REDUCTION EFFICIENCY OF INDEX PATHOGENS IN DRY SANITATION COMPARED WITH TRADITIONAL AND ALTERNATIVE WASTEWATER TREATMENT SYSTEMS

Thor Axel Stenström
Professor, Chief Microbiologist
Head of Department of Water and Environmental Microbiology
Swedish Institute for Infectious Disease Control
SE-171 82 Solna
SWEDEN

Introduction

Bad water, sanitation and personal hygiene combined are after malnutrition globally considered as the major treats to human health. According to Michaud et al (2001) malnutrition accounted for nearly 6 million deaths (11.7% overall) and 220 million DALYs (15.9% overall) and the corresponding figures for poor water supply, sanitation, and personal hygiene accounted for 2.6 million deaths and 93 million DALYs in 1990. These were considered the top 2 of risk factor groups for the total global burden of disease.

Tab 1. Global Burden of Disease and Injury Attributable to Selected Risk Factors in 1990. Adapted from Michaud et al (2001). DALY

Ranking	Risk Factor	Deaths	% of total Deaths	DALYs	%of total DALY
1.	Malnutrition	5880	11.7	220 000	16
2.	Poor water, sanitation and personal/domestic hygiene	2670	5.3	93 400	6.8
5.	Alcohol use	774	1.5	47 700	3.5
10.	Air pollution	570	1.1	7 250	0.5

In addition, infectious and parasitic diseases in developing countries rank among the foremost groups of diseases and have been estimated to represent up to 30% of the total disease burden in these regions. Due to the potentially high concentration of pathogens in fresh feces and low infective dose of viral and parasitic etiological agents direct exposure to small amounts of fecal material always constitute a health risk. Therefore the reduction of direct contact to fecal material is of prime importance in the reduction of potential disease transmission. Fecal contamination and disease transmission may also occur through indirect routes, like contaminated water, soil and vegetables and may also be transmitted to and by animals and birds, domestic or wild. This is of concern both in traditional exposure and sanitation as well as in relation to ecological alternatives. However, if the material is reused in agriculture or on different public premises transmission may be severe, as well as under traditional situations. It is therefore of importance to define the efficiency of different treatment and exposure barriers to safeguard against disease transmission.

A major challenge in ecological sanitation, where the nutrient rich urine and feacal fraction are circulated back to agricultural land as fertilizers, is to document that new transmission routes are not established of pathogens to human. In addition, a documentation of the efficiency of cheap low-cost on-site treatment options in destroying different types of pathogenic microorganisms is necessary. The risk of transmission should optionally be lower than the earlier prevailing situation and superior to traditional water sewerage.

Ecological sanitation versus traditional treatment

Investigations have been carried out in dry latrines in different regions of the world to get baseline values in assessing the efficiency of dry sanitation in relation to the die-off of different representatives of microbial groups. Traditionally evaluations are carried out with different types of indicator organisms instead of a direct evaluation of pathogens. This approach has also been taken with some ecosan evaluations. In a study performed in Mexico Redlinger et al (2001) investigated the occurrence of feacal coliforms in the collected dry material over a 6-month period. Only about 1/3 of the samples fulfilled the Class A values, according to the US EPA. The reduction of the coliforms was mainly related to the desiccation, with a higher percentage of drier samples fulfilling the regulations. 6 months storage gave lower values of coliforms. pH was not measured. US EPA applies a classification for reuse of biosolids (for Class A compost <1000 faecal coliforms/ g). In addition there is alternative options to measure the absence of viruses, helminth ova and Salmonella. EPA rules divide sludge — which it calls biosolids — into two categories, depending on how it is treated and cleaned (EPA 1999). The more expensive Class A treatment aims to kills all the pathogens that live in the waste. The more common Class B treatment kills some of the pathogens. CDC (US Center for Disease Control) is now recommending that all sludge be cleaned to Class A in US because of the risk that diseases could be transmitted through the Class B sludge.

Table 2. Summary of the effects of sewage sludge treatment on pathogens expressed as log_{10}- reduction (from US EPA 1999).

PSRP Treatment	Bacteria	Viruses	Parasites (protozoa & helminthes
Anaerobic Digestion	0.5-4	0.5-2	0.5
Aerobic Digestion	0.5-4	0.5-2	0.5
Composting (PSRP)	2-4	2-4	2-4
Air Drying	0.5-4	0.5-4	0.5-4
Lime stabilization	0.5-4	4	0.5

In Europe compost guidelines is currently under discussion. In the current official third draft from the EU committee, sludge is divided into an advanced and a conventional category. For the advanced treatment it is stated that the process should be initially validated by an at least 6 log reduction of a test organism such as *Salmonella senftenberg* 775w, should not contain any *Salmonella* in 50 g samples and less than 5×10^2 cfu/g with an at least 6 log reduction. For conventional treatment just a 2 log reduction of *E coli* is required. However in the later, the application rules for fruits and vegetables are very strict. Fruit and vegetables in contact with the site of application is not allowed for consumption within a 12 month period and if eaten raw, not for 30 months following application (Working Document on Sludge, 3rd official draft, EU, 2000).

It has been argued that the faecal enterococci are a more relevant measurement than faecal coliforms to measure the safety of a compost product. It has also recently been argued that the coliform guideline may be to stringent for wastewater irrigation in developing countries and could be relaxed to <10 000 faecal coliforms/100 ml (Blumenthal *et al*, 2000).
However, it is currently well known that indicators like the coliform organisms and fecal streptococci, may not necessary mimic, the occurrence, die-off and thereby risks of pathogenic organisms, These indicators does for example not follow the same die-off kinetic as viruses, parasitic protozoa and parasitic worms. It is therefore surprising that a choice can be made between evaluations based on coliforms and viruses or parasites in the US guidelines, and likewise surprising that the EU draft proposal still mainly consider the validation of bacteria, in this case *Salmonella senftenberg*, that actually have the capacity to regrow within the system, rather than an organism that do not regrow but are more resistant to environmental presure like viruses or parasites.

Contradictory to traditional analysis of the number of indicator bacteria, the approach in recent evaluations of ecosan has been to select more resistant representative organisms, like viruses and parasites. The die-off of these, here called index organisms, thereby aims to validate the process alternatives as such. This will also ensure an even higher reduction of pathogens of the respective group. In all investigations the reduction of viable organisms has been considered based on the last added ones, and not as a mean value during the collection period. All reductions of microorganisms are time dependent, independent of method. The reduction may vary from less than a minute in high temperature to “death of old age” after several years for parasitic ova under favorable conditions in soil. For the treatment it is therefore necessary to define a target time, which under the practical circumstances available, can be followed. This time has been set to six months for the dry ecosan toilets. Validations have been based on that.

Investigations have been carried out of the urine and the dry feacal fractions independently. In addition, wet thermophilic aerobic composting and traditional composting have been assessed or is under way of assessment. A factor analysis have been made, mainly taking into account time, temperature, pH and where appropriate moisture. Biological interaction has been less considered.

Table 3. Reduction efficiency in dry latrines, with a storage time of 6 months and a pH value in the material of around 9 or more. Based on validation of added organisms, or present organisms at time 0. Reduction values are given as log_{10} values.

Parameters	Reduction efficiency	Remark
Bacteria (coliforms)	> 6 log	Chinese experiments
Bacteria (fecal enterococci)	4-6 log	Extrapolations/Mexico
Bacteriophages (index virus)	5->6 log	Chinese experiments
		Vietnamese experiments

		Mexican
extrapolations		
Ascaris ova (index parasite)	100% reduktion	Vietnamese
experiments		
	of viability	Chinese
experiments		

In the material of the dry latrine material the destruction was mainly governed by time and high pH. The later ensured by addition of ash, lime or similar additives. Just addition of moisture absorbing materials should be disregarded, as they do not ensure an as efficient reduction. Within a time period of less than 6 months a total destruction of Ascaris ova occurred as well as of the index viruses used, if a pH of around 9 could be obtained. A decimal reduction occurred during shorter time periods. Reduction of Esherichia coli was generally faster, thereby not reflecting a die-off of non-bacterial pathogens. Likewise in collected urine pH around 9 seems to be a major reduction factor. Temperature also played a major role in collected urine with a faster reduction at 20 oC than at 4 oC. Higher temperatures have not been systematically evaluated but can be assumed to give a faster reduction. However, viruses seem to be reduced slower than other pathogenic groups.

Temperature is a major governing factor in reduction of most groups of pathogenic organisms. In the dry feacal material of the latrines temperatures above 45 oC were not registered. If temperatures of above 50 oC could be obtained a much shorter collection time could still ensure a more or less total destruction of pathogens. This is evident when comparing the results with a aerobic thermophilic wet composting system, where a total destruction of both Ascaris ova, index viruses, index bacteria as well as traditional bacterial indicator organisms occurred within 48-72 hours at temperatures around 55 oC. However, in this system a re-infection of the material with some bacterial pathogens may result in an after-growth.

Comparative discussion

If requirements of time, temperature or pH are met, and during certain circumstances with a synergistic effect of low moisture, all the tested ecological sanitation treatment alternatives independent of region, where superior to traditional wastewater treatment. A normally functioning traditional wastewater treatment plant (mechanical, chemical and biological treatment) will give a reduction of about 1-3 logs of different groups of pathogens dependent of type of organism. A similar reduction is obtained in traditional soil infiltration systems. A six-month storage of dry collected feacal material at pH 9 will give an additional at least 3 log reduction to a total eradication of pathogens. However regrowth may occur, due to partial wetting that start a degradation or localized composting, favoring short periods of growth. Stabilization ponds in tropical areas may under optimal conditions give a similar reduction but are water dependent and does not support a similar nutrient circulation to arable land. Within the current guidelines for reuse of wastewater and excreta (Mara & Cairncross, 1989) reference is made to expected removal efficiency of different types of treatment processes (Tab 4).

Table 4. Expected removal of excreted organisms in various wastewater treatment processes (from Mara & Cairncross 1989). Values are expressed as $\log_{10}$ removals.

Treatment process	Bacteria	Helminths	Viruses	Cysts
Primary sedimentation (plain)	0-1	0-2	0-1	0-1
Primary sedimentation (chemically assited)	1-2	1-3	0-1	0-1
Activated sludge	0-2	0-2	0-1	0-1
Biofiltration	0-2	0-2	0-1	0-1
Aerated lagoon	1-2	1-3	1-2	0-1
Oxidation ditch	1-2	0-2	1-2	0-1
Disinfection	2-6	0-1	0-4	0-3
Waste stabilization ponds	1-6	1-3	1-4	1-4
Effluent storage reservoirs	1-6	1-3	1-4	1-4

It can, thus, be concluded that based on the investigations so far performed, the on-site ecological sanitation treatment alternatives, are a favorable and partly superior alternative to traditional wastewater treatment. Further insights in transmission due to handling, collection and scaling-up is however necessary, since current investigations still have been done on a limited scale. Regrowth potential of indicator organisms and bacterial pathogens are also of concern. Prospective epidemiological investigations furthermore can give insight in the impact of introducing these systems on a larger scale.

References

Blumenthal U, Mara D, Peasey A, Ruiz-Palacios G and Stott R. Guidelines for the microbiological quality of treated wastewater used in agriculture: recommendations for revising WHO guidelines. Bulletin of the World Health Organization 78(9):1104-1116

EPA.(1999) Control of Pathogens and Vector Attraction in Sewage Sludge. EPA/625/R-92/013

Mara D, Cairncross S. Guidelines for the safe use of wastewater ad excreta in agriculture and aquaculture, 1989, WHO

Michaud, C., Murray, C. and Bloom, B. 2001. Burden of Disease—Implications for Future Research. JAMA. 2001;285:535-539

Redlinger T, Graham J, Corella-Barud, V, Avitia, R. Survival of fecal coliforms in dry composting toilets. Appl Environ Microbiol 2001, 67(9):4036-4040.