Provincia, in the centre of San Salvador. The fact that 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).

Characteristics: It consists of 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 urine flows down a pipe into a pot being stored for a certain period. The compost removal can be made at the back of each chamber through installed doors.

Operation and Maintenance: Addition of ash, chalk or earth is added after each defecation to keep the excreta dry is required. It is recommended to remove the human excreta after 10-12 months of storage period in the chamber.

Material: It is easily constructed using basic building materials.

Total Cost: Including labour, it is estimated around US$40-100 depending on the materials used for the superstructure (Peasey, 2000).

South Africa Urine Diversion Dry Toilet (Modified Version of Vietnamese System)

The urine diversion "dry box" toilet implementation in South Africa had the principal objective to overcome many problems that had been confronted with Ventilated Improved Toilets (Holden, 1999).

Material: The toilet seat is constructed with a blow moulded plastic, whereas the chambers and the superstructure are constructed with locally available materials.

Characteristics: The toilet is raised above the ground with two storage containers underneath the toilet seat. The process is played in a batch function. While the faeces are collected in one container, the second container is not used until the first is filled and further sealed. The urine flows separately into a soak-pit. It is recommended to add ash after each defecation.

Regarding public acceptance, most families in the pilot implementation were enthusiastic about the new technology since the toilets presented no odours or flies, even though there was no vent pipe (Austin & van Vuuren, 1999).

Costs: US$42

Pilot studies are now under way using the urine separating toilet seat designed by Cesar Anorve in Mexico that uses a fibre glass mould and a cement mortar mix, which substantially reduced the cost of each toilet seat from US$42 to US$100 (Holden, 1999).

Ethiopia ECOSAN toilet

This toilet was developed by the Society for Urban Development in East Africa (SUDEA).

Characteristics: The urine and faeces are collected in different containers and the faeces are mixed with ashes, soil, leaves, grass or sawdust.

Material: Constructed with locally available and appropriate materials.

Costs: US$100 per toilet including the total construction and implementation.

Yemen- One-chamber dehydrating toilet

This model is commonly used in the city of Sanaa, Yemen (Peasey, 2000).

Characteristics: Differently from multi chambers, this is a one-chamber dehydrating toilet. The toilet is usually placed in a bathroom several floors above the street level and the faeces drop down a vertical shaft inside the building. The urine and water from anal cleaning drain down a vertical pipe on the outside of the building.

Advantages: The city of Sanaa has a hot dry climate, being the solid phase quickly dried out (Peasey, 2000). Similarly, most of the urine amount evaporates on the way down, and the small remained quantity drains into a soak pit (Winblad, 1985).

El Salvador - Tecpan solar heated toilet prototype

This toilet design was developed in El Salvador (Gough, 1997).

Characteristics: It is a similar toilet as DAFF toilet system implemented in Guatemala, nevertheless the toilet has a single chamber and solar heating to minimise high moisture content. The liquid phase is piped away to a soak-pit near the toilet.

Operation and Maintenance: After each use, addition of wood ash, soil or lime is required. It is suggested in each 1-2 weeks to push the pile to the back of the vault with a rake. Furthermore, in every 2 or 3 months, the dry and odour-free humus at the rear of the vault is removed with an additional storage period in a sack.

Costs: The toilet costs about US$164 including the chamber, the superstructure and the solar heater (Peasey, 2000).

Ecuador Two-chambered solar-heated composting toilet

Characteristics: It consists in a two-chambered solar-heated composting toilet. Its model has been built in the Andean Region in Ecuador. An observed interesting fact at this altitude is that urine diversion is not necessary since natural evaporation eliminates any surplus of humidity (Peasey, 2000). Each chamber has a diagonally sloping lid, made of a wooden frame covered with thin galvanised iron painted in black. Each chamber has a ventilation channel and the chamber lids have vents; being both covered with metal mesh.

Operation and Maintenance: After defecation, a handful of sawdust and/or ash are added.

Material: The toilet chambers and superstructure are built from locally-made sun-dried bricks. The toilet seat, the lid for the toilet hole, ventilation pipe and the door are prefabricated from wood (Esrey *et al*., 1998). Concerning its function, it is still unclear whether it works as dehydration or a composting toilet (Dudley, 1993).
No data available regarding costs.

Mexico Ecological Sanitary Unit

It is also based on the double chamber Vietnamese dry toilet concepts. The chamber is covered with a polyethylene lid and a toilet seat, which separates the urine and faecal material.

Material: This Unit is a prefabricated toilet constructed from high-impact recycled polyethylene.

Operation and Maintenance: It is required the addition of 0.5 kg 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 of soil to 1 part of lime is also reported to be effective, once it raises the pH of the faecal material, assisting the pathogens removal (Winblad, 2004).
The urine drains away into a soak-pit of gravel or tezontle (a Mexican porous stone). Toilet paper must not be added into the chamber.

When the ecological sanitary unit is correctly operated, the microbiological quality achieved can be about <100 total coliforms per 100ml (Personal communication, Josefina Mena Abraham *in* Winblad, 2004).

Double Vault Toilet Adaptation for "Washers"

The Vietnamese double-vault toilet was developed for people who use toilet paper, dry leaves and other forms for anal cleaning ('wipers') than water. However, in some cultures people use water instead ('washers') or a combination of solid material and water ('wipe-washers'), and in this case, some toilets have been adapted to its situation, as described in the next topic.

India

Characteristics: In Kerala, India, a double-vault toilet was redesigned by Paul Calvert (EcoSolutions, Trivandrum, Kerala, India) to suit a population of washers to use it (Figure 4). These toilets are built either close to or attached to the house, or even inside urban houses. In this case, additional urine and water used for anal cleaning are diverted to an evapo-transpiration bed next to the toilet (Calvert, 1994).

Operation and Maintenance: Before its use, the vault should be lined (generally with straw) providing a high capability to absorb the excessive moisture. A scoopful of ashes is required to be added over the faeces after each use. Occasionally it may be added also some straw, leafy material and paper scraps (Winblad et al, 2004). The implemented evapo-transpiration bed is also suitable to receive shower and kitchen grey water flows with little maintenance required. This bed can be even used for the improvement of aesthetics conditions and increasing public acceptance.

Costs: Construction costs are estimated in between US$ 80 and US$ 150, depending on superstructure and standard of finish (Calvert, 1998).

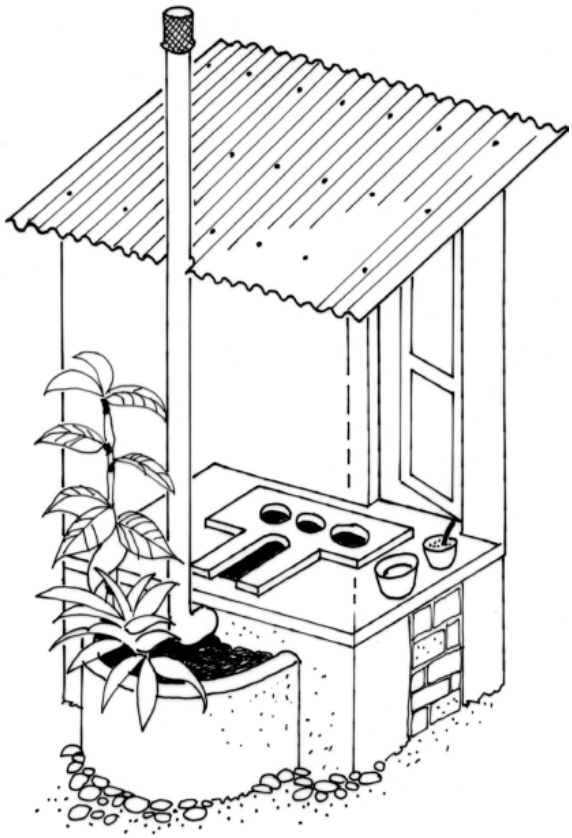

Figure 4**:** The Kerala double-vault toilet adapted for anal cleaning, between the two vaults. (Winblad, 2004)

Palestine

This is another known example of the Vietnamese double-vault toilet adaptation to a washer culture (wipe-washers in this case). This is a Palestinian case, from the city of Hebron, in Palestine, where 28 households were provided with eco-toilets in a Sida-funded project managed by the Palestine Hydrology Group (PHG), Jerusalem, in 2001 and 2002 (Winblad, 2002)

Characteristics: The eco-toilets in this project consist of a squatting pan for urine diversion; a drain for anal cleaning water, and underneath the floor level, a processing chamber for the human faeces. It works in a batch process.

Costs: The total cost of each unit in 2002 was in the range US$ 700–1000 (Winblad, 2004).

4.1.1.2 High Income Countries

Australia – EnviroLoo Toilet

This is a urine diversion toilet system developed in Australia in which can be considered and described as an evaporation/dehydration system (Figure 5 and Figure 6).

Characteristics*:* The liquids are drained into the bottom of the container, whereas the solids are collected on a drying tray.

In case of higher usages and possible overload it is recommended to install an overflow drain device, especially concerning colder and humid climates.
For odour control this model has a ventilation system installed creating a negative pressure within the container.

Maintenance*:* The Enviro Loo Toilets require periodic raking of the material after installation. The dry material is removed to a special drying bag for a period of at least 6 months for stabilisation for further removal. After this period it is then removed. The frequency of maintenance is strongly dependent on the usage frequency.

Important Consideration*:* It is significantly important to check if the prevailing wind at the installation site could bring negative pressures on the leeward side of the structure, which if strong enough, it might reverse the airflow through the toilet bringing an odour problem and nuisance, as presented in Figure 5

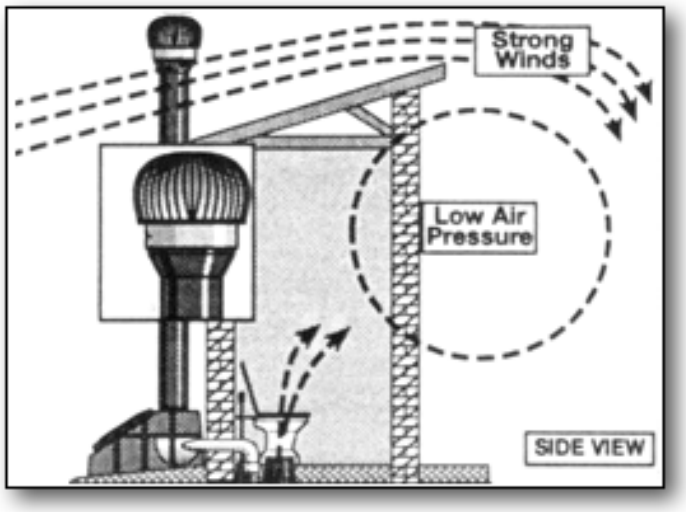

Figure 5: Schematic figure of possible problems with existing low air pressure in EnviroLoo Toilet models (http://www.enviro-options.com.au)

EnviroLoo Models

ENVIRO LOO 2010

- Domestic Use
- **Capacity**: 4 people times 3 uses per day
- **Range of Application**: Suitable for homes, low traffic areas.
- **Costs:** US$ 2660.00 per unit.

ENVIRO LOO 2040

- Commercial Use
- **Capacity**: 20 people times 3 uses per day
- **Range of Application**: Suitable for Parks, Camping grounds, Public Amenities Schools, Government projects, Villages etc
- **Costs**: US$ 3150.00 per unit.

ENVIRO LOO URINAL

- Commercial Model
- **Capacity:** is approximately 50 people times 3 uses per day
- **Range of Application**: Suitable for Schools, Resorts, Tourism destinations, Parks, Eco-tourism, high traffic areas, etc.

- **Costs:** US$4290.00 per unit.

Figure 6: Example of EnviroLoo toilet installed in a public area (http://www.enviro-options.com.au)

Australia-RotaLoo Toilets

Characteristics: *RotaLoo toilet models (*Figure 7) *are* built with six removable compost bins coupled on a manually rotated turntable (hence RotaLoo). An advantageous fact is that if the installation receives a shock loading and all the bins become full before the first has fully composted, a spare bin can be put in its place and the other removed to finish composting in a safe place.

Sizes*:* Rota-Loo Toilets are made in several sizes, being available for either remote usage or for residential households being continuously used. The principal available models are:

- The Rota-Loo 101, is designed for use principally in developing countries
- The Mobile Rota-Loo, as a transportable or high altitude composting toilet,
- The Maxi Rota-Loo, for commercial facilities normally using a Soltran Building.

RotaLoo 101

The concept of the patented 101 design use rigid compost bins mounted on a turntable contained in a main holding tank. The radial arms and interlocking arcs support the compost bags that are permeable and semi rigid to allow the air go through and to drain liquid out.

For its implementation this model must have available space underneath the toilet room to the compost bins.

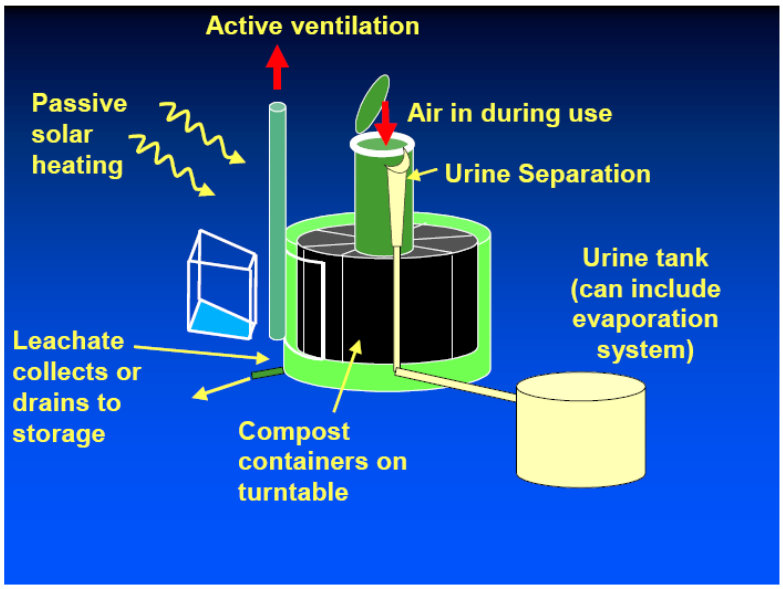

Figure 7: RotaLoo composting toilets (http://www.rotaloo.com)

It is recommended to provide a door to allow the removal of the compost bag when necessary in the side or the top of the housing.
Generally used in Australia, its side is used to be built facing the sun light improving and speeding up the composting and evaporation process.

Function: A separating pedestal allows the urine to be advantageously drained or stored separately from the solid material, making it easier to compost and reducing any odour from the vent pipe.

Odour Control*:* There is a fan pulling continually air through the Rota-Loo toilet cabin to the vent, creating a negative pressure at the pedestal. Consequently, the evaporation of liquid which has drained through the bins takes place.

Costs*: US$ 560,00*

Maxi RotaLoo 2000

This model was designed with a huge capacity which makes it particularly suitable for public facilities

It is designed and can be implemented for use either in a remote area or in high traffic locations.

Maintenance: Every Maxi ROTA-LOO 2000 is equipped with 8 removable composting bins instead of 6. In case of an overload it is possible to put a lid onto the overused bin, remove it from the system and replace the bin with an empty spare. The full bin can then be moved to a secure location to finish its composting process.

Maintaining Temperature: This model is built in a structure called Soltran building (Figure 8). It is designed to generate heat naturally by using the direct solar incidence. A 10mm, twin wall Polycarbonate is positioned in such a way to receive most of time the sun light allowing to accumulate heat reaching and keeping desirable temperature ranges.

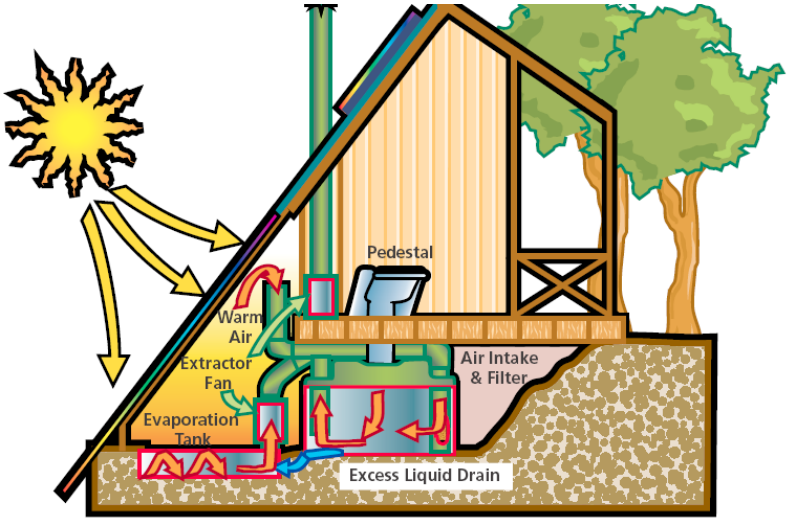

Figure 8: Schematic Diagram of an Operational Soltran Building (http://www.rotaloo.com/)

Excess Liquid Tank: The ELT takes liquid from the Rota-loo and evaporates it by providing a greater differential in ambient temperatures, a significantly larger and independent airflow and an increased surface area.

Venting: There is a natural heat generation when correctly sited generating sufficient heat to create a thermal convection to pull the air through the system.

Sweden – Wost Man Ecology AB Toilet Models

WM-Classic

This is urine diversion toilet (Figure 9) in which the Solids fall into a bin housed in an insulated wall, whereas the urine section is rinsed with approximately 0.1 litres of water in each use.

It is recommended to dry the faeces in a period for at least six months.

There is a fan coupled with a vent channel creating a negative pressure ensuring no odour release

Toilet Technical Specification:

- **Material**: Porcelain toilet
- **Dimensions***:* Length x Width x Height: (570 mm x 370 mm x 400 mm)

Container Technical Specifications

- **Material**: Insulated container for bin of galvanized sheet metal
- **Dimensions**: Length x Diameter x Height: (600 mm x 630 mm x 600 mm).
- **Vent pipe**: Ø100 mm

Figure 9: WM-Classic, its pedestal and underneath compost container (http://www.wost-man-ecology.se/)

WM-Privvy with WM-Classic

It is a similar model to the WM – Classic model already described, however it does not need space under the house, being constructed directly under the toilet (Figure 10).
The toilet is delivered with a self closing valve for rinsing of the urine section.

There is a ventilation system implemented with a fan and vent channel.

Toilet Technical Specification

- **Material***:* Porcelain toilet
- **Dimensions***:* Length x Width x Height: 570 mm x 370 mm x 400 mm

Container Technical Specifications

- **Material**: Polythene container with external insulation
- **Vent Pipe**: Ø100 mm

Figure 10: Pedestal and its container constructed directly under the toilet (http://www.wost-man-ecology.se/)

Sweden- Separett® Toilets

Construction Materials of all models: Upper and lower main sections are made with recyclable materials: impact-resistant, high-gloss polypropylene.
Seat: high gloss polypropylene.
Inner container and cover: Polypropylene

Separett® Villa Model 9000

Technical Specifications:

- **Container Volume**: 23 litres
- **Weight**: 13 kg
- **Venting pipe**: Ø75 mm, Urine waste pipe: Ø32 mm
- **Electrical equipment:** Two speed Fan, 230 V, 16.5 / 11.5 W
- **Electrical connection:** 1.7 m lead with earthed plug
- **Power consumption**: 0.396/0.276 kWh/24 hrs

Separett® Villa Model 9010 (Figure 11)

Technical Specifications:

- **Container Volume**: 23 litres
- **Weight**: 13 kg
- **Venting pipe**: Ø75 mm, Urine waste pipe: Ø32 mm
- **Electrical equipment:** Fan, 12 V, 210 mA, 2.5 W
- **Electrical connection:** Battery cable
- **Power consumption**: 0,06 kWh/24 hrs

Figure 11: Separett® Villa Model 9010 pedestal (http://www.separett.com)

Separett® Villa Model 9100

Technical Specifications

- **Container Volume**: 23 litres
- **Weight**: 13 kg
- **Venting pipe**: Ø75 mm, Urine waste pipe: Ø32 mm
- **Electrical equipment**: Fan, 120 V, 60 Hz, 14.6/18.9 W

- **Electrical connection**: 1.22 metre / 4 feet lead with earthed plug; cable 1.22 metres/4 feet
- **Power consumption**: 0,350/ 0,453 kWh/24 hrs

Separett® "Chalet" Model 4210

Technical Specifications

Container Volume: 27 litres

Weight: 11 kg

Venting pipe: Ø75 mm, Urine waste pipe: Ø32 mm

Electrical equipment: Fan, 12V DC, 210 mA, 2.5 W

Electrical connection: 2 m battery cable

Power consumption: 0,06 kWh/24 hrs

Separett® Classic Model 3000 (Lectrolav)

This model (Figure 12) is specially recommended for summer and Vacation Houses.

Technical Specifications

- **Dimensions**: Diameter – 650mm, Height – 550mm
- **Material**: Self Extinguishing Nylon Plastic (Outer part and inner part)
- **Weight** (empty): 18 kg
- **Electrical Equipment**: Heater, 250 W, complete with thermostat, over heating protection and a special switch
- **Ventilation**: 75 mm plastic pipe
- **Energy Consumption**: Approximately 3-5 KWh per 24 hour period, depending on the surrounding temperature.

Figure 12: Separett® Classic Model 3000 (http://www.separett.com)

Separett® Weekend 5210 12V/230V

- **Construction Materials**: Upper and lower main sections made with recyclable materials: impact-resistant, high-gloss polypropylene. Seat: high gloss polypropylene. Inner container and cover: Polypropylene
- **Weight**: 13 kg
- **Venting pipe**: Ø75 mm, Urine waste pipe: Ø32 mm
- **Electrical equipment**: Fan, 12V, 160 mA, 1.92 W
- **Electrical connection**: battery cable
- **Power consumption**: 0,046 kWh/24 hrs (16,79 kWh/year)

Separett® Weekend 5200

- **Construction Materials**: Upper and lower main sections made with recyclable materials: impact-resistant, high-gloss polypropylene. Seat: high gloss polypropylene. Inner container and cover: Polypropylene
- **Weight**: 13 kg
- **Venting pipe**: Ø75 mm, Urine waste pipe: Ø32 mm
- **Electrical equipment**: Fan, 230 V, 11 W
- **Electrical connection**: 2 metre lead with earthed plug
- **Power consumption**: 0.264 kWh/24 hours (96.36 kWh/year)

Separett® Villa 6000

Technical Specifications

- **Construction Materials**: Upper and lower main sections made with recyclable materials: impact-resistant, high-gloss polypropylene. Seat: high gloss polypropylene. Inner container and cover: Polypropylene
- **Weight**: 13 kg
- **Venting pipe**: Ø75 mm, Urine waste pipe: Ø32 mm
- **Electrical equipment**: Fan 230 V, 19 W
- **Electrical connection**: 2 metre lead with earthed plug
- **Power consumption**: 0.456 kWh/24 hours (166 kWh/year)

Separett® Villa 6200

Technical Specifications

- **Construction Materials**: Upper and lower main sections made with recyclable materials: impact-resistant, high-gloss polypropylene. Seat: high gloss polypropylene. Inner container and cover: Polypropylene
- **Weight**: 13 kg
- **Venting pipe**: Ø75 mm, Urine waste pipe: Ø32 mm
- **Electrical equipment**: Fan 230V, 16.5/11.5W
- **Electrical connection**: 2 metre lead with earthed plug
- **Power consumption**: 0.396/0.276kWh /24 hours

Germany – Berger Biotechnik GmbH

Terra Nova® Composting Toilets

Characteristics: This toilet model is developed to receive besides human excreta, also kitchen and garden organic waste. This system consists in a toilet pedestal with a storage container underneath the toilet seat.

Range of Applications: The Terra Nova® Composting Toilet System type is suitable for family houses, weekend- and summerhouses, and public recreation areas, with the principal requirement that the compost container must be placed under the toilets.

Capacity: The container capacity (Figure 13) is limited up to 40 uses per day (year round). It is recommended to store the organic content in the containers for at least 2 years.

Figure 13: Terra Nova® composting container (http://www.berger-biotechnik.de/)

4.2.2- Composting toilets (Non Diversion Toilets)

4.2.2.1 High Income Countries

Sweden - Clivus Multrum

Characteristics: This is a single-vault composting toilet (Figure 14) with combined processing of urine, faeces and organic household residues developed in 1930 (Hills, 1972). It consists of a composting vault with a slight sloped floor, air conduits and at the lower end a storage space. Odours and excessive moisture content are controlled by natural convection and air flow through existing air channel with an electric fan.

The Clivus Multrum was designed to receive besides faeces, toilet paper, and urine, all kinds of organic kitchen and household residues.

The designed slight slope in the processing chamber floor makes the introduced organic contents to slide slowly from the upper end down to the lower part of the

vault. The process of decomposition reduces the initial volume to less than 10% of the original volume (Winblad, 2004).

Maintenance: It is recommended to remove the mineralized content once a year.
This toilet system is advantageous in terms of cleaning and maintenance easily carried. The toilet bowl can be easily cleaned with biodegradable cleaner and toilet brush. In terms of maintenance an existing large inspection door allows the operator to easily check if the system is working efficiently. This is very important concerning with undesirable contents that accidentally could fall down into the chamber.

Capacity: In most cases the maximum for one Clivus in regular, year-round use is 8–10 people.

Possible Constraints: Frequent problems of liquid accumulation at the lower end of the composting vault have been found in Clivus models, bringing considerable constraints once these liquids may contaminate old material in the bottom that was already degraded. This is a real problem when taking into account mixed systems (urine and faeces being collected together). Another considerable constraint is that the solids often get trapped downwards the lower part of the vault.

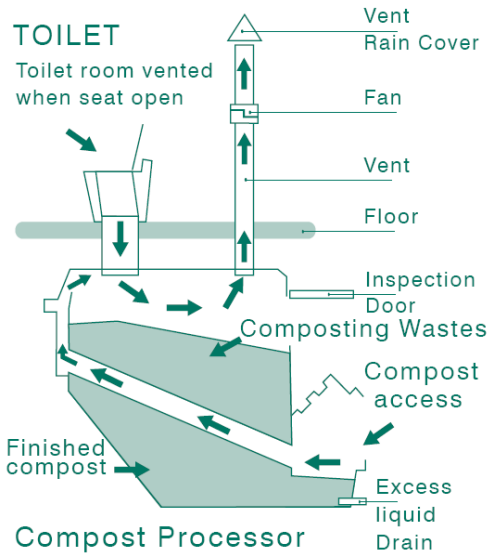

Figure 14: *Clivus Multrum* function explanation (www.clivusmultrum.com.au)

Norway- Carrousel

It is known that 60,000 units have been installed around the world since 1973. Similar types are also manufactured in other countries (Petersens, 2004 *in* Winblad, 2004).

Characteristics: The design of the Carousel toilet (Figure 15) consists in a processing vault that is 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) working in a batch process, filled in sequence. The liquid drains through existing holes at the bottom of the inner tank into the outer one, where it may be collected and further discharged into an evapo-transpiration bed or evaporated. An electric fan ensures adequate ventilation and aids evaporation. The Carousel can be equipped with either a urine diverting or with a non-diverting seat-riser.

Before start to use the chambers, a bed of small stone gravel (20 mm), coconut husks and a scoop of garden soil is placed in the bottom to allow a proper liquid drainage and provide soil bacteria to digest the waste.

Maintenance: According to del Porto (1996), the minimum routine maintenance is to add a small handful of organic matter after each use (e.g. leaves or coconut husks), to ensure minimum oxygen concentration.

Costs: Several different size units of varying capacity are available at prices between US$ 2000–2800.

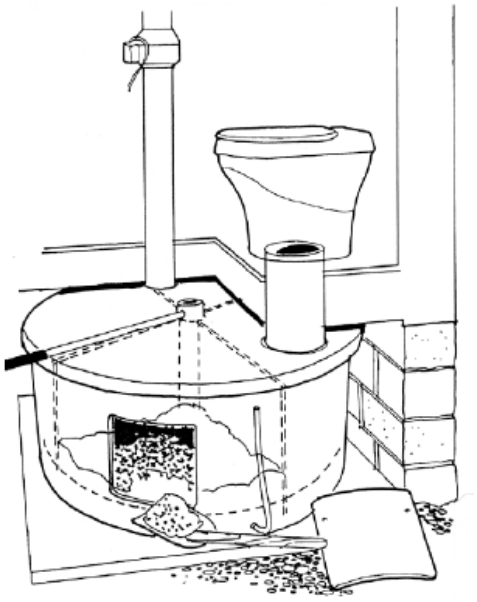

Figure 15: The ‘Carousel’ composting toilet from Norway (Winblad, 2004).

United States - SUN MARS:

This model of dry sanitation was developed basically in two different ways to deal with the human excreta, each of them with their own characteristics to be implemented, operated and maintained. These systems are called, depending on this specific way of function: *Central Units* and *Self Contained Units*

Central Units

All models that are called Central Units they basically consist in three different isolated chambers for organic composting: Compost chamber called also by Bio-drum (Figure 16 and 17), evaporation chamber and the finishing composting chamber (finishing drawer).

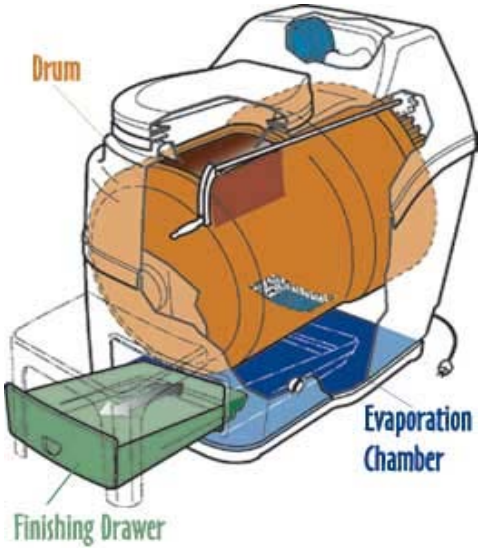

Figure 16: Sun Mars Bio Drum Unit, its evaporation chamber and finishing drawer (http://www.sun-mar.com/)

Operation and Maintenance: For a proper function it depends on some operational and maintenance processes.

Aeration: For aeration it is necessary to mix and aerate the organic content periodically. It can be made in such an easy way, by manually rotating the chamber.

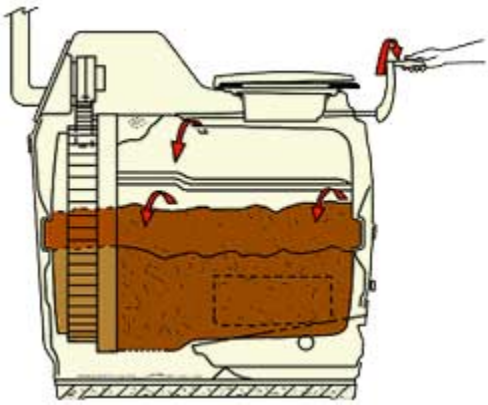

Figure 17: Drum Rotation and mixing the organic content in Sun Mar Bio Drum Toilet (http://www.sun-mar.com/)

For Emptying Procedure*:* To take out the compost from the chamber, it is necessary to release the drum locker and rotate the drum backwards. The inlet port will open automatically and the compost will drop directly into the compost finishing drawer.

Moisture Control*:* Sun Mars system must be kept with a minimum moisture content of about 40% for efficient function. This is the reason that it does not receive heat directly to the compost

When moisture content reach values up than 60% of moisture content, Sun-Mar's Unit automatically will drain any liquid surplus through a screen at the bottom of the drum directly into the evaporation chamber.

The excess liquid from the drum strains through a stainless mesh screen into an evaporation chamber that consists in a large surface area combined with heat and moving air. Furthermore, any liquid that is not absorbed by the compost in the drum drains through the screen directly into the evaporating chamber.

When taking into account developed non-electric units, it can present some problems for fully liquid evaporation, being required to connect an overflow drain in case of emergence.

Maintaining Temperature: The desirable temperature is held in the compost by indirect heat from the base heater (in electric units) to avoid water loss.

Separate Compost Finishing Drawer: This model was developed with an installed drawer underneath the bio-drum (already showed in Figure 16) with the principal objective to complete the composting and sanitization process without any contamination with fresh waste. It works basically by receiving a stream of drying air to dry the solid matter already treated for further adequate removal

Self Contained Units

Sun Mars Self-contained units were developed to be installed directly into the household bathroom and they are available in both electric and non-electric versions. Electric units are used principally to power a fan and a thermostatically controlled heating, and in face of this they normally have more capacity than non-electric units

due to extra heat and air diffusion. They are more suited to winter operations than central units, because it is often easier to keep the bathroom warm.

SUN MARS Available Composting toilet models:

Self Contained Units

Excel- High Capacity (Electric)

The excel model is ideal for residential use and also ideal for cottage use. Its model is tested and labelled by NSF (National Sanitation Foundation of United States).

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): 3 adults or families of 5
- Seasonal/Vacation (Adults/Families): 6 adults or families of 8

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Maximum Amps (With Heater On): 2.4
- Fan Watts (Required or Optional Hookup) 30 W Required
- Heater Watts (When Thermostat switches it on): 250 W
- Average Power Use in Watts (Heater on 1/2 time):150 W

Vent and Drains

- Vent Pipe Ø50 mm PVC Thinwall
- Drains (Required or optional Hookup) Ø10 mm Drains, Optional Seasonal/Vac use, Required for residential/Heavy Use

Weight and Dimensions

- Product Weight 28 kg
- Unit Height/Width/Depth: 813 mm x 572 mm x 838 mm

COSTS: US$ 1339.00

Compact: Medium Capacity (electric)

The Compact model is a low profile unit, which makes this model ideally suited to light residential or light to medium cottage use.

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): 1 adult
- Seasonal/Vacation (Adults/Families) 3 adults or families of 4

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Maximum Amps (With Heater On) 2.0
- Fan Watts (Required or Optional Hookup): AC 30W Required
- Heater Watts (When Thermostat switches it on): 200 W
- Average Power Use in Watts (Heater on 1/2 time):125 W

Vent and Drains

- Vent Pipe 50 mm PVC Thinwall
- Drains (Required or optional Hookup): 10 mm Drains, Optional Seasonal/Vac use, required for residential/Heavy Use

Weight and Dimensions

- Product Weight: 23 kg
- Unit Height/Width/Depth: 700 mm x 600 mm x 840 mm

COSTS: US$1239.00

Excel-NE: Medium Capacity Non-Electric

The Excel NE (Figure 18) has no fan or heater, bringing the necessity to increase the diameter of the vent pipe to improve the “chimney effect” eliminating odour nuisance. An optional 12 Volt Fan should be installed if you need to install the toilet with any bends in the vent, however it is recommended no more than 2 45° bends are encouraged, even with the fan.

Evaporating capacity on the Excel NE is variable, so the Ø25 mm drain at the rear should be connected to an approved drain pit, container, or other facility.

Figure 18: Excel-NE: Medium Capacity Non-Electric (http://www.sun-mar.com/)

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): 2 adults or families of 3
- Seasonal/Vacation (Adults/Families): 5 adults or families of 7

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Maximum Amps (With Heater On): NA
- Fan Watts (Required or Optional Hookup): 1.4 optional

Vent and Drains

- Vent Pipe: Ø100 mm PVC Thinwall
- Drains (Required or optional Hookup): Ø 25 mm Drains required

Weight and Dimensions

- Product Weight:23 kg
- Unit Height/Width/Depth: 820 mm x 570 mm 840 mm

Costs: US$ 1139,00

EXCEL AC/DC: Dual Voltage 110vAC/12vDC

The Excel AC/DC is a standard 115 volt Excel unit. This unit uses the regular Ø50 mm vent when 115 Volt power is available and defaults to the Ø100 mm NE vent when it is not.

An Ø25 mm overflow drain on the Excel AC/DC should be connected if the unit is being used heavily in AC mode, and if it is being used in DC or non-electric mode. It will only evaporate all liquids while working in the AC mode continuously.

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): AC 3/5, DC or NE 2/3
- Seasonal/Vacation (Adults/Families): AC 6/8, DC or NE 5/7

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Maximum Amps (With Heater On): 2.4 A
- Fan Watts (Required or Optional Hookup): AC 30 W Required, DC 1.4 W Required
- Heater Watts (When Thermostat switches it on): 250 W (AC Only)
- Average Power use in Watts (Heater on 1/2 time):150 W (AC Only)

Vent and Drains

- Vent Pipe: Ø50 mm Central Vacuum Tubing (PVC Thinwall), Ø100 mm ABS Thinwall
- Drains (Required or optional Hookup): Ø25 mm Drains required

Weight and Dimensions

- Product Weight: 28 kg
- Unit Height/Width/Depth: 857 mm x 572 mm x 838 mm

COSTS: US$1439,00

Figure 19: *Excel AC/DC Dual Voltage 110v AC/12v DC* (http://www.sun-mar.com/)

Space Saver Medium Capacity -Electric

This model is designed specifically for situations where space is extremely limited.

The SPACE SAVER unit has its evaporation process limited by the smaller heater and evaporating surface, so it is strongly recommended to connect the safety drain.

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): 1
- Seasonal/Vacation (Adults/Families): 3 adults or families of 4

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Maximum Amps (With Heater on):1.2A
- Fan Watts (Required or Optional Hookup): AC 20W Required
- Heater Watts (When Thermostat switches it on): 120 W
- Average Power Use in Watts (Heater on 1/2 time):80 W

Vent and Drains:

- Vent Pipe: Ø75 mm PVC Thin wall
- Drains (Required or optional Hook-up): Ø25 mm Drains required

Weight and Dimensions

- Product Weight: 28 kg
- Unit Height/Width/Depth: 710 mm x 480 mm x 530 mm

COSTS: US$1239,00

Centrex 2000 AF Electric Dry Toilet

This is a developed model (Figure 20) designed with capacity to receive large volume of wastes. Additionally it presents a desirable evaporation rate of liquids due to its increased surface area. However, in case of heavy usage it is recommended to be connected an extra drain

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): 4 adults or families of 6

- Seasonal/Vacation (Adults/Families): 6 adults or families of 8

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Maximum Amps (With Heater on):3.5 A
- Fan Watts (Required or Optional Hookup): 30 W Required
- Heater Watts (When Thermostat switches it on): 370 W
- Average Power Use in Watts (Heater on 1/2 time):215 W

Vent and Drains:

- Vent Pipe: Ø50 mm Central Vacuum Tubing (PVC Thinwall)
- Drains (Required or optional Hook-up): Ø25 mm Drains Optional

Weight and Dimensions

- Product Weight: 47 kg
- Unit Height/Width/Depth: 700 mm x 1130 mm x 675 mm

COSTS: US$1579, 00

Figure 20: *Centrex 2000 AF Electric Dry Toilet* (http://www.sun-mar.com/)

Centrex 2000 AF/NE Non-Electric Dry Toilet

The Centrex 2000 A/F NE is the non-electric version of the Centrex 2000 AF With the lower evaporating capacity due the lack of an electric heater; the overflow drain should be installed to avoid problems of excessive liquid.

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): 3 adults or families of 5
- Seasonal/Vacation (Adults/Families): 5 adults or families of 7

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Fan Watts (Required or Optional Hook-up): 2.4W Required

Vent and Drains

- Vent Pipe: Ø100 mm PVC Thin wall
- Drains (Required or optional Hook-up): Ø 25 mm Required

Weight and Dimensions

- Product Weight: 43 kg
- Unit Height/Width/Depth: 700 mm x 1130 mm x 675 mm

COSTS: US$1429,00

Centrex 2000 AF AC/DC Dry Toilet Dual 110VAC/12V DC

This model is designed for medium to heavy seasonal or light residential use. It has also capacity to receive large volumes of waste. The increased surface area in the evaporating chamber coupled with the larger heating element also provides better evaporation when the unit is on AC power.

Even with desirable evaporation capacity, the overflow drain should be installed with this unit once it might present an overflow when being used in either DC mode, or when it is used to maximum capacity in AC mode.

The Centrex 2000 A/F AC/DC requires that 2 vent stacks be installed to handle the separate venting functions. The Ø50 mm vent is in use when the AC fan is in operation, and the Ø100 mm vent is venting the unit passively when there is no power available.

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous: (Adults/Families): 3/6 (AC use), 3/5 (DC use)
- Seasonal/Vacation (Adults/Families): 6/8 (AC use), 5/7 (DC use)

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Maximum Amps (With Heater on): 3.3
- Fan Watts (Required or Optional Hookup): 1.4 W required (in DC use)
- Heater Watts (When Thermostat switches it on): 370 W
- Average Power Use in Watts (Heater on 1/2 time):215 W

Vent and Drains

- Vent Pipe: Ø50 mm Central Vacuum Tubing (PVC Thinwall), Ø100 mm PVC Thinwall
- Drains (Required or optional Hook-up): Ø25 mm Required

Weight and Dimensions

- Product Weight: 50 kg
- Unit Height/Width/Depth: 700 mm x 1130 mm x 675 mm

COSTS: US$1679, 00

Centrex 3000 AF Electric Dry Toilet

This model was designed principally for very heavy cottage or medium residential use. With a continuous flow system, the rotation of the drum moves the compost along the larger and longer drum before automatically drop into the collection housing at the end of the unit. Under normal operating conditions the drum will not have to be turned backwards for emptying.

The only restriction on installation is that the Dry Toilet needs to be directly above the unit so that there is a straight drop.

This particular model should be able to evaporate all liquids as long as the heater is on, and it is not being used heavily, so an overflow drain may not be necessary

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): 5 to 7
- Seasonal/Vacation (Adults/Families): 8 to 10

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Maximum Amps (With Heater on): 3.6 W
- Fan Watts (Required or Optional Hookup) 30W Required
- Heater Watts (When Thermostat switches it on): 370 W
- Average Power Use in Watts (Heater on 1/2 time):215 W

Vent and Drains

- Vent Pipe: Ø50 mm Central Vacuum Tubing (PVC Thinwall)
- Drains (Required or optional Hook-up) Ø25 mm optional

Weight and Dimensions

- Product: Weight: 50 kg
- Unit Height/Width/Depth: 770 mm x 690 mm x 1745 mm

COSTS: US$1799, 00

Centrex 3000 AF (Air Flow) NE (Non-Electric)

The Centrex 3000 AF (Air Flow) NE (Non-Electric) is a similar model of the 3000 AF that employs continuous flow design for very heavy cottage or medium residential use.

It is recommended to install a 12 volt 2.4 watt fan that is required in the vent stack to assist airflow.

It has the same restriction on the installation and the toilet needs to be directly above the compost unit.

It is required an Ø25 mm drain hose which should be connected to the Ø25 mm drain at the bottom left of the unit.

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): 4 adults or families of 6
- Seasonal/Vacation (Adults/Families): 7 adults or families of 9

Electricals (Electricals must be connected while the unit is in AC use for proper operation)

- Fan Watts (Required or Optional Hookup): 2.4 W Required
- Average Power Use in Watts: 2.4 W- 12 Volts

Vent and Drains

- Vent Pipe: Ø100 mm Thinwall PVC
- Drains (Required or optional Hook-up): Ø25 mm Required

Weight and Dimensions

- Product Weight: 43 kg
- Unit Height/Width/Depth: 740 mm x 690 mm x 1740 mm

COSTS: US$1639, 00

Centrex 3000 AF AC/DC Dry Toilet 110AC/12 DC

The Centrex 3000 AF (Air Flow) AC/DC composting toilet system has a continuous flow design for very heavy cottage or medium residential use.

It has a thermostatically controlled heater for the liquid evaporation.

The Centrex 3000 AF AC/DC also features an Ø100 mm vent stack which may be used to vent the unit when no electricity is present. It is recommended a 12 volt 2.4 watt fan. It is suggested to be installed in the vent stack, especially if you need to put a bend in the vent as shown in the diagram.

This unit should be able to evaporate all liquids while operating in AC mode, with the heater on. Drains should still be connected for heavy use or use in DC mode.

Capacity (Listed capacities refer to the amount of people, on average, using the unit per day)

- Residential/Continuous (Adults/Families): 7-8 (AC) or 5-6 (DC)
- Seasonal/Vacation (Adults/Families): 10-12 (AC) or 8-10 (DC)

Electricals (Electricals must be connected while the unit is in AC use for proper operation

- Maximum Amps (With Heater on): 3.6 A
- Fan Watts (Required or Optional Hookup) 30W/2.4 W Required

- Heater Watts (When Thermostat switches it on): 370 W
- Average Power Use in Watts (Heater on 1/2 time):215W AC, 2.4W DC

Vent and Drains:

- Vent Pipe: Ø50 mm Thinwall PVC, Ø100 mm Thinwall PVC
- Drains (Required or optional Hook-up): Ø25 mm Required

Weight and Dimensions

- Product Weight: 50 kg
- Unit Height/Width/Depth: 770 mm x 680 mm x 1740 mm

Costs: US$1899, 00

SWEDEN - BIOLET

BioLet toilets are on-site, self contained, biological toilets, collecting faeces, urine and toilet paper together. The excess of liquid is evaporated and the solid material is biologically decomposed.

Generally all models are capable to reduce the volume of the waste entering the toilets by approximately 90%, leaving only 10% of an end-product.

These toilets are designed to allow a desirable air flow providing additional oxygen, evaporation of the excess liquid through the vent pipe, and odours control.

Biolet Toilet Models

Biolet DeLuxe

Characteristics: Proper mixing of the compost is accomplished by an electric motor that rotates two mixing blades inside the composting chamber activated automatically after each use.

Technical Specifications

Capacity (Persons/day):

- 3 people - full-time use
- 4 people - part-time use

Electrical Specifications:

- Total - 290 W
- Average continuous consumption over 24 hr period - 55 W
- Heater - 225 W
- Fan motor - 25 W
- Mixer motor - 40 W

Weight Limit: 160 kg

Required Room Temperature: 18ºC during the toilet use.

Measurements and Weight:

- Depht/width/height: 740 mm x 545 mm x 660 mm
- Weight: 28 kg

Costs: US$ 1,499.00

Biolet Basic

The Biolet Basic is designed principally to be installed in areas where there is no electricity available. Its model of toilet has a convenient device to handle and mix the organic matter received instead of an automatic device. Since these models have no electrical components it lacks the capability to evaporate most of the liquids being necessary to be installed together with a drain pipe discharging the liquids into a holding tank.

This model is recommended to be installed in cottages.

Technical Specifications:

Capacity (persons/day):

- 2 people - full-time use
- 3 people - part-time use

It may be increased by the addition of an auxiliary 12V DC Ventilation fan.

Weight Limit: 160 kg

Required Room Temperature: 18ºC during periods while the toilet is in use.

Measurements and Weight:

- Depth/width/height: 740 mm x 545 mm x 660 mm
- Weight: 28 kg

Costs: US$ 999.00

BioLet XL

It is a model designed with an extra capacity. It is Equipped with the same automatic features as the BioLet Deluxe, the BioLet XL has a larger composting chamber and an extra heating element in the bottom to help the excessive liquid evaporation. The BioLet XL is equipped with 3 mixing arms equipped with "cutting blades" to help break-down toilet paper and keep the product in an airy, homogenous state. It is also equipped with a float switch that operates the heaters when excess liquid is detected.

BioLet XL is approved and labelled under NSF (United States National Foundation)-Standard 41, for residential use by a family of four persons.

Table 1: Performance Data in regard to Liquid containment, Odour and Fecal Coliform (from the NSF-Standard 41 test and approved for listing). (http://www.biolet.com)

PARAMETER	OBSERVATION	REQUIREMENT	ANALYTICAL RESULTS
Liquid Containment		no leakage	no liquid escape evident
Odour	Bowl	non objectionable	no offensive odour
	Vent	non objectionable	no offensive odour
Fecal Coliform (No/Gm) in final end product		<= 200 MPN/gm	3 MPN/gm

Technical Specifications

Capacity (Persons/day**)**:

- 4 people - full-time use
- 6 people - part-time use

Electrical Specifications:

- Total - 370 W
- Average continuous consumption over 24 hr period - 65 W
- Heater (thermostatically controlled) - 305 W
- Fan motor - 25 W
- Mixer motor - 40 W

Weight Limit: 160 kg

Room Temperature Required: 18ºC during periods while the toilet is in use.

Measurements and Weight:

- Depth/width/height: 810 mm x 635 mm x 660 mm
- Weight: 37 kg

Costs: US$ 1,599.00

BioLet Standard

It is equipped basically with a heating element, a fan and a thermostat to keep a proper temperature.

Technical Specifications

Capacity:

- 3 people - full-time use
- 4 people - part-time use

Electrical Specifications:

- Total - 250 Watts
- Average continuous consumption over 24 hr period - 55 W
- Heater (thermostatically controlled) - 225 W
- Fan motor - 25 W

Weight Limit: 160 kg

Room Temperature Required: 18ºC during periods while the toilet is in use.

Measurements and Weight:

- Depth/width/height: 750 mm x 545 mm x 660 mm
- Weight: 28 kg

Costs: US$ 1,399.00

Biolet NE

This model is designed with two composting chamber (Figure 21) working in a batch process, filled in a sequence.

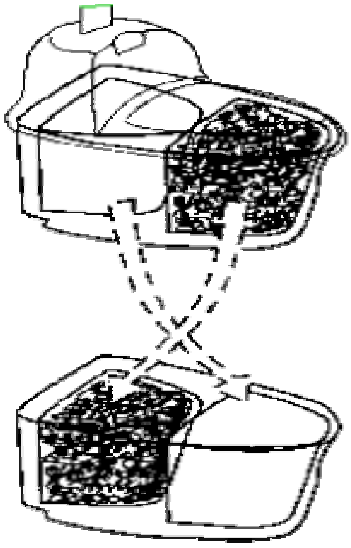

Figure 21: Biolet NE and its double composting chamber (http://www.biolet.com)

The BioLet NE doesn't have an electric heater to assist the evaporation of excessive liquid being not capable to fully evaporate the total volume through the existing vent. Therefore, it's necessary to install a small drainage system.

Technical Specifications

Capacity (persons/day**)**:

- 4-6 people - full-time use
- 4 -6 people - part-time use

May be increased by the addition of an auxiliary 12V DC Ventilation Fan

Electrical Specifications:

- Total - 250 W
- Average continuous consumption over 24 hr period - 55 W
- Heater (thermostatically controlled) - 225 W
- Fan motor - 25 W

Weight Limit: 160 kg

Room Temperature Required: 18ºC during periods while the toilet is in use.

Measurements and Weight:

- Depth/width/height: 740 mm x 525 mm x 660 mm

- Weight: 30 kg

Costs: US$ 999.00

Sweden-Pacto® Toilet

The Pacto® Toilet System is a model designed with possibilities to be implemented in a wide range of different areas and weather conditions due to its easy adaptation.

Characteristics: This model is innovative and it uses a flush foil to encapsulate the waste. There are two types of available flush foil:

- Ecological flush foil, mostly recommended for leisure homes that are made from corn starch and they are fully degradable when composted and,
- Polythene flush foil that are not compostable and must be incinerated after its use.

PACTO® 501 Drug Toilets

Figure 22: PACTO® 501 Drug Toilet (http://www.danfo.com/)

Technical Specifications:

Weight: 20 kg
Dimensions: Depth/ Width/ Height: 470 mm x 530 mm x 504 mm

PACTO® CARE

This is specific developed model (Figure 23) suited where perfect standards of hygiene are essential such as Hospitals and Care homes.

Specific Function*:* a polythene flush foil is used to flush and enclose the waste in sealed bags. The flushing is made electrically and after the flushing, new fresh foil will cover the toilet bowl.

Figure 23: PACTO® CARE toilet (http://www.danfo.com)

6- Discussion

In order to carry out a preliminary comparison and correlation of some dry toilet models presented in this report, some aspects and sub-aspects were considered and put together as it can be observed in Table 2. Considered aspects are: *Economical, Technical, Environmental, Physical, Public Health and Aesthetic Aspects.* Even though this information bring easiness to carry out an evaluation and comparison, it is important to highlight that studies of this nature require a more detailed assessment to bring reliable analysis and consequent results. Besides, theses aspects are based on market companies that have been developing dry systems and delivering information regarding their products. Nevertheless preliminary ideas towards a better knowledge of their advantages and limitations can be pointed out.

Table 2: Dry toilet systems and Relationship among some principal aspects

	Vietnamese Dry Toilet	Mexican Eco Toilet	Enviro Loo (Australia)	Carrousel (Norway)
Economical Aspects				
Prices of Installation Feasible for	Developing Countries	Developing Countries	Developed Countries	Both
Technical Aspects				
Maintenance	Simple	Simple	Require Technical Skills	Simple
Operation	Simple	Simple	Require Technical Skills	Simple
Range of Application	Rural Areas	Rural Areas	Residential and Commercial. Low and High Traffic Areas	No Data
Environmental Aspects				
Construction Material	Concrete, Stone or unbaked bricks	high impact recycled polyethylene	Polyethylene Plastics	Fiber Glass
Physical Aspects				
Weight	No Data	No Data	No Data	No Data
Public Health Aspects				
Odour emission	No odours	No odours	Possible	No Data
Vectors	No attraction of flies	No vectors	No Vectors	No Data
Sanitization	85% of Helminth Eggs	<100 Total Coliforms/100ml when well managed	No Data	No Data
Exposure to Excreta	Risks for those who maintain	Risks for those who maintain	Risks for those who maintain	Risks when emptying the container
Aesthetic Aspects				
Acceptability	High (Asia and Central America)	No Data	High	High

	Sun Mars (USA)	Biolet (Sweden)	Separett®(Sweden)	Clivus Multrum (Sweden)	Terra Nova® (Germany)
Economical Aspects					
Prices of Installation Feasible for	Developed Countries	Developed Countries	Developed Countries	Developed Countries	Developed Coutries
Technical Aspects					
Maintenance	Simple	Simple	Simple	Require Technical Skills	Require Technical Skills
Operation	Simple	Simple	Simple	Require Technical Skills	No Data
Range of Application	Residential and Boats	Residential Use and Boats	Residential. Rural and Urban Areas	Residential use, Public Areas and Community Facilities	Residential and Public Areas
Environmental Aspects					
Construction Material	Fiber Glass and Stainless Steel	ABS Plastic and Stainless Steel	Recyclabe High Gloss Polypropylene	Stainless steel and Polyethylene	Porcelain and Fiber Glass Plastic
Physical Aspects					
Weight	Range between 23-50 kg	Range between 28-37 kg	Range between 11-18 kg	No Data	No Data
Public Health Aspects					
Odour emission	No offensive odours*	No offensive odours*	No Data	No Data	No
Vectors	No Vectors*	No Vectors*	No	No Data	No
Sanitization	27 MPN/gram*	3 MPN/gram*	No Data	No Data	No Data
Exposure to Excreta	No risks	No risks	Risks when emptying the inner container	Risks when emptying the inner container	Risks when emptying the inner container
Aesthetic Aspects					
Acceptability	High	High	Equivalent to Ordinary Pedestals	High	Equivalent to Ordinary Pedestals

* Under the certification of the National Sanitation Foundation – NSF Standard 41, <200 MPN faecal Coliforms/gram

Economical Aspects

With the exception of the *Mexican dry toilet* system and the *Vietnamese model*, most of the available products presented in this report are in general terms preferably affordable for developed countries, as a result of their high costs of implementation (Table 3. An exception can be observed over the *Carrousel Toilet* developed on Norway, that according to Winblad, (2004), it can be implemented in both developed and undeveloped countries. However in undeveloped countries modified and adapted models with lower costs following the basic concepts of *Carrousel* have been implemented, instead of the original one.

Table 3: Global Economical Feasibility of implementing dry toilet models according to their costs

Vietnamese Dry Toilet	High Affordability
Mexican Eco Toilet	High Affordability
EnviroLoo	Low Affordability
Carrousel	Low Affordability
Sun Mars	Low Affordability
BioLet	Low Affordability
Separett®	Low Affordability
Clivus Multrum	Low Affordability
Terra Nova®	Low Affordability

Technical Aspects

Maintenance and Operation: The principal aspects in order to bring a desirable performance of dry systems are the proper maintenance as well as the operation. However, it can be observed, that different models have diverse manners to be maintained and some systems are more simple and easier than others to be kept in proper conditions. Whereas some dry toilets can be maintained by the user, personnel staff with some technical skills shall be considered in others. The *EnviroLoo*, the *Clivus Multrum* and the *Terra Nova®* are those that require special attention and need a certain technical skills to be maintained and operated, making these systems mostly viable for public facilities instead of residential use, decreasing their range of implementation. Even though difficulties can be seen in the maintenance process, these models have been implemented for residential use as well.

Range of Application: Concerning the range of applications, basically it may be divided in terms of density: *Rural* or *Urban areas* and in terms of customers: *Residential* or *commercial* use. Some systems are restricted to be used in rural areas such as the *Vietnamese Toilet* and the *Mexican Eco Toilet*. It can be reasonably understood, once they have been implemented mostly in developing countries and in low density areas with no water supply and sewage systems. Moreover, the Swedish model *Separett*® can be addressed as well for rural and country side regions. However the Swedish model advantageously can also be implemented in urban residential houses, being not restricted only to country side.

Environmental Aspects

The environmental approach should be focused in the product life cycle assessment, meaning that to gain knowledge and information regarding all different dry toilet systems, an extended period of survey is required, reason why it can not be presented here some robust discussions and conclusions. Nevertheless, according to Table 2 and as regards the construction material, it can be observed that the *Mexican Eco Toilet* is constructed with recycle polyethylene and the Swedish *Separett*® with recyclable polypropylene, meaning that these models could be in a preliminary manner considered as environmentally friend products.

Public Health Aspects

The public health aspect may be considered as the most important aspect to be evaluated, once if not performing in a proper way, whichever dry toilet is, it may bring serious constraints for users as well as for those who maintain and operate it. It is important to emphasize these constraints do not have a very significance in those models developed and implemented for residential use, differently than systems implemented in public areas, that should be under more stringent control and frequent maintenance.

***Odours*:** Predominantly, the presented models showed to have no odour emissions. However the condition of no odour emission is supposed to take place in a desirable and proper function situation, meaning that it is difficult to assess all sold and in use

systems regarding their correct function, unless either a specific and addressed survey is carried out or some feedbacks between customers and the companies occur.
The toilet models *Sun Mars* and *BioLet* are certified by the *North American National Sanitation Foundation- NSF Standard 41* related to Evaluation of Wastewater Reuse/Recycle and Water Conservation Devices. It means that under evaluation of the Sanitation Foundation, no offensive odours were found to be emitted and the microbiological quality of the final product is appropriate as well.

Moreover, special attention can be brought for the *EnviroLoo* system, once if not well planned it has great probabilities to emit offensive odours. This system is developed to take advantages of prevailing wind flow and its negative pressure on the leeward side of the facility structure. However, with a strong enough wind, it might reverse the airflow through the toilet bringing odour. The *EnviroLoo* scheme can be observed in Figure 5.

***Vectors*:** Similarly, as already mentioned, it is difficult to carry out an assessment of all sold and in use toilets. However, data found in literature point out that mostly, these models are not attractive to flies and insects. Reasonably, these data takes into account the proper function of the system.

***Sanitization*:** Besides the stabilization of the organic matter, the sanitization of the human excreta is one of the principal objectives of dry toilets,. However, concerning the human health aspects, the stabilization does not have significant meanings. According to the North American NSF Standard 41 (Table 1), a maximum density of 200 MPN (Most Probable Number) of faecal coliforms /gram in treated excreta is required and as already presented, both *Sun Mars* and *BioLet* models are under provision of this standard (Table 2). It can be considered feasible and safe in terms of public health aspects. However, it is important to emphasize that although several models can be certified and considered hygienic and safe as well, there is a lack of data and carried out evaluation in order to obtain a better understand of the microbiological aspects of dry toilets, principally regarding the die-off rates and the final quality of the produced compost. The lack of data can be clearly observed in Table 2, where with the exception of the *Sun Mars*, *BioL*et, *Mexican EcoToilet* and

Vietnamese Toilet, no information are available for one of the most important aspect of dry sanitation: microbiological quality and health impacts.

7 - Conclusions

Currently, it can be observed that a number of different dry sanitation technologies are available in the market for different purposes. It is clearly evident that though predominantly each different technology follow the identical basic concept of storage and sanitization of human excreta without the use of water as a carrier material, there are some aspects inherent to their design, implementation, function, maintenance, performance, capacity and costs that make each model exclusive. However neither of them has been under a simultaneous evaluation and comparison in such a manner that information could be brought regarding their characteristics as well as the possibility to identify under in which circumstances these different systems may perform efficiently. According to Strauss, (1992); Winblad, (1996); Otterpohl & Grotker, (1996) research about dry toilets is very limited and there are several topics to be examined and included in comparative investigations.

For this purpose, the present author suggest that indicators as well as some indexes and classifications related to environmental, technical, economical, cultural, social, and health aspects should be created in order to aid a further comparative evaluation among different systems. Moreover, an extended period should be considered with the objective of profound assessment of a dry toilet model.

Hygienic investigations of the final product are crucial, principally concerning the presence of harmful substances such as human pathogens and chemical pharmaceutical compounds. It could be observed that there is a lack of information regarding the final microbiological quality of the treated excreta and urine. Dry sanitation must be taken into account in a current world with several sanitation problems, however it is important to develop this technology in such a way that the treatment is optimized and that it is user-friendly and hygienic.

Finally, it must be highlighted that affordability of dry toilet systems is relative and while some of the existing systems are high-tech and expensive, suitable only for developed countries, others are simple and extremely affordable. Concerning the range of application, dry systems could either be implemented for small scale and low density areas (rural areas) or even for medium to high density areas (urban areas).

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