Evaluation of waterless sanitation for hot arid climates

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Ecological sanitation systems are of particular interest in hot arid climates where water is in short supply. This article compares the effectiveness of dehydrating and biodegrading toilets in reducing pathogenic micro-organisms in human waste.

Waterless sanitation systems were evaluated for their ability to function in hot arid climates. Their effectiveness was based on their ability to reduce human pathogenic micro-organisms in biosolid waste. We constructed five each of four different waterless toilet types: single and double-vault non-urine diverting (biodegrading) and single and double-vault urine diverting (dehydrating). The biodegrading toilet is similar in principle to the aerobic toilet described in the Technical Brief in this issue; the dehydrating toilet is similar to the anaerobic toilet described. Results indicated that a combination of low moisture content in biosolids and pH >10 were best to reduce micro-organism content in biosolid waste.

Ecological sanitation systems, which require neither water nor sewerage infrastructure for their operation, are a viable solution for areas where poor sanitation exists and water is scarce. They have an advantages over the pit latrine, as there is minimum environmental pollution to groundwater and they provide a more permanent structure that does not require moving to a new site when the pit is full.

Project design

Results from our prior study[1] suggested that it was important to determine which type of waterless sanitation system was best suited for a particular environment. To determine this, we constructed five each of four different waterless sanitation systems: single and double-vault non-urine diverting (biodegrading) and single and double-vault urine diverting (dehydrating). Analyses of the four systems were based on biosolid waste samples in which pH and moisture content were measured. In addition, three indicator micro-organisms – faecal coliforms, *Cryptosporidium parvum,* and *Giardia lamblia* – provided information about the systems' efficiency in treating biosolid waste. *Cryptosporidium* and *Giardia* were chosen because of their high prevalence in the study area and their production of oocysts and cysts, which are more resistant life forms.

We studied a peri-urban community located in an under-developed area of Ciudad Juárez, Chihuahua, Mexico. Ciudad Juárez is a city of approximately 1.4 million inhabitants located on the Mexico/USA border where rapidly expanding areas of the city lack municipal water and sanitation services. Most participants had pit latrines and were of low socio-economic status.

Toilet designs

The four types of waterless toilets were designed and constructed to determine which system was better suited to the hot and arid environment of the area. Basic differences in design features of the biodegrading and dehydrating systems are outlined in Table 1. There were two forms for both biodegrading and dehydrating toilets, the single and double-vault structures.

Single-vault biodegrading toilets had passive solar panels to heat the composting chamber. Sawdust and toilet paper were added as soak materials to adjust the moisture content and the carbon: nitrogen (C:N) ratio. Since the biodegradation of pathogens was aided by aerobic bacteria growth, the biosolid waste was mixed each week to oxygenate the composting heap. The double-vault biodegrading toilet was similar to the single-vault biodegrading toilet, except that it had two processing chambers, so there was a physical barrier between fresh faecal matter and the composting waste.

Table 1 Feature comparison of biodegrading versus dehydrating systems

Toilet features	Biodegrading	Dehydrating
Urine diverting	No	Yes
Soak materials	Yes	No
Lime/soil mixture	No	Yes
Aeration (mixing)	Yes	No

The single-vault, dehydrating toilet used a urine-diverting pedestal to decrease the amount of moisture that entered the processing chamber. Urine was diverted to a soak-pit filled with gravel and sand located outside the toilet. A mixture of soil and lime was added to the processing chamber to assist the desiccation process and raise the pH above 10, which aids in pathogen reduction.[2] The double-vault dehydrating toilet was similar to the single-vault dehydrating toilet but had separate vaults.

Toilet construction

The construction of all waterless toilets was under the supervision of a local

Box 1. Biodegradation versus dehydration

There are two basic types of waterless toilets, based on whether they treat biosolid waster by biodegradation or dehydration. Biodegrading toilets promote pathogen reduction by increasing the temperature of the composting pile to as high as 70°C by the action of thermophilic aerobic bacterial growth.[5] Dehydrating toilets rely on desiccation and high pH (>10), a result of low moisture content (<25% moisture by weight) and the addition of an alkaline agent.[2]

construction engineer. Building materials included concrete blocks, with metal doors and roof. From a construction point of view, there were two designs: one for the single-vault and one for the double-vault toilets. The type of pedestal added after construction determined whether a toilet used urine diversion or not. The overall dimensions (width, length, height) of the two systems were: double-vault base 170 × 200 × 60 cm and superstructure 170 × 130 × 200 cm; single-vault base 120 × 190 × 60 cm and superstructure 120 × 130 × 200 cm.

Biosolid waste collection and analyses

Samples were taken from five different positions in the composting heap and consisted of 100–200 g fresh weight. Samples were transported to the laboratory in an ice chest and analysed for faecal coliforms on the same day. Other pathogens were analysed within 48 hours. After analysis, samples were disinfected or autoclaved.

In the single-vault toilets at two months, the accumulated pile was pulled down into the secondary processing area, which separates it from new waste additions. This separation began a four-month period during which the biodegrading pile was aerated by stirring 1–2 times per week (this was not necessary for the dehydrating toilet). After this four-month period in the secondary processing area, the biosolid waste was removed for disposal. In the double-vault systems, the pedestal was moved to the other vault after two months, which physically separated the composting biosolid waste from new additions.

Biosolid waste samples were collected and analysed at approximately two, four and six months after the accumulated pile was pulled down into the secondary processing area. Faecal coliform concentrations were estimated using the multiple tube fermentation with A-1 Medium[3] as described in the USEPA Standard Method 9221 E.[4] Some pathogens, especially those forming spores or eggs, may be less affected by biodegradation and desiccation and can survive for much longer times.[1,5] Therefore, we also monitored *Cryptosporidium* oocysts and *Giardia* cysts by the immuno-fluorescence technique[1] utilizing the Merifluor detection kit (Meridian Diagnostics, Inc, Cincinnati). The number of oocysts per microscopic sample (10 μl) was semi-quantified by averaging five microscopic fields and scoring samples as high (> 10), low (1–10), or negative (0). For the purpose of comparison between the different sanitation systems, average numbers were adjusted for sample dilution, microscopic magnification and original moisture content in samples.

Biosolid moisture content and pH

Results from both single- and double-vault toilets were combined for the analyses. For biodegrading systems, there was a moisture content (by weight) of approximately 25 per cent by the fourth month (Table 2). This moisture level was already too low for

The double-vault biodegrading toilet has passive solar panels to raise the temperature

Table 2 Performance of biodegrading and dehydrating toilets over six months

	Duration (months)			
	two	four	six	p-value
Moisture content – % by weight and (standard deviation – SD)				
Biodegrading	47.8 (19.3)	25.2 (20.3)	20.4 (19.2)	0.07[1]
Dehydrating	23.3 (15.0)	7.0 (6.7)	15.8 (21.9)	0.07[1]
pH – mean and (SD)				
Biodegrading	7.9 (0.4)	7.5 (0.5)	7.3 (0.5)	0.18[1]
Dehydrating	10.1 (1.7)	9.8 (1.5)	9.7 (1.5)	0.80
F. coliforms $\log_{10}$ (CFU/100 ml) – mean and (SD)				
Biodegrading	7.3 (0.4)	6.4 (0.9)	5.5 (1.2)	0.001[1]
Dehydrating	7.0 (0.7)	6.3 (0.9)	5.5 (1.1)	0.02[1]
Giardia (positive) – decrease over time, from 100% initially (No.)				
Biodegrading	100 (6)	100 (6)	83.3 (5)	0.35[2]
Dehydrating	100 (13)	84.5 (11)	66.7 (8)	0.07[2]
Crypto (positive) – decrease over time, from 100% initially (No.)				
Biodegrading	66.7 (4)	50.0 (3)	50.0 (3)	0.80[2]
Dehydrating	46.2 (6)	23.1 (3)	0.0	0.03[2]

Notes: [1]ANOVA, [2]Fishers exact test

Top view of a urine-diverting pedestal. Moulds for casting were obtained from César Añorve, CITA (Centro de Innovación en Tecnología Alternativa, Cuernavaca, Mexico)

efficient biodegradation, which requires moisture levels of 40–60 per cent.[6,7] On the other hand, the dehydrating system had only 7 per cent moisture at four months (see Table 2), which is appropriate for a desiccating system. Thus, in terms of moisture content, the dehydrating system was performing better than the biodegrading system.

The mean pH of the two systems was below 8 for the biodegrading and approximately 10 for the dehydrating system (Table 2). The increased pH in the latter was the result of added lime. Since high pH values are known to promote the killing of pathogens, [2] the dehydration system had an advantage over the biodegrading system.

Indicator micro-organisms

There was a statistically significant difference over time in *Cryptosporidium* detected in the dehydrating system ($p=0.03$) compared to that of the biodegrading system ($p=0.80$) after six months (Table 2). This dramatic decrease was probably the result of the added lime, which increased pH in the dehydrating system. Moreover, it has already been mentioned that the biodegrading system was not optimized with respect to moisture content. For *Giardia*, there was also a decrease, but this was less pronounced, and the dehydrating system was statistically superior ($p=0.07$) when compared to the biodegrading system ($p=0.35$) after six months (Table 2). Although this assay does not measure viable oocysts and cysts, it is a valid indicator for their absence, which is the objective in this study.

After six months, both the biodegrading and dehydrating systems had the same level of faecal coliforms, 5.5 (i.e. $\log_{10}$ number of CFU/100ml = 5.5, Table 2). In both systems, the level of faecal coliforms present at two months was reduced by approximately a factor of 2 logs, or from 10 000 000 to about 100 000. This reduction was probably the result of desiccation rather than biodegradation or high pH, since the moisture content was low in both systems. Both the biodegrading and dehydrating systems had statistically significant differences in faecal coliforms over time, with $p=0.001$ and $p<0.02$, respectively.

Hot–arid climate

The climate was an important factor in the result that dehydration was better for treating biosolid waste. Summer months are hot and dry and winter months sunny, dry, and cool. With a year-round dry climate, moisture levels in the compost heap are lower than would be expected in humid, tropical environments. Thus, the biodegrading toilets did not perform well since the composting pile rapidly lost moisture to below the critical level required to support microbiological growth. In this study, on no occasion was the pile temperature found to be above that of the ambient temperature. This finding was consistent with that of our previous study on single-vault toilets.[8]

Based on moisture content and pile temperature, the desiccating toilet was the most appropriate choice in the dry atmosphere of northern central México. It also does not require stirring, which is an advantage in those societies where contact with human waste is considered offensive. Levels of indicator micro-organisms were greatly reduced after six months; however, it is difficult to say from this study how safe the resulting compost was, and it is generally considered necessary to take this compost to a special site for secondary composting and treatment before use as a soil additive. [9]

Conclusions

In general, all waterless toilet users were very satisfied with their new toilets regardless of the type. A feature that users considered important was the absence of flies and odour, which was an improvement on their previous pit latrine system. With respect to single- versus double-vault design, the double-vault system provided a clear and undisturbed separation of biosolids in the second chamber during the four-month treatment. The double vault also provided more room for the installation of the urinal in the dehydrating toilets. Disadvantages of the double-vault design were a slight increase in cost and a larger site required for construction.

Based on the micro-organism indicators used, the dehydrating system worked better, especially for treating *Cryptosporidium*. When all parameters (moisture content, pH, and micro-organisms) were considered, the better choice for treating biosolid waste in this study area was consistently the dehydrating system over the biodegrading system.

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agency news

WSSCC: Water, Sanitation and Hygiene for All, the WASH campaign

The Water, Sanitation and Hygiene for All (WASH) campaign is a concerted global advocacy effort by members and partners of the Water Supply and Sanitation Collaborative Council (WSSCC) to place water, sanitation and hygiene promotion firmly on the political agenda. A staggering 1.1 billion people worldwide are without access to safe water, and a further 2.4 billion people are without adequate sanitation facilities.

The WASH campaign was launched at the International Conference on Freshwater in Bonn, Germany, in December 2001. WSSCC is working with governments, parliamentarians, non-governmental organizations, community groups and other stakeholders to make true the *Vision 21* principal of a world, by the year 2025, where everyone knows the importance of hygiene, and enjoys safe and adequate water and sanitation.

The WASH campaign aims to raise the commitment of political and social leaders to achieving these goals and effecting the necessary behavioural changes through various information and communication channels; using traditional and mass media, promotion in schools, training and building local capacity in advocacy and improving networking and research. Under the guidance of the WSSCC Secretariat, national and regional co-ordinators champion the guiding principles of the WASH campaign in their respective regions and countries.

The practical benefits of the WASH campaign can be seen in various parts of the world. For instance, the WASH Campaign was launched in the Philippines in 2002. As a direct result of collaboration between local NGOs, local government agencies, the media, education, community and women's groups, the Isla Puting Bato pilot project, located along the northern harbour of Manila Bay, was initiated. The use of appropriate technology in setting up community built and managed water and sanitation infrastructure, has significantly enhanced the squatter community's physical quality of life. The success of the Isla Putting Bato pilot project will act as a blueprint for other areas of the Philippines.

In March 2003, at the Third World Water Forum in Kyoto, Japan, The United Nations Children's Fund and WSSCC announced the launch of a joint venture: WASH in Schools. It aims to empower young people (especially girls) through hygiene promotion and education, and will result in a safer and cleaner learning environment. Young people's involvement in the programme design is a key component of its innovative approach. The WASH in Schools venture is being implemented in many urban and rural areas of Africa, Asia and Latin America.

WSSCC is an international organization dedicated to enhancing collaboration in the water supply and sanitation sector. WSSCC's fundamental objective is to help provide safe and adequate water and sanitation services for poor people around the world. WSSCC helps sector professionals share their concerns, knowledge and experience with one another. It provides opportunities for problem solving, access to combined expertise and continuous dialogue on key issues. And it produces publications setting out guidelines, procedures and codes of conduct developed by experts working together over several years.

Matthew England, WSSCC. For more information about the WASH campaign and how to register as a WSSCC member, please visit the website: www.wsscc.org