PRACTICAL ACTION
Technology challenging poverty

technical brief

REUSE OF FAECES AND URINE FROM ECOLOGICAL SANITATION

Introduction

The concept of ecological sanitation (ecosan) has been explained in the technical brief *Ecological Sanitation: A Concept*. This brief outlines in more detail the methods used to render both faeces and urine safe for agricultural use and provide guidance on application methods.

Excreta from one person can provide nearly enough nutrients to produce approximately 250kg of cereal per annum (Strauss, 2000). This is one of the reasons the resource has been used throughout history in both aquaculture and agriculture (the by-product from ecosan is usually used in the latter). Historically excreta has not always been treated before use, correctly operated ecosan allows excreta to be reused whilst minimising health risks.

This valuable resource should be used safely; the 'f-diagram' shows the numerous routes by which disease from excreta can be transmitted and the barriers to these infections. When considering the re-use of urine and faeces from ecosan the barrier of most interest is the blocking faeces transmission from fields. Figure 1 identifies toilets as a means of preventing transmission. Re-using excreta from ecosan retains the toilet barrier, but, as opposed to containing faeces, ecosan toilets treat it prior to application. In addition ecosan can reduce flies and prevent pollution of groundwater and other freshwater sources.

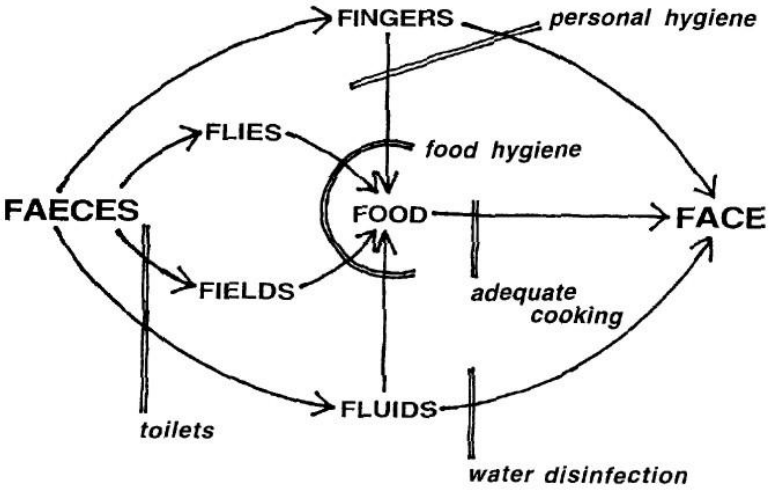

Figure 1: F-diagram including barriers to potential infection routes [Illustrator: Uno Winblad; Source: Esrey et al, 1998]

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This technical brief briefly explains when risks are associated with re-use and who is at risk during each stage. There is some explanation of the treatment methods for the three types of product i.e. faeces, urine and combined urine and faeces. Finally some practical guidelines are given on how to apply excreta and how to do this safely.

Stages of exposure

There are essentially six phases in the re-use of urine and faeces, table 1 shows these phases and who is at risk during each phase. It also suggests some possible mitigation procedures at various stages, some of which will be discussed in more detail later.

Table 1 – Major exposure points when reusing excreta [Adapted from: WHO, 2006]

Risk Activity	Exposure Route	Groups at Risk	Mitigation
Emptying collection vessel/chamber	Contact	Entrepreneurs Residents Local community	Protective clothing Training Optimise on-site treatment Avoid spillage
Transportation	Contact Spread through equipment	Entrepreneurs Local community	Clean equipment before using it on other material Avoid spillage
Secondary (off-site) treatment	Contact Vectors	Workers Nearby community	Efficient treatment Protective clothing Restrict access Reduce vector propagation
Application	Contact Inhalation	Entrepreneurs Farmers Local community	Work material into soil Restrict access to field if quality is not guaranteed Protective clothing for workers
Crops, harvest, processing and sale	Consumption Handling	Consumers Workers Vendors	Allow one month between application and harvest Food consumed raw is highest risk Protective clothing Provide water for cleaning
Consumption	Consumption	Consumers	Practising good hygiene Cooking thoroughly

Many practical steps to ensure the excreta is used safely are discussed below, these focus mostly on the application, harvesting and consumption of crops. One of the simplest methods to mitigate all risks is to ensure thorough primary treatment (on-site) takes place. The earlier in the sequence of events treatment takes place the better, as risks will be minimised further down the line. The methods used to kill pathogens will now be discussed in order to clarify the factors affecting pathogen survival in excreta.

Factors contributing to pathogen die off

The factors listed in table 2 cause pathogens within excreta to die off. One or a combination of these will render faeces safe, note that urine does not contain a high level of pathogens and a certain level of storage will render it completely safe (see below).

Table 2: Factors affecting micro organisms in the environment
[Adapted from Schonning and Strenstrom, 2004]

Temperature	Most micro organisms will survive well at low temperatures (<5 ºC), die off occurs at high temperatures (40-50 ºC). Unfortunately many ecosan composting processes do not reach these temperatures throughout the entire volume of the compost.
pH	Micro organisms survive best at pH neutral (7), if a mixture becomes very acidic or alkaline pathogens will die off. Therefore lime is added to ecosan toilets to increase pH (a pH >9 is required), the higher the pH the higher the die off rate (if pH >11-12).
Ammonia	High levels of ammonia kill off pathogens, chemicals can be added.
Moisture	A low moisture content will kill pathogens, this is the reasoning behind dehydrating ecosan latrines. A satisfactory moisture content target would be <25%.
Solar/UV light	UV-light reduces pathogen numbers, therefore the die off of pathogens after application to fields will increase.
Other organisms	Micro organisms live longer in sterilized material, therefore when soil (as well as other materials) is added the competing bacteria encourage die off.
Nutrients	Due to the nature of the dangerous pathogens they are unable to compete with other pathogens for scarce nutrients resulting in die off of pathogens from excreta.
Others	Oxygen availability can also affect pathogen survival, as can the presence of various organic and inorganic compounds.

This table shows the factors that kill pathogens, the particular pathogens located within faeces and urine will not be listed in detail. The following sections looks into the best way to treat each component, both separately and when they are mixed together, along with guidelines on application practices.

Faeces

When separated from urine, faeces contain a minimal level of nutrients and high level of pathogens. Despite this it contains the bulk of organic material and makes a very good soil conditioner.

Pathogens

The pathogens found within faeces can be split into four categories, bacteria, viruses, parasitic protozoa and helminths. This brief will not describe the pathogens in any great detail; diseases which can be transmitted include cholera, typhoid and hepatitis A.

Treatment of faeces

There a numerous means of reducing the pathogen content in faeces, some can be advised as primary treatment (on-site; within the sanitation systems itself), whereas others should be recommended as a secondary (off-site) treatment. The main reason for employing primary treatment is to reduce volume and weight of faecal sludge this facilitates simpler storage, transport and secondary treatment, and in some cases reduces pathogen content to make further handling safer. Secondary treatment makes the faeces safe enough to return to the soil. The following are the main treatment methods.

Storage – Through storage of faeces a number of the processes within table 2 will take place. Storage is often recommended as a primary treatment method, the success displayed in practice is variable. The pH of the material, the moisture content, ambient temperature and biological competition will all affect die off, since these factors will vary continuously the level of pathogen die off will also vary. Different studies have shown the required storage time to be different however the WHO guidelines (WHO, 2006) suggests that if the ambient temperature is between 2 – 20 ºC a storage period of 1.5 – 2 years will be sufficient, and for an ambient temperature of 20 – 35 ºC a storage duration of 1 year or more is needed. Storage is best applied alongside other measures and is limited by the die off of Ascaris eggs.

Heat Treatment/Composting – High temperature is one of the most reliable methods of reducing pathogen content, thermophilic composting is one method of ensuring high temperatures. Although many toilets are described as composting they do not actually maintain these conditions which require good management to hold a temperature of > 50 ºC for > 1 week (WHO, 2006) (despite this the storage conditions can still render faeces safe). Faeces can also be solar heated whilst composting to increase the temperature. Composting is best applied as a secondary large scale treatment process where it can be adequately managed. Small scale composting needs further evaluation.

Alkaline Treatment – This can take place using either ash and lime or urea. Ash and lime can be added at a household facility level to provide a primary level of treatment, raising the pH above 9 will assist die off in combination with storage. Further benefits include reduced smell, reduction of flies (as material covers faeces) and assistance in moisture content reduction. At least 1 – 2 cups (200-500 ml) of ash and/or lime should be added after each defecation (or enough to cover the faeces) (Schönning and Stenström, 2004). Urea is an additive used for elevating the pH level of faeces, it can also add to the fertilizer value. It is generally accepted as a method for larger scale secondary treatment when professionals can handle the chemicals.

Incineration – This process is accepted to be for larger scale secondary treatment when it needs to be assured that no pathogens remain, the resulting ash will have a lower nutritional value as the nitrogen is lost. Moving the waste to incineration will pose a health risk to workers. Further evaluation of incineration in practice still needs to take place.

Practical guidelines for application

The following practical recommendations should be followed when applying faeces to land, treatment processes may allow survival of some pathogens and precautions should be taken (Slob, 2005):

- personal protective equipment such as gloves and washing of equipment and hands should be practiced;
- a period of one month should be observed between fertilizing and harvesting, allowing further die off of pathogens whilst the material is on the crops;
- large levels of phosphorous in faeces make this a good indicator for application rates, more detailed information can be found from EcoSanRes (n.d:b);
- equipment for sanitised material should not be used for un-sanitized material;
- faeces should be worked into the soil to minimise exposure to humans or animals;
- crops that are consumed raw (except fruit trees) should not be fertilized with faecal material;
- faeces should be buried deep, but not below the rooting depth of the crop; and
- faeces should be added to soil before planting of crops.

Following these guidelines will minimise the risk of disease transmission. Four separate methods to apply faeces are suggested by Slob (2005):

- ploughing with tractor or animal drawn;
- burying faeces under a layer of plain soil forming a bed;
- placing faeces into channels and covering with unmixed soil; and
- placing into holes close to where crops will be planted and covering with soil.

Storage

Stored material should be kept dry before use, this could be achieved by elevating and covering the material. Animals and children should not be allowed access to the stored material, simply fencing off the area can achieve this.

Alternative use for faeces

If use of faeces in agriculture is not culturally acceptable the material could be mixed with animal manure and added to a bio-gas digester, although this technology is yet to prove very reliable. If responsibly handled, faeces can also be buried in shallow pits and a tree planted

on top, in a similar vein as an 'aborloo'. If use is not possible at all the faeces should be disposed of safely.

Urine

Urine carries the majority of nutrients and few pathogens. This is one of the reasons for employing urine diversion methods as the nutrients are preserved. This section will run through the main methods of urine treatment, the methods for application and other practical recommendations.

Pathogens in urine

Pathogen content in urine is very low, the majority being present due to cross contamination with faeces. Therefore it is of primary concern not to allow faeces into diverted urine.

Treatment

Due to the lower pathogen content the treatment methods of urine are much simpler than for faeces. Storage remains the main methodology. In all cases it is preferable that urine is not diluted, as undiluted urine increases die-off of pathogens and prevents mosquitoes breeding. Treatment options are outlined below.

Storage – This has long been the accepted method of treatment, the level of pathogen die-off will vary with additional factors, most notably temperature. At a household level it is generally acceptable for the urine to be applied to land without storage as long as the crop is for the households own consumption and a month passes between fertilising and harvesting. This is advised because person-to-person transmission of disease within the household is of greater probability than transmission of disease through contaminated crops. Table 3 shows the recommended storage times at different ambient temperatures.

Table 3: Recommended storage time for urine based on ambient temperature
[Adapted from: Schönning and Stenström, 2004]

Storage temperature (°C)	Storage time	Possible pathogens present after storage	Recommended crops [a]
4	≥ 1 month	Viruses, protozoa	Food and fodder crops to be processed
4	≥ 6 months	Viruses	Food crops to be processed; fodder crops[b]
20	≥ 1 month	Viruses	Food crops to be processed; fodder crops[b]
20	≥ 6 months	Probably none	All crops[c]

[a] – The recommended crop is for larger systems where crops will be consumed by individuals other than members of the household where the urine was collected.
[b] – Not grasslands for production of fodder.
[c] – For food crops consumed raw leave one month between fertilising and harvesting and work the urine into the ground where the edible part of the plant is above the soil surface.

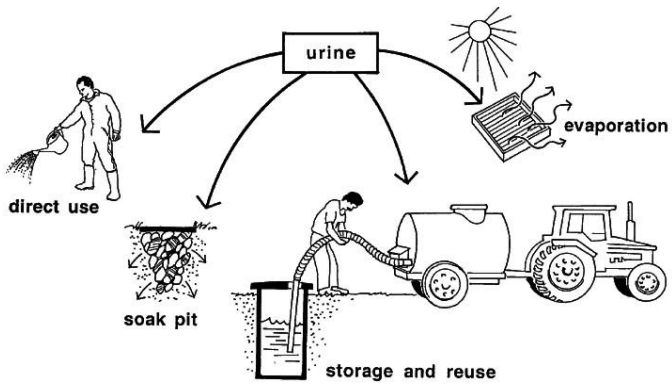

Figure 2: Options for re-use of urine from ecosan.
[Illustrator: Hans Mårtensson; Source: Esrey et al, 1998]

Other Treatments – Storage is the only treatment method that has been widely practiced to date. Evaporation of urine to concentrate nutrients has been attempted but is not yet efficient enough to practice. Increasing the temperature and/or pH of the urine will speed up inactivation further. Increasing temperatures above 20°C have not yet been practiced (Schönning and Stenström, 2004).

Application of Urine

Urine can be dealt with in a number of ways. As mentioned above, direct use should only be practiced on a household level, on a larger scale one should practice storage and re-use. In some ecosan toilets the urine will automatically go to a selected soil bed for soaking or to fertilise a small group of plants (e.g. the Kerala double vault dehydration toilet). The various options are shown in figure 2.

The following are practical recommendations when utilising urine from ecosan facilities (WHO, 2006; Schönning and Stenström, 2004; EcoSanRes, n.d:a; EcoSanRes, n.d:b; Slob, 2005):

- urine should ideally be worked into the soil, this could be achieved via mechanical means or it could be subsequently watered into the soil i.e. with irrigation water (as mentioned urine should ideally not be stored diluted);
- the urine should be applied close to the ground to minimise aerosol formation, this could be done manually or, on a larger scale, with agricultural equipment;
- if *Schistosoma haematobium* is endemic in a region the urine must not be used near freshwater sources;
- a general rule of thumb is that the urine from one person in 24 hours can be applied to $1m^2$ of land per growing season (guidelines based on local fertiliser requirements can be found from EcoSanRes (n.d:b));
- use of urine should stop between approximately 2/3 and 3/4 of the time between sowing and harvest, after this time the plants reach their reproductive stage and take up less nutrients; and
- if the urine is likely to have suffered cross contamination further precautions such as protective clothing should be worn. Hand washing should always be practiced.

Alternative use for urine

If the use of urine is not culturally acceptable in food production, the urine can also be added to compost piles to assist the decomposition process. As mentioned the urine can also be soaked away, evaporated or discharge to a plant box connected directly to the toilet.

Mixed faeces and urine

In some forms of ecosan urine diversion does not take place and the faeces are mixed with the urine. In this case the waste is treated in the same way as faeces. The most established ecosan systems using this method are the Fossa Alterna and the Aborloo. If removed from the pit the resulting compost is similar to that from just faeces, carrying no offensive smell and resembling soil (figure 3).

Figure 3: Inspecting mixed compost.
[Source: Morgan, 2007]

Pathogens

The pathogens in the material will be the same as faeces, the difference will be that many useful nutrients contained within the urine may be lost in the process. Assuming enough educational support and cultural acceptance urine diversion should ideally be used, as this utilises the most useful aspects of both components.

Treatment

Treatment processes are relatively similar to those for faeces, but the inclusion of urine makes the systems less dry and therefore less susceptible to treatment from reduced moisture content. The process mostly involves competition with other organisms (within the soil or added material) and increased temperature. Secondary treatment typically takes place by leaving the waste in the ground and using an alternate pit. Some methodologies will then remove the waste from the pit after a set period of time (long enough to allow pathogens to die off - approximately 1-2 years in tropical conditions), whilst others simply use the nutrients by planting a tree directly onto the pit once it becomes full.

Application and storage advice

In application and storage mixed urine and faeces should be treated the same as separated faeces.

General guidance on application

Alongside the points above there are some more general recommendations (Schönning and Stenström, 2004):

- urine diversion is generally recommended;
- twin pit collection within in a sealed vault is preferable;
- every effort should be taken to reduce faecal contamination of diverted urine;
- solar heating can increase die-off of pathogens;
- toilet paper should be collected separately unless composting or incineration are the intended treatment processes;
- anal cleansing material should not be collected with urine;
- stones used for anal cleansing should be collected separately, vegetable material used for this purpose can be added to the faeces compartment;
- contents of nappies/diapers should be emptied into the faecal compartment;
- other material such as sanitary napkins should only go into the faecal compartment if they are degradable, otherwise they should be treated as solid waste; and
- if diarrhoea is prevalent extra absorbent material may have to be added.

Conclusion

There are clearly many important considerations for householders when using ecological sanitation. This technical brief has described the main treatment methods and application techniques, wherever possible the following control measures should all be practiced (WHO, 2006):

- treatment of excreta;
- crop restriction (e.g. only applying material to crops that are either non-food crops or require cooking before eating).
- practice recommended excreta handling and application techniques;
- allow recommended time between fertilising and harvesting/consumption;
- practice appropriate food preparation (e.g. peeling, washing and cooking); and
- restrict exposure to excreta and implement hygiene education.

The WHO guidance notes on this topic have recently been revised and provide excellent guidance on the topic (WHO, 2006), as do publications by Schönning and Stenström (2004) and Jönsson et al (2004).

The benefits of ecological sanitation are potentially high, following these guidelines will assist in ensuring that these benefits are achieved safely and hygienically. It is worth bearing in mind the barriers illustrated in figure 1 and ensuring that communities practice all possible initiatives to reduce the risk of faecal-oral disease. Simple hand washing devices are detailed in Morgan (2007) that could be installed near to ecosan facilities and other toilets, they should also be adopted for use by those applying material from ecosan facilities to fields.

References and further reading

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- *Lifting the Lid: Ecological approach to toilet systems*, Peter Harper with Louise Halestrap, CAT (address as above) ISBN 1 89804 979 3
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- Practical Action Technical Briefs Sanitation and Waste

Useful websites

WASTE (a Dutch NGO) is doing a large amount of work on ecological sanitation. Information can be found at www.ecosan.nl

A Swedish funded ecological sanitation research group provide a wide range of useful information at www.ecosanres.org

The German international cooperation enterprise for sustainable development, GTZ, provide a wealth of technical information at www.gtz.de/ecosan

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