Green techniques for toilet waste management in emergency situations

Lebanese Red Cross and Swedish Red Cross

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Preamble

With over 1.5 million Syrian refugees in Lebanon, the impacts of protracted conflict continue to worsen. Refugee settlements are scattered throughout the country and vary in size and conditions. Already inadequate service provision in the country is under severe strain with intensified demand. For example wastewater management has been poor for a long time with only around 8 % of total wastewater treated before the Syria crisis. Increased pressure on wastewater management services, is resulting in a negative impact on the environment, health and society.

Together with Red Cross and Red Crescent (RCRC) movement partners, the Lebanese Red Cross (LRC) has built strong experience implementing Water Sanitation and Hygiene (WASH) activities designed to support host communities and Syrian refugees. As a key supporter of the overall LRC WASH program, the Swedish Red Cross (SRC) works in partnership with the French Red Cross (FRC) and the International Red Cross Committee (ICRC). The specific aim of SRC's contribution is to "improve the WASH facilities and provide direct assistance to Syrian refugees and host communities in Zahle, Saida and Tripoli". The SRC support to LRC encompasses safe water supply, access to improved sanitation facilities and hygiene promotion. Two pilot projects funded by SRC are currently focused on green and sustainable solutions in the field of solid waste management and blackwater management.

This report is the result of a feasibility study presenting the findings that offer a way to evaluate different techniques for blackwater/toilet waste treatment in Lebanon. This has occurred through the development and use of criteria through the Open Wastewater Planning tool.

The aim of this study is for LRC and other RCRC National Societies to use this report as a guide when implementing toilet waste management activities in both host and refugee communities. The report explores sanitation and health aspects, considerations such as maintenance, working environment, community engagement, cost, product quality and environmental issues. It will therefore be particularly relevant for technical practitioners, program staff and interested sector colleagues as the techniques outlined include a technical description which can be used to strengthen implementation in different contexts. Technique suitability depends on the often highly localised circumstances including hazard profile, vulnerability and community resilience. The technical examples provided here should be used to encourage local solutions and promote best practice.

The report has been produced by the Swedish consultant company Water Revival Systems.

Content

1 Introduction

The project has been carried out by WRS AB, Water Revival Systems, Uppsala, Sweden, for the Swedish Red Cross. WRS is a consultant company with long experience of small scale waste water treatment in Sweden and abroad, with focus on outdoor and recycling systems. Project leader has been Ebba af Petersens and Tova Forkman has been case worker. Peter Ridderstolpe has contributed as an expert. Peter Ridderstolpe has developed the tool Open Wastewater Planning, described in section 3.

1.1 Purpose

The purpose of the project is to find, describe and evaluate different methods for sanitization and treatment of black water from toilets in refugee camps - informal tent settlements (ITS) - in Lebanon.

The project was carried out in the following steps:

- Relevant criteria were listed on basis of environmental and health aspects, the Lebanese rules on discharge of wastewater, and the Red Cross and the users' need of well-functioning and economical methods for treatment. These criteria are a result of a workshop in Uppsala, Sweden, but can be completed afterwards if necessary.
- Different alternatives for treatment are presented in the report. The alternatives that fulfilled the criteria are described more thoroughly. This includes technical descriptions, hygienic aspects and how the solutions work practically.
- During the workshop, the alternatives were evaluated according to the criteria and compared.
- The described alternatives will serve as a "tool box" for the Red Cross in Lebanon and elsewhere – various techniques to choose between in future situations and locations.

1.2 Conditions and delimitations

The focus has been to find solutions for treatment of blackwater (see section 2.1 Toilet waste below). Some solutions with dry toilets have also been included. The solutions should not include permanent structures, such as centralised pipes systems, as the ITS only are temporary.

2 Background

2.1 Toilet waste

In the Lebanese ITS the toilet waste normally is in the form of blackwater. Blackwater is used to describe wastewater containing faeces, urine and flushwater from flush toilets along with anal cleansing water (if water is used for cleansing) or toilet paper. Depending on type of toilet and the flush volume, the blackwater can have a higher or lower content of water, hence a higher or a lower concentration of pathogens, nutrients and organic material. A lower flush volume gives a smaller volume of blackwater to collect and transport.

A dry toilet is a toilet without flushing, for example a composting toilet. In a composting toilet, dry organic material such as sawdust or peat moss is often added to obtain optimal moisture for the composting process. Adding of organic material also results in less odour and flies, which can be the case if the toilet waste is too wet. The toilet waste from a dry toilet can be more or less dried and more or less composted, depending on type of toilet system, load, and how often the collection container is emptied.

From urine diverting toilets, the toilet waste comes in two fractions – urine and faeces. Urine is diverted in a separate pipe to a container, and faeces, sometimes together with toilet paper, is collected usually in or below the toilet. The two fractions are handled separately. Apart from collecting urine for usage as plant fertilizer, the diverting toilets also contribute to a lower water consumption, less odour, and a more easily handled faecal fraction.

Beside of toilet waste, water from showers, kitchen and washbasins (so called greywater) is also produced from households. If possible it is recommended to keep the toilet waste and the greywater separated. One big advantage of keeping the toilet waste separate from greywater is that the toilet waste, which is a small volume to handle compared to the greywater, contains a lot of pathogens and nutrients that can affect drinking water and cause problems in the environment. The greywater is therefore much less contaminated and consequently needs less treatment before being discharged into a ditch, river or a lake.

Another advantage of keeping the toilet waste separate from greywater, is that the nutrients in the toilet waste can be used as fertilizer on farmland or forest. The table below shows the nutrient content in toilet waste from a person during a year.

Table 1. Nutrient content in toilet waste, per person and year.[1]

Kg/p yr	Urine	Faeces	Total
Nitrogen (N)	4	0,6	4,6
Phosphorous (P)	0,4	0,2	0,6
Potassium (K)	1	0,4	1,4

A rule of thumb is that urine from one person during one day is sufficient to fertilize one square metre of crop[2]. But it is recommended to calculate the application rate based on local recommendations for a certain crop and the nutrient content in the urine or blackwater to be used.

All types of toilet waste are recommended to be sanitized before being used as fertilizer, if used on production of crops for human consumption.

In chapter 4, where the different techniques are presented, there is a section discussing the quality of the toilet waste. Some methods can be used for all different types of toilet waste, whereas other methods require for example a dry material from a composting

[1] Vinnerås, B. 2002. Possibilities för sustainable nutrient recycling by faecal separation combined with urine diversion. Swedish university of agricultural sciences.
[2] Jönsson et al. 2004. Guidelines on the Use of Urine and Faeces in Crop Production. EcoSanRes Report 2004-2.

toilet. The techniques based on larvae or worms are usually sensitive to high urine content.

2.2 Greywater

In this report focus is on blackwater and toilet waste management due to the description of the project. Nevertheless, some questions about greywater management were discussed during the workshops.

Greywater contains most often less nutrients and far less bacteria and hazardous substances than toilet waste. Due to this greywater treatment seems easier to handle, especially from a working environment perspective. Still, the volume of greywater is much higher than blackwater, and it has to be taken care of to avoid local problems with standing water, flies, odour, contamination of local drinking wells etc. Characteristic of greywater is that it often contain high concentrations of easily degradable organic material, i e fat, oil and other organic substances from cooking, residues from soap and tensides from detergents. Greywater therefore needs some kind of biological treatment, for example in a sand filter, before being discharged of in a safe way.

Greywater can be used as a resource, for watering of plants for example. It can also be infiltrated through the soil and form groundwater.

To evaluate possible solutions for greywater management in the ITS, the same questions as in workshop 1 (described in section 3.1) should be answered: - what kind of criteria are most important, is there a working infrastructure, what kind of greywater do we have (quality and amount), before a solution is chosen.

2.3 Regulations on wastewater discharge and reuse in Lebanon

Discharge of wastewater to the sea, surface water and to sewerage systems in Lebanon is regulated by national wastewater standards[3]. Table 2 gives an extract from the standards of Environmental Limit Values (ELV) for wastewater discharges into surface water in Lebanon.

Table 2. Extract from Standards of Environmental Limit Values (ELV) for wastewater discharges into surface water
(Ministry of Environment. Decision No. 8/1, March 2001).

Parameter	For discharge to the sea	For discharge to surface watercourses	For discharge to downstream sewer networks
Total Phosphorus mg/l	10	10	10
Total Nitrogen mg/l	30	30	60
Ammonia mg/l	10	10	-
BOD mg O_2/l	25	25	125
COD mg O_2/l	125	125	500
Coliform Bacteria 37°C in 100 ml	2000	2000	-

Wastewater for crop irrigation is permitted in Lebanon. There are four classes of reclaimed wastewater, with different approved uses, depending on the wastewater treatment quality. To be reused for irrigation of food crops, at least tertiary wastewater

[3] Ministry of Environment. Decision No. 8/1, March 2001.

treatment is required, and there should be no contact between the edible portion of the crop and the wastewater. In general the following apply for reuse of wastewater:

- Effluent shall not be used to spray irrigate food crops;
- Effluent shall only be applied to slopes greater than 15° by trickle irrigation;
- Effluent shall be applied so both direct and windblown spray remains within the area approved for application
- No irrigation shall take place within 400 m of surface waters used for potable supply; and
- The depth to ground water below irrigated areas shall be 3 m or more.

There are not yet Lebanese standards for the effluent to be used for reuse. The Red Cross follows FAO Wastewater quality guidelines for agricultural use[4], with for example recommendations on microbiological quality.

3 Method

The project is carried out using the planning tool Open Wastewater Planning. This tool is developed specifically to help analyzing and developing criteria for water and sanitation systems due to the local circumstances. The tool provides a structured method to evaluate different techniques, and to find the best solution for the specific situation.

In order to find and evaluate techniques suitable for the local circumstances, it is important to set up criteria of what the technique needs to achieve. This was done through a workshop where staff from the Lebanese Red Cross and the Swedish Red Cross participated. The criteria involve technical performance as well as maintenance, user aspects, environmental aspects, organisation and economy. By involving relevant stakeholders early in the process, their needs and preferences are also included in the criteria. Therefore the final choice of solution will be well suited for the specific situation as well as well-anchored among the stakeholders.

Information about the various techniques was found by search in literature, interviews with researchers and experts, and by study visits to relevant Swedish sites and to the Swedish University of Agricultural Sciences.

3.1 Workshop 1 - criteria

At the first workshop the current situation in the ITS in Lebanon was presented and discussed. The following work was done in small and large groups focusing on functions important for the wastewater system in the camps. Below are the instructions for the group work:

[4] FAO, 1992. Wastewater treatment and use in agriculture.

Group work – ”beehives”

1. For yourself: think about which functions are important for the wastewater system in Lebanese refugee camps. 3 min.
2. In groups of two or three: discuss together, and write down each function on a post-it note.
   - Are there some important functions missing?
   - Are some of the functions contradictory?
   - Are the aspects of: installation/building, use, operation and maintenance all covered?
3. After about 10 minutes, put your post-its on the white-board.
4. Discussion in the whole group

5. Discuss the importance of the different functions, and then prioritize on the post-it notes:
   - Put a 1) on the most important functions
   - Put a 2) on the functions that are important, but can be modified
   - Put a 3) on the functions that are desirable, but less important.

The result of the first workshop, presented in section 3.3, was a list of important criteria or functions. The different functions were discussed by the group. From the list of important criteria or functions, each participant then ranked the functions or criteria as follows: 1) most important functions listed, 2) important functions that may be modified and 3) desirable functions but less important. The individual ranking was compiled and added to the list, which can act as a checklist when discussing future systems (see appendix 1).

3.2 Workshop 2 - techniques

The second workshop focused on the techniques for treatment and sanitization of toilet waste.

The current system was described and discussed. The common system that the Lebanese Red Cross is using in the ITS is pit latrines. If the area is sensitive, the sides of the pit are sealed with concrete bricks. In the bottom of the pit, water can infiltrate, while sludge is trapped in the pit. The pits are emptied when needed, normally once a year. The waste is at best transported to a wastewater treatment plant, but not seldom illegally dumped in a ditch or other place.

The latrine includes a squatting toilet, and a water tap for washing (Figure 1). There is a separate tap for cooking and drinking water. Water is often transported to the ITS, and stored in tanks, one for each household. The handwashing water from the toilet house is led to the pit. The grey water from the kitchen tap is led to a soak pit.

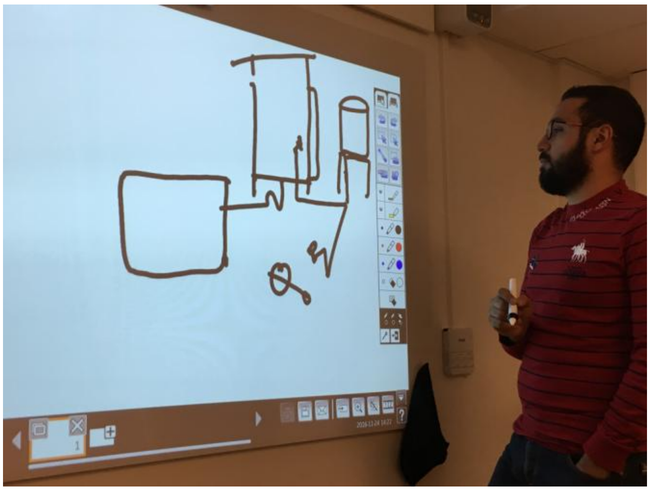

Figure 1. Sketch of the current system for handling toilet waste.

A number of relevant techniques were presented and discussed. Based on the criteria set up in workshop 1, the various techniques were evaluated (Figure 2).

Figure 2. Evaluation of the suggested techniques.

3.3 Assessment

At the workshop, a list of desired functions or criteria for the future system for handling toilet waste, were set up by the group. The different criteria were sorted under different headings, and then evaluated on how important they are. Below are the list of criteria, where the green are the ones the group regarded as most important, see also Appendix 1.

Table 3. Criteria for the future system for handling toilet waste

Health

Decrease pathogens

Environment

No harm product
Protect waters
Zero Waste (reuse of materials)

Resource management

End product should be re-usable (handling)
Low energy demand
Final destination??

Economy

Cost efficient
Source of income solution

User aspects

Low maintenance (easy to repair) and low energy consumption
Consider cultural background and acceptance
Inclusion of the community in the solution (community board)
Accepted from community and culture
Access during all times a day

Institutional aspects

Collection and transport systems
Build society community capacity

Technical function

Sustainable and long term solution
Decentralised solution
Scale-wise, flexible
Decrease produced volume
Material needed from local market
Simple and easily maintained technology
No permanent infrastructure
Robust system

The techniques, presented in chapter 4, were evaluated according to the criteria above. The complete evaluation can be found in Appendix 2, and is summarized below.

Table 4. Evaluation of techniques, summary.

Criteria/ Techniques	Lime	Urea/ Ammonia	Vermi-compost	Black soldier flies	Reed bed	Open dry compost	DRDO Bio-digester *
Health	🟢	🟢	🟢	⚫	🟢	🟢	⚫
Environment	🟡	🟢	🟢	⚫	🟡	🟢	🟡
Resource management	🟡	🟢	🟡	⚫	🟡	🟢	🟡
Economy	🟢	🟡	🟡	🔴	🟡	🟢	🔴
User aspects	🟢	🟡	🟢	🔴	🟡	🟢	🟢
Institutional aspects	🟡	🟢	🟢	🔴	🟢	🟢	🔴
Technical function	🟢	🟢	🟡	🔴	🟡	🟡	🟡

🟢 Green marker: the technique seems to meet the criteria
🟡 Yellow marker: the technique seems to almost meet the criteria
🔴 Red marker: the technique does not seem to meet the criteria
⚫ Black marker: more information is needed about the technique

The techniques that the group regarded as fulfilling the criteria the most were sanitization with urea/ammonia and open dry compost. The technique with larvae from black soldier flies, and the DRDO Biodigester that the Red Cross currently is testing, did not seem to fulfil some of the criteria set up by the group, given the information they had about the techniques. More research and information about these techniques is required, before being realistic alternatives.

This evaluation is not absolute, it is only a hint of which techniques are interesting to find more information about, and which are irrelevant to discuss any further at the moment. When more information is found, the evaluation can be done again. The evaluation, together with the information of the techniques, is a good base for finding the best solution for a specific situation.

4 Different techniques for toilet waste management

The different techniques that were presented at workshop 2 are described in more detail in this chapter. The information given responds to the criteria from workshop 1.

The following techniques were evaluated to fulfil the criteria:

- Sanitization of toilet waste with lime
- Sanitization of toilet waste with urea/ammonia
- Open dry compost
- Vermicompost

The following techniques were discussed during work shop 2 and are also presented in the report:

- Black soldier flies (larvae)
- Reed bed
- Filter technique with biochar
- Constructed wetlands

The techniques that fulfilled the criteria contains a bit more technical information and also some comments on reference plants.

In this chapter, some information about the investment cost and the maintenance cost is given but no amounts are specified since they will vary between different countries. The cost will also differ for the same solution since it is possible with different scales and different ways to build the same solution.

4.1 Collection and transport

It is important to keep in mind that regardless the choice of toilet and choice of method for treatment and sanitization of the toilet waste there will be an end product that needs to be collected and handled.

Most of the different techniques need some kind of collection container in or near each toilet, and often also another container for a central treatment. The container can be of different material and constructed in different ways, depending on the scale and what is available on the local market. On household level, the toilet waste can be collected in a plastic bin or a tank below ground.

Figure 3. Simple collection container for urine using an IBC container. Example from the Philippines. Photo: Ebba af Petersens

On village level, for example a central treatment, a clay or rubber sealed dam, or a large concrete container can be used.

Figure 4. Rubber sealed dams for storage of blackwater. Example from Enköping, Sweden. Photo: Ebba af Petersens.

Before choosing a method for sanitation the management of the end product need to be taken in account. It is important to evaluate what kind of transport system is possible in the camps as some kind of transport almost always will be needed.

4.2 Techniques for treatment of toilet waste in informal tent settlements in Lebanon

In this chapter possible techniques for treatment of toilet waste from ITS in Lebanon are presented. The techniques have been evaluated in a workshop and found fulfilling most criteria set up by the group (described in section 3.1 and 3.2).

4.2.1 Sanitization of toilet waste with lime

The technique involves adding lime to the toilet waste, in order to eliminate pathogens. The addition can be done before or after the addition of toilet waste in the container and the sanitization is due to the high pH-value. Depending on which form of lime is used the pH-value will differ. It is possible to treat different types of toilet waste (see section 2.1) with lime. Important aspects are the amount of lime added, pH-value and time.

Technical description

The lime is added and mixed with the toilet waste in a container; see Figure 5 for examples (adding lime is similar to adding urea or ammonia). The lime could be added in the container before or after the toilet waste is added. Sometimes stirring is needed; it depends on the water content in the toilet water and the duration of the treatment. The wetter the less need of stirring, and the longer duration of the treatment the less need of stirring. It is recommended to add an amount of lime which is equal to up to 15 % of the wet volume.

It is possible to use containers in different scales but is most common in bigger scales (like a container per camp or village for example). It is most common to use a container construction in concrete and a construction that enable stirring. The lime is then added in the big container and the toilet waste is collected from each household and added to the big container. When the container is full the content is stored for as long time as needed to be sanitized.

Hygienic aspects

The sanitization is due to the high pH-value. The pH-value have to be higher than, or at least, pH12 during the sanitization process[2].

The duration of the treatment depends on the concentration and which type of lime is used. If $Ca(OH)_2$ is used the duration is about three months and if CaO is used the temperature will increase and the duration therefore will decrease[5], and be shorter than three months. The duration needed is the time the substance has been in contact with the lime, meaning that if substance is added at different times to the same container the time needed is counted from the last adding of substance.

To evaluate the sanitization the temperature and the pH-value need to be measured to ensure that the pH-value is higher than 12 during the whole treatment process. The temperature can be measured to evaluate if the duration could be decreased due to a high temperature.

[5] Vinnerås, B, 2013. *Hygieniseringsteknik för säker återföring av fosfor i kretsloppet* [Techniques for sanitation and circulation of phosphorus]. Uppsala: SLU Department of Energy and Technology.

Quality of substance needed

For sanitization with lime the quality of the toilet waste (substance added in the container) can differ, see chapter 2.1. It is possible to use blackwater, toilet waste from dry systems or urine and faeces from separated systems[3].

Maintenance, working environment and user aspects

Lime should be handled with care due to risk of corrosive injury because of the high pH-value. Lime also give rise to dust which affect the working environment negatively[6].

The maintenance needed except from adding the lime is, in some cases, some kind of mixing or stirring and emptying the container. Mixing, or stirring, is needed when the water volume in the toilet waste is low to obtain a homogeneous mixture[7]. After the treatment is done the container needs to be emptied and the treated toilet waste need to be transported somewhere else.

Economical cost

The economical cost consists of investment costs and maintenance costs. The investments costs consist of the containers and, if used, also the stirrers. The maintenance costs consist of purchase of lime.

End product and environmental issues

The addition of lime to the toilet waste contributes with increased value as a fertilizer, especially on loamy soils. On the other hand, due to the high pH-value the end product is not recommended on growing crop but on uncultivated soil[2]. If not stored in a closed container, the treated toilet waste may have lost a considering part of the nitrogen content due to ammonia losses. Moreover ammonia is a green house gas, so ammonia loss to air should be avoided if possible.

References

Treatment with lime is a common method for sanitizing wastewater sludge and also to reduce pathogens in manure.

Short summary:

The advantages with this technique are:

- It is possible to use for different types of the toilet waste.
- Low cost possible.
- Low technical need.
- Lime is easy to purchase

The disadvantages with this technique are:

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[6] Länsstyrelsen i Västra Götalands län, 2011. *Kretsloppsanpassning av små avlopp* [Circulation managemant of small sewage]. Rapport 2011:33, ISSN 1403-168X. Länsstyrelsen i Västra Götalands län, vattenvårdsenheten.

[7] Avfall Sverige, 2007. *Alternativa hygieniseringsmetoder* [Alternative methods of sanitation]. Rapport B2007:1, ISSN 1103-4092. Malmö: Avfall Sverige Utveckling.

- There is a risk with the maintenance/working environment when adding lime.
- Mixing or stirring will probably be necessary.
- Risk of ammonia loss.
- Primarily a solution for a village, not suitable on household level.

4.2.2 Sanitization of toilet waste with urea/ammonia

Adding urea or ammonia is more or less the same kind of technique as adding lime. The urea or ammonia can be added before or after the toilet waste is added in the container and the sanitization is due to the high pH-value. The technique is applicable in different scales and it is also possible to use on different types of toilet waste. Important aspects are concentration/amount of ammonia-nitrogen, temperature, pH-value and time.

Technical description

When adding urea ($CO(NH_2)_2$) or liquid ammonia for sanitization, it is important to use a closed container, otherwise the ammonia will evaporate and then the amount needed will increase. The container is often constructed in concrete or plastic/rubber. The sealing could be a rubber sheet or a lid of plastic for example. Sometimes stirring is needed, it depends on the water content in the toilet water and the duration of the treatment. The wetter the less need of stirring, and the longer duration of the treatment the less need of stirring.

The recommendation is that stirring should be done in combination with adding the urea or ammonia[8]. Urea can be added as a liquid or as granulate. The amount ammonia needed is up to 1 % of the wet volume which contributes to an amount of 2 % of the wet volume if urea is used instead of ammonia. The advantage, according to the users in Sweden, with liquid urea is that it is possible to pump it which make the adding procedure easier. Another advantage with liquid urea compared to urea granulate is that it takes shorter time to be mixed. Although the time for urea granulate to get properly mixed is only around one hour if stirring is used. The disadvantaged with liquid urea compared to granulate is that the liquid urea demands more space to store and will probably need more transportation.

It is possible to use containers in different scales. The scale can differ from one container (or bag) per toilet visit (so called peepoo bag[9]) or a big container per camp or village. Figure 5 shows two examples of closed containers for central storage from e.g. a village. Figure b is a permanent concrete tank, and figure c is a portable flexible tank in a rubber material or PVC.

[8] Nordin, Annika; Researcher at the Department of Energy and Technology, Environmental Engineering Unit, Swedish University of Agricultural Sciences. 2017

[9] www.peepoople.com

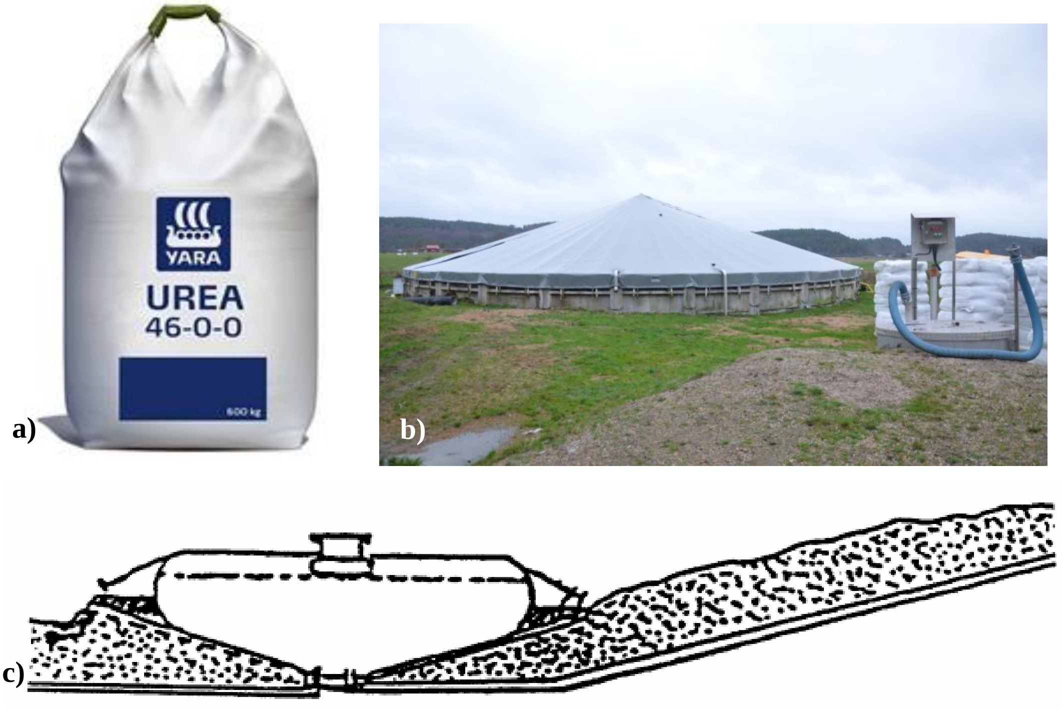


Figure 5 a) Urea is a common nitrogen fertilizer, which can be used for sanitization of blackwater or sludge. (Photo: Yara)
b) Swedish example, large covered container for treatment of blackwater with urea. (Photo: E af Petersens)
c) Flexible bladder tank. (Source: Björn Vinnerås, SLU)

The urea or ammonia can be added in different ways and stages in the process. For example, the urea or ammonia can be added in an empty container which is connected to the toilet. The container can also be separated from the toilet, then the toilet waste needs to be collected and transported to the container for treatment. The urea or ammonia can also be added directly in the container connected to the toilet and then, when the container is full, transported to a container for central storage with the rest of the toilet waste from the same camp for treatment during the right amount of time.

Hygienic aspects

The sanitization is due to the high pH-value and the high concentration of ammonia, and especially the amount of uncharged ammonia[10]. When the pH increase the amount of uncharged ammonia is increased and therefore the effect is better at a higher pH-value. Sanitization with urea or ammonia usually works at a pH-value higher than 8,5 but a pH-value at around 9 is recommended. There is no need for high temperatures, but the higher the temperature the lower amount of urea is needed, and the method will work at temperatures as low as 4 °C even though better results has been showed at temperatures above 20 °C. If the temperature is increased above 20 °C it will have a big impact on the duration needed to fulfil the sanitization requirement.

[10] Nordin, A. et al, 2006. *Ammonia and urea manure hygienisation*. Rapport – miljö, teknik och lantbruk 2006:02, ISSN 1652-3237. Uppsala: SLU Department of Biometry and Engineering, Uppsal.

The duration of the treatment depends on the concentration of ammonia and the total concentration of ammonia-nitrogen but the time needed can vary between 0,5 days up to 200 days depending on the concentration of ammonia, the temperature and which requirements of sanitization that is required[11], see also table Table 5.

Table 5. Treatment time required to achieve a reduction in Salmonella spp. and E.coli, Enterococcus and Ascaris eggs in source-separated faeces during urea treatment (0-2% urea) at temperatures 14, 24 och 34°C. Source: Nordin, 2010[12]

Temperature (°C)	Urea (% w/w)	*Salmonella and E. coli* *(7 log_{10})*	*Enterococcus* *(5 log_{10})*	*Ascaris* eggs (3 log_{10})
14	0	10 months	Slow reduction	–
	1	2 months	14 months	–
	2	2 weeks	8 months	–
24	0	1.5 months	7.5 months	11 months
	1	1 week	3 months	7 months
	2	<1 week	2.5 months	2.5 months
34	0	1.5 weeks	1 months	1.5 months
	1	<1 week	2.5 weeks	1.5 weeks
	2	<1 week	<2 weeks	<1 week

The duration needed is the time the substance has been in contact with the ammonia or urea, meaning that if substance is added at different times to the same container the time needed is counted from the last addition of substance. If the ammonia is preserved in the material, there is a very low risk for regrowth of bacteria.

To evaluate the sanitization effect, the temperature, the pH-value and the concentration of the total amount of ammonia nitrogen need to be measured.

Quality of substance needed

For sanitization with ammonia or urea the type of toilet waste can differ. It is possible to treat blackwater (urine, faeces and water from flushing or washing), toilet waste from dry systems or urine and faeces from separated systems[8]. There is no need for extra addition of ammonia or urea if the urine is collected separately due to the high concentration in the urine itself.

Maintenance, working environment and user aspects

Liquid ammonia should be handled with care due to risk of corrosive injure because of the high pH-value. Urea as a granulate on the other hand does not have the same attributes and is not that corrosive. When using ammonia instead of urea a lower amount needs to be added. This is because of the pH-value increase faster when adding liquid ammonia compared to adding granulated urea[8].

[11] Vinnerås, B, 2013. *Hygieniseringsteknik för säker återföring av fosfor i kretsloppet* [Techniques for sanitation and circulation of phosphorus]. Uppsala: SLU Department of Energy and Technology.

[12] Nordin, A. (2010) Ammonia Sanitisation of Human Excreta. Treatment Technology for Production of Fertiliser. Doctoral Thesis No. 2010:67, Faculty of Natural Resources and Agricultural Sciences. Swedish University of Agricultural Sciences.

The maintenance needed except from adding the urea or ammonia is, in some cases, some kind of mixing or stirring and emptying the container.

Economical cost

The economical cost consists of investment costs and maintenance costs. The investments costs consist of the containers and, if used, also the stirrers. The maintenance costs consist of purchase of urea or ammonia. Urea is a common nitrogen fertilizer and should be easily available in Lebanon.

End product and environmental issues

Blackwater or latrine treated with urea or ammonia is nitrogen rich and free from pathogens, and is therefore an excellent fertilizer. The treated toilet waste may lose a considering part of the nitrogen content due to ammonia losses if an open container is used. Moreover, ammonia is a greenhouse gas, so ammonia loss to air should be avoided if possible.

References

Urea is commonly used for sanitization of blackwater in Sweden for example. Urea already exist in the market as a fertilizer which makes it easy to get hold of. In Sweden urea is used both in liquid form and as a granulate.

Short summary:

The advantages with this technique is:

- Different scales of the solution are possible
- Low risk of regrowth of bacteria in the toilet waste
- It is possible to use for different types of toilet waste
- The end product has a high nutrient value due to the adding of urea or ammonia, and is therefore interesting as a fertilizer.

The disadvantages with this technique is:

- There is some risk with the maintenance/working environment when/if adding ammonia

4.2.3 Open dry compost

An open dry compost is very commonly used in Sweden for example. It requires a dewatered toilet waste which is transported to a compact plate where it is stored over time. Open dry composts are commonly used in big scales, for many households, and the storage need to be separate from people and animals or fenced (see Figure 6).

Figure 6. Sketch of an open dry compost.

Technical description

In many cases the toilet waste is stored on a plate of concrete. It is possible though to use other kind of layers if the infiltration is low (like loam for example).

During storing the waste needs to be turned due to oxygen supply and to achieve a homogenous temperature. An open dry compost requires relatively much space (see Figure 7).

A rubber sheet or some other sealing could be used to increase the temperature and decrease the duration until full sanitization is met.

Figure 7. An example of an open dry compost. The picture is taken from: http://gwri.calpoly.edu

Most open dry composts used are in big scale with toilet waste from many households, but it is also possible on household level.

Figure 8. Small scale open dry compost. Example from the Philippines.
Photo: Ebba af Petersens

Hygienic aspects

Sanitization is due to time. If the temperature is increased the time needed will decrease. The time needed will differ but some in between 6 months and 2 years.

When using techniques based on sanitization by time there is always a risk of regrowth, nevertheless this is a worldwide used technique and it is possible to combine different techniques if needed/wanted.

To evaluate the reduction of pathogens the temperature and the time needs to be measured.

Quality of substance needed

To use an open dry compost the toilet waste need to be dewatered and dry, for example from a dry toilet or a urine diverting toilet.

Maintenance, working environment and user aspects

The maintenance needed is turning of the material. In big scale a tractor, or similar, is needed for the turning.

There is a risk of odour and a fence or some kind of enclosure will be needed to prevent human and animals from contamination.

Economical cost

The investments cost consists of building the plate if the soil not is impermeable by itself (clay for example). The maintenance cost consists of turning the compost with some kind of tractor. Transport of the toilet waste from the camp to the location of the compost will also be needed.

End product and environmental issues

The end product can be used as a soil improver or fertilizer. The nitrogen content is often low, due to ammonia loss.

References

Open dry compost is used widely in Sweden as a technique for stabilisation and storage of dewatered, and often also digested, sludge from waste water treatment plants.

Short summary:

The advantages with this technique are:

- It is easy to use in big scale

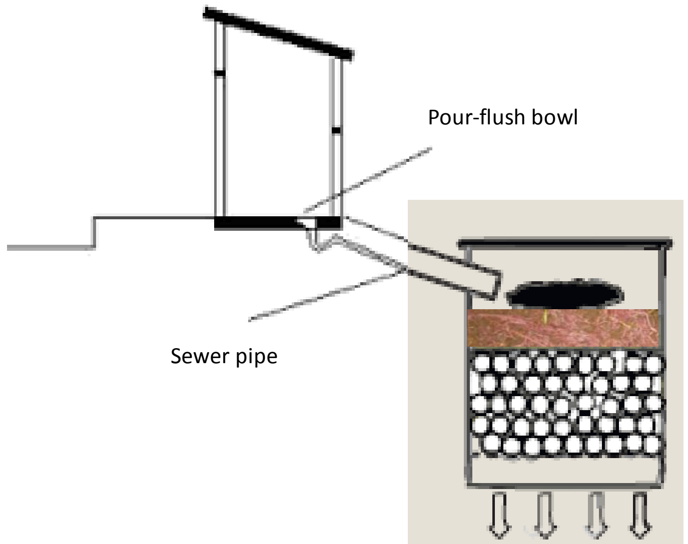
The disadvantages with this technique are:

- There is a risk of regrowth of bacteria
- Not applicable for all types of toilet waste. The toilet waste needs to be dewatered or dry.

4.2.4 Vermicompost

The toilet waste is placed in a container with worms in (see Figure 9 for an example). The worms reduce harmful bacteria and also reduce the volume of the waste[13]. It is important to keep a good environment for the worms (e.g. temperature, pH-value, oxygen supply and humidity).

[13] Nordin, Annika; Researcher at the Department of Energy and Technology, Environmental Engineering Unit, Swedish University of Agricultural Sciences. 2016.



Source: https://www.wsp.org/ *Source: http://www.bearvalleyventures.com/#!tiger-1*

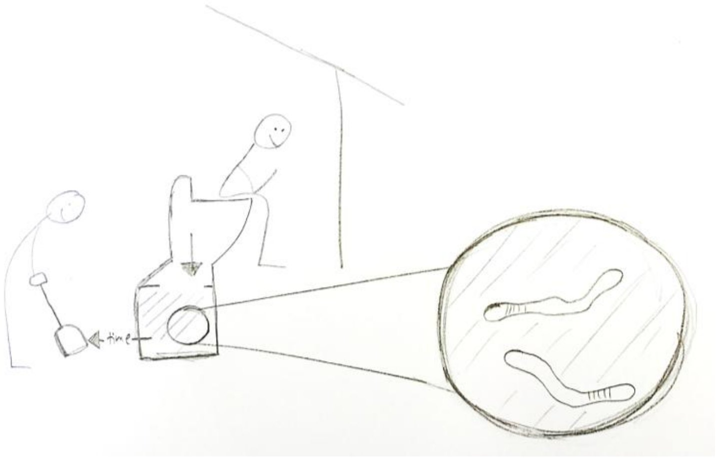


Figure 9. Two examples on composting toilet. The first picture shows a vermicompost in a semi-wet system (pour-flush) and the second picture shows a vermicompost in a dry system. The first picture is a combination of two pictures taken from https://wsp.org/ and http://www.bearvalleyventures.com/#!tiger-1

Technical description

This technique is applicable with different scales on the container/compost. The toilet can be connected directly to the container/compost or the toilet waste from many toilets can be transported to a larger compost for central storage (see Figure 10 for example). The container can be built in different layers where the toilet waste is added at the top layer and the treated end product is emptied from the bottom layer instead of emptying the entire container at the same time. If the container is sealed it is important to have a stabilized compost and to have zones with oxygen (buffer zones). These zones can consist of straw or paper. The buffer zones should be as porous as possible. The worms process the toilet waste in the top of the compost and if there is around 15 kg of worms they will decompose around 15 kg/m^2.

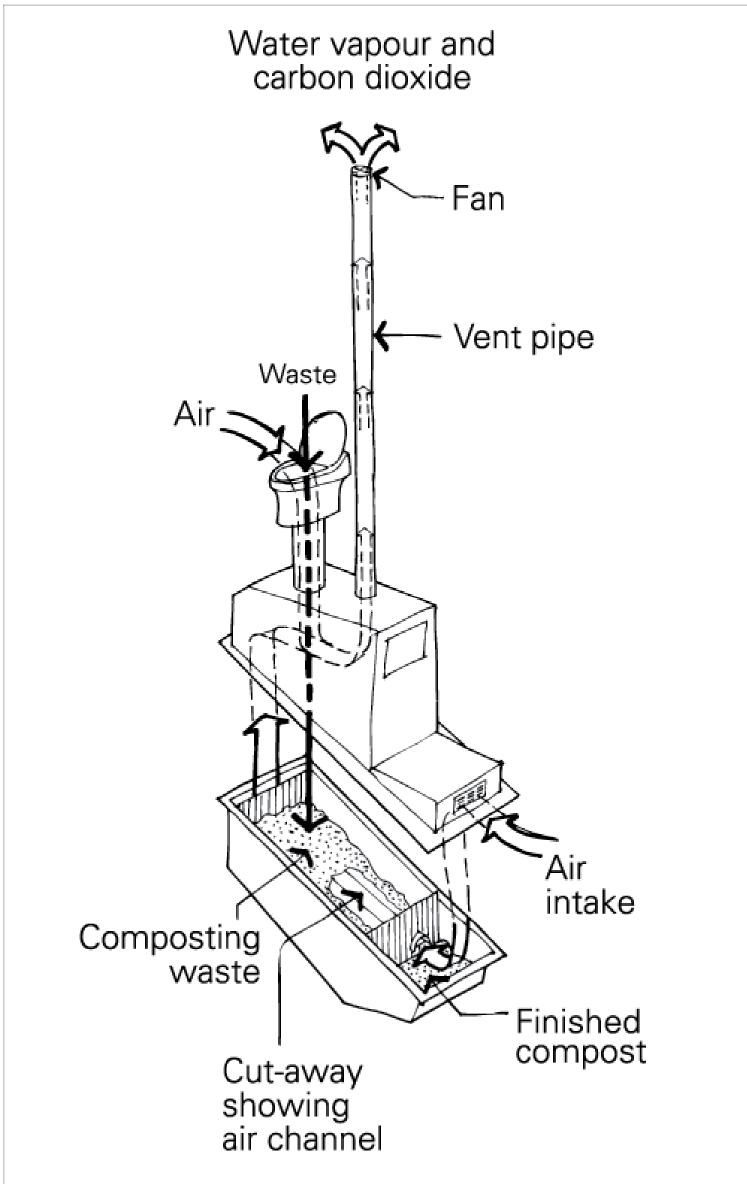


Figure 10. Example of a composting toilet. The picture is taken from: http://www.yourhome.gov.au/water/waterless-toilets

It is recommended to use so called tiger worms (Eisenia feotida), or local variations of epigeous worms, which can be found all over the world[14]. It is often possible to buy a start-up kit with worms, otherwise they could be find in dunghills. It is possible to use earthworms but they are not as effective when it comes to decomposing toilet- or food waste as the epigeous worms.

The worms will regenerate by them self after added in the compost, if the environment is good. If the entire container is emptied at the same time there will be a need of regeneration/replacing of worms if the container should be used as a compost again. The worms duplicate within a month and will regulate the quantity by them self relating to the environment and the access of substrate (toilet waste). It is recommended to have a big quantity of worms, a big quantity also improves the environment for them. The worms will process approximal their own weight a day and it is therefore recommended to have

[14] Cecilia Lalander, Researcher at the Department of Energy and Technology, Environmental Engineering Unit, Swedish University of Agricultural Sciences. 2017

the same weight of worms in the compost as the weight of toilet waste added in the compost per day[15].

The worms can be sensitive to changes in their environment such as increasing or decreasing temperature and pH-value, not enough oxygen or humidity for example. It could also be necessary to cultivate worms for regeneration of the compost. The temperature should be around 5-29 °C and the humidity around 60-75 %[16] and the pH-value some were in between 5 and 7. It is recommended to place the toilet waste in thin layers/small amounts per time at the top of the compost.

Hygienic aspects

Sanitization of the material is due to time and the amount of worms. As described above it is recommended to have a large amount of worms. Vermicomposts are used to decrease the volume of the toilet waste and due to that minimizing the times you need to be in contact with the toilet waste. There is still research ongoing on the sanitization effects in this kind of composts. In a continuous process, the compost substrate should be left to further composting for some months when the container is full[17]. Research has shown that some pathogens, salmonella for example, is inactivated or destroyed but eggs from parasites could still be active afterwards.

To evaluate the sanitization, the time after the compost is full needs to be measured, the time it takes for sanitization of the toilet waste more is some months. It is also important to control the environment for the worms, as pH, temperature and humidity.

When using techniques based on sanitization by time there is always a risk of regrowth, nevertheless this is a worldwide used technique and it is possible to combine different techniques if needed/wanted.

Quality of substance needed

When using sanitization with worms it is most common to use dry material as dewatered sludge or separated faeces or a mix of black water and other substances to make it drier (e.g food waste). The worms are sensitive to ammonia so if a dry toilet is used the urine needs to be separated. If a wet system is used the ammonia is in a lower concentration and is not that harmful for the worms. Some studies have shown that solutions using only separated faeces has a higher reduction of E.coli for example[18].

Some studies have been done using wet systems (e.g. flushing toilets) which shows good results[19] but it is still most common to use dry systems.

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[15] Cecilia Lalander (same as 10)

[16] Hill, G. B., Baldwin, S. A. 2012. Vermicomposting toilets, an alternative to latrine style microbial composting toilets, prove far superior in mass reduction, pathogen destruction, compst quality, and operational cost. *Waste Managemant*. 32: 1811-1820.

[17] Cecilia Lalander. (Same as 11)

[18] Hill, G. B., Baldwin, S. A. 2012. Vermicomposting toilets, an alternative to latrine style microbial composting toilets, prove far superior in mass reduction, pathogen destruction, compst quality, and operational cost. *Waste Managemant*. 32: 1811-1820.

[19] Furlong, C., Templeton, M. R., Gibson, W. T. 2014. Processing of human feaces by wet vermifiltration for improved on-site sanitation. *Journal of Water, Sanitation and Hygiene for Development.* 4 (2): 231-239.

Maintenance, working environment and user aspects

The maintenance needed is emptying the container and also some control of the status of the worms. Depending on how the system is built and the function of the system, cultivation of worms could be necessary.

If the container is ventilated there are none, or a very low, risk of odour and there are then no problems with the working environment.

Economical cost

The investment cost consists of the compost. The maintenance cost consists of cultivation of the worms.

End product and environmental issues

The end product could be used as soil improvement or fertilizer. The end product should not be used as a fertilizer on crop that is eaten raw. The nutrient content is lower when using a vermicompost compared to adding urea or ammonia for example.

References

There is a lot of different examples on vermicomposts around the world. In France, for example, they use a separating toilet system combined to a vermicompost (for pictures and more information: https://www.flickr.com/photos/gtzecosan/sets/72157625874807184/). In Uganda they use vermicompost for composting manure from cows and in New Zeeland they have a big scale compost where the worms decompose a mixture of sludge from paper mills and sludge from dairy industries.

Short summary:

The advantages with this technique are:

- Different scales of the solution are possible
- The maintenance and the maintenance cost is very low
- The volume of the end product is reduced

The disadvantages with this technique are:

- There is a risk of regrowth of bacteria
- The worms are sensitive to changes in their environment
- Cultivation of worms could be needed

4.3 Other interesting techniques

In this chapter the techniques that did not fully fulfil the criteria are presented. Also, some techniques where there is a lack of knowledge from full-scale use and techniques with on-going research are presented. The information given in this chapter is, because of that, not that thorough as in chapter 4.2.

4.3.1 Black soldier flies (larvae)

The toilet waste is placed in a container with larvae from black soldier flies (see Figure 11 for an example) and works in similar way as the vermicompost. The larvae reduce the volume of the waste but the research about the reduction of pathogens (e.g. the sanitization) is still ongoing[20]. It is important to keep a good environment for the larvae (e.g. temperature, pH-value, oxygen supply and humidity).

Figure 11. Black soldier flies larvae. The picture is taken from: blacksoldierflyblog.com

Technical description

This technique is possible in different scales of the compost. The toilet can be connected directly to the container/compost or the toilet waste from many toilets can be transported to a larger container for treatment. The container can be built in different layers where the toilet waste is added at the top layer and the treated end product is emptied from the bottom layer instead of emptying the entire container at the same time (see Figure 10, the same figure as for the vermicompost).

The larvae can be sensitive to changes in their environment such as increasing or decreasing temperature and pH-value, not enough oxygen or humidity for example. It is also necessary to cultivate larvae for regeneration of the compost since it is difficult to control where the flies lay their eggs.

Hygienic aspects

Research is ongoing to evaluate the sanitization effect[12].

Quality of substance needed

When using the treatment with larvae for sanitization it is most common to use only separated faeces since the larvae has shown sensibility to urine.

Maintenance, working environment and user aspects

The maintenance needed is emptying the container and also some control of the status of the larvae. Cultivation of larvae is necessary and work consuming.

If the container is ventilated there are none, or a very low, risk of odour and therefore low risk in the working environment. When the larvae become flies they may be a problem if

[20] Vinnerås, Björn; Researcher at the Department of Energy and Technology, Environmental Engineering Unit, Swedish University of Agricultural Sciences. 2016.

they are enable to fly in to the toilet or to other places where the can spread disease to humans.

Economical cost

The investment cost consists of the container. The maintenance cost consists of cultivation of the larvae or buying larvae.

End product and environmental issues

The end product could be used as soil improvement or fertilizer. The nutrient content is lower when using a larvae compost compared to adding urea or ammonia for example. Due to the lack of knowledge about the bacteria reduction, reuse of the end product should be done with care, for example not as fertilizer for vegetables.

Short summary:

The advantages with this technique are:

- The volume of the end product is reduced

The disadvantages with this technique are:

- More research is needed about the pathogen reduction
- The larvae are sensitive to changes in their environment
- Cultivation of larvae is necessary

4.3.2 Reed bed

A reed bed is a sort of combined infiltration plant and compost (see Figure 12 for example). Sanitization and treatment is done by time and biodegradation. It is important with a good drainage system and the plants and the microorganisms play an important role for the function of the system.

Figure 12. An example of a reed bed "in action", picture from: http://www.reedbeds.co.uk.

Technical description

The reed bed is built with different layers to provide good drainage for the water which will infiltrate through a layer of microorganisms (a kind of biofilter, see Figure 13)[21]. The toilet waste is transported to the reed bed from every single toilet or collected and then transported to the reed bed.

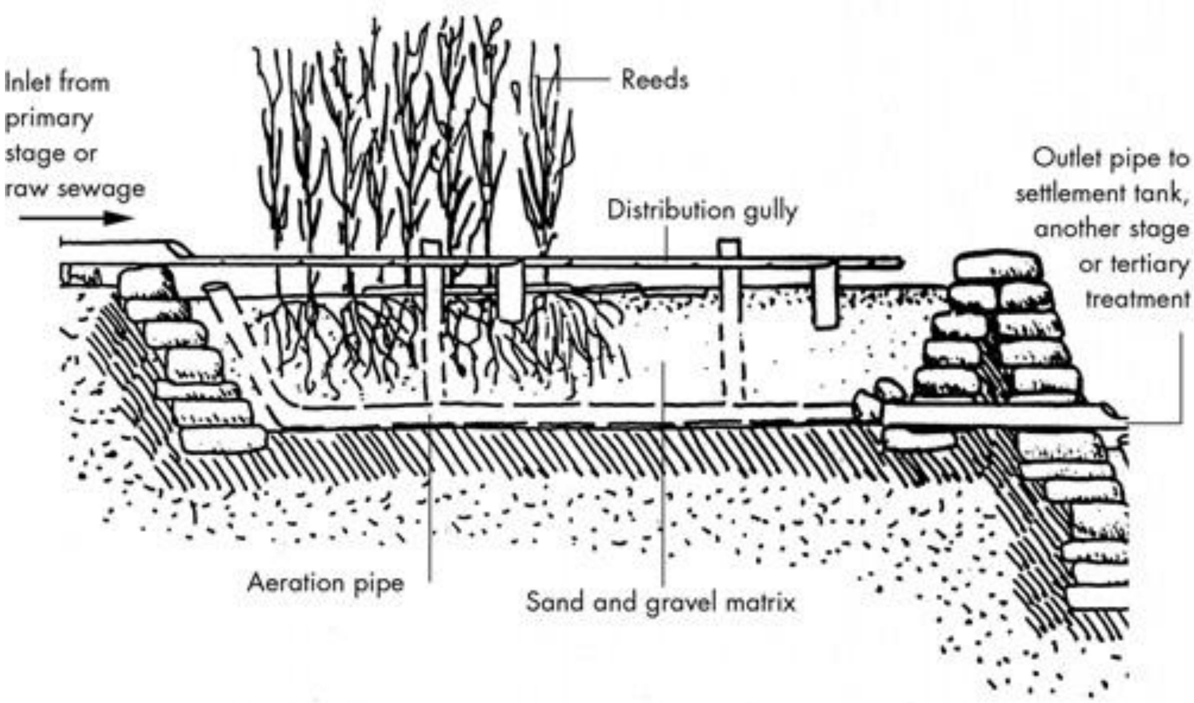

Figure 13. An example of the construction of a reed bed, picture from http://tcpermaculture.com

The bed could be built with an open bottom or open walls letting the water infiltrate through the natural soil to the groundwater or the bed could be built with sealed walls and bottom and the water is collected in a resorption ditch and lead to a tank or a soak pit. The plants will contribute with oxygen and will also stabilize the material and microorganisms will decrease the bacteria.

It is important to use plants that thrive in such environment, it is important to take in account if the toilet system is wet, semi-wet or dry and the local environment.

Hygienic aspects

Sanitization is due to time and biodegradation by the plants and the microorganisms. If the temperature is high the time needed is shorter than in colder climates.

When using techniques based on sanitization by time there is always a risk of regrowth, nevertheless this is a worldwide used technique and it is possible to combine different techniques if needed/wanted.

To evaluate the expected sanitization the time needs to be measured.

[21] Malmén, L., 1999. *Kretsloppsanpassning av hushållens avlopp och organiska köksavfall på Vätö* [Techniques for circulation of food waste and toilet waste from housholds on Vätö]. ISSN 1401-4955. Uppsala: Jordbrukstekniska institutet (JTI).

Quality of substance needed

For sanitization in a reed bed the quality of the substance can differ. It is possible to use black water, toilet waste from dry systems or faeces from separated systems.

Maintenance, working environment and user aspects

The reed bed requires a very low maintenance. The plants need to be cut/harvested every year.

A fence or some kind of enclosure will be needed to prevent people and animals from contamination.

Economical cost

The investment cost consists of building the reed bed. The maintenance cost consists of cutting the reed sometimes.

End product and environmental issues

The volume will be reduced in the reed bed over time. The reed bed can be leaved as it is or the sludge could be transported to other places after sanitization is done. The end product could be used as soil improver.

The technique requires a safety distance from the ground water level and therefore not suitable in areas with a high ground water level.

Short summary:

The advantages with this technique are:

- It is possible to use different quality of toilet waste
- The volume of the end product is reduced
- Emptying of the reedbed is normally not needed more than 1-2 times every 10 years.

The disadvantages with this technique are:

- The solutions require digging/construction in the ground
- The technique requires a safety distance from the ground water level
- Large area is needed.

4.3.3 Biochar filter

During the study visit at the Swedish University of Agricultural Sciences in Uppsala, a technique that use biochar filter for wastewater treatment where presented. The research for biochar filter used as a treatment for waste water is ongoing and there are no results ready yet[22]. In this chapter, we will present some information about the technique but results from the on-going research is needed to evaluate the method further. All of the information is given from Sahar Dalahmeh, researcher at the Swedish University of Agricultural Sciences.

[22] Dalameh, Sahar; PhD researcher at the Deparment of Energy and Technology. Swedish University of Agricultural Sciences. 2017

Technical description

The biochar filters used in the study are vertical flow filters. The water is spread on the top layer and infiltrate into the deeper layers. While the water is moving, particles are strained between the pores and organic matter and NH_4 is adsorbed to the surface. A biofilm is formed on the large specific surface of the biochar which contribute to degradation of the organic matter.

Hygienic aspects

The filter is designed for removal of organic matter as BOD and COD. Nevertheless, the technique has been tested for removal of some indicator bacteria. The results showed that the size of the charcoal particles plays a significant role of removal of bacteria and pathogens. There will probably be further tests and research about the potential of bacterial removal.

References

There is a project ongoing in Jordan where the biochar filter is used for treatment of the greywater from one household with seven people. It has also been tests using mixed wastewater. In Jordan, the treated water is used for irrigation for trees in the garden.

4.3.4 Constructed wetlands

Constructed wetlands can be used for treatment of storm water and pre-treated wastewater, as well as e.g. agriculture runoff. In a constructed wetland there can be a reduction of nitrogen, phosphorous, organic matter, pathogens and other substances. For Lebanon, wetlands can be interesting for treatment of runoff from ITS with poor treatment of greywater and insufficient latrines, perhaps also already contaminated from activities upstream.

Technical description

Constructed wetlands can be designed in many different ways, with different requirements of excavation and construction. The wetland relies on a simple technology, where large shallow ponds, densely covered with emergent and submerged plants can be combined with overland flow areas that are flooded during certain periods, and dry in between. By damming up a local stream or ditch, less excavation is needed. It is necessary to have a sealed bottom, either by natural clay soil, or by a rubber sheet, to keep the water in the system.

To make the water flowing through the system, the constructed wetland is preferably built on a weak slope. If there is no slope, more excavation will be needed, perhaps also pumping.

For storm water, the area needed for treatment is normally about 1-2 % of the drainage area. For wastewater from a treatment plant, the area is depending on the hydraulic load.

The removal of phosphorous can be about 30-65 % of the incoming phosphorous load. The removal of nitrogen is generally higher with higher concentrations in incoming water, up to around 1-1.5 ton per ha and year.

Hygienic aspects

The process of filtering water through plants and adding oxygen through running water and plant roots, gives a good reduction of pathogens. Standing water should be avoided as it can cause problems with odour and flies.

Maintenance, working environment and user aspects

Maintaining a constructed wetland consists of cutting plants regularly to enable the water to flow as planned through the system. It could also involve removing sediments after some years of operation. If pumping is needed, maintenance of the pumps is included.

The location and the design have to be such that there is no risk for children or other people to fall in the water.

Economical cost

The cost is very much depending on size and design, but the technique has proven to be a cost-efficient alternative to more technical solutions, provided that the land prices are low.

References

There are many examples of constructed wetlands for treatment of storm water and treated wastewater in for example Sweden, the Netherlands, Ireland and USA.

Short summary:

The advantages with this technique are:

- A constructed wetland can be designed for taking care of high floods, e.g. after heavy rainfall, as well as reduction of nutrients and pathogens.
- It is a robust system, not sensitive for variations in flow or concentrations.
- Constructed wetlands require little maintenance.

The disadvantages with this technique are:

- Large area is needed.
- It is a more permanent structure.
- A constructed wetland placed downstream an ITS does not help the sanitary situation in the camp.

Figure 14. A constructed wetland for treatment of effluent from a wastewater treatment plant. The wetland acts as a biological step and reduce the content of bacteria and nutrients in the wastewater. Photos: Marcus Nilsson; WRS.

5 Discussion

Regardless of the choice of technique, there will always be a toilet fraction that needs to be transported away from the toilets in some way. It is important that this toilet fraction can be handled without risk for people, animals or the environment. There are at least three places in the system where the hygienic aspects are especially important: locally around the toilet; when transporting the fraction to another place; and at the final destination. Below are a picture of the various steps from toilet to final destination, where the forth step, the treatment, not always exists. Sometimes the treatment can be carried out on-site, for example in the collection tank.

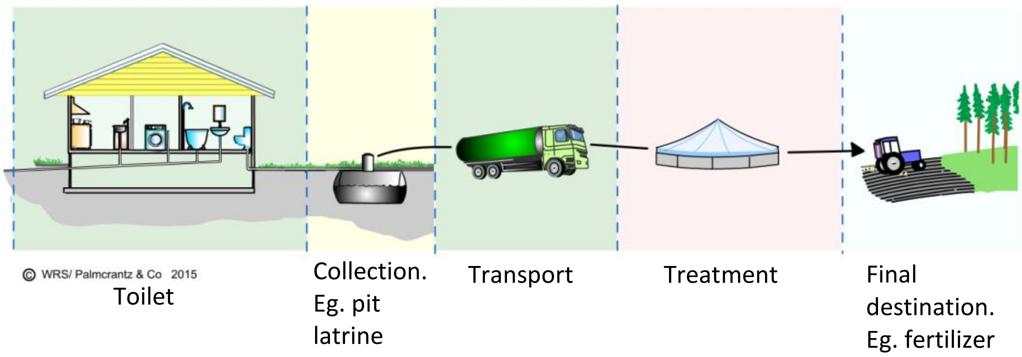

Figure 15. The toilet fraction system from toilet to final destination. (All steps are not always included.)

Firstly, it the design and function of the toilet facility should be discussed. Which options for the toilet solution is possible? Is it possible to separate faeces and urine? Is it desirable to limit the water use? Dry solutions, or limited water use, are recommended by researchers at Swedish University of Agricultural Sciences [23,24].

[23] Nordin, Annika; Researcher at the Department of Energy and Technology, Environmental Engineering Unit, Swedish University of Agricultural Sciences. 2016.

Secondly, the collection container can be designed in different ways. A closed container gives no emission of pathogens or other substances on the local environment and groundwater. On the other hand, a closed container requires a low- or no-flush toilet to not get filled up immediately, or a regular emptying interval and hence many transports. The container can be movable, or more permanent below ground.

Some transport, short or long distance, from the collection container is almost always needed. This can be done in ditches, pipes, or by a vehicle. The transport vehicle should be suitable for the conditions at the ITS. The collection container, if it is movable, could be adapted to the vehicle, e.g. jerry cans that fit on a small pickup or a wheel barrow. Maintenance and handling the toilet waste should always be done with care due to the risk of infection.

Treatment of the toilet fraction can be done in many ways, as described in chapter 4 above. The need for treatment is depending on what the final destination is. What are the options for reuse or disposal of toilet fractions in Lebanon today? If the toilet fraction finally will be used as a fertilizer on vegetables and other food crops, reduction of pathogens is needed, and as much nutrients as possible left in the material. If the toilet fraction will be spread as a fertilizer for energy crops, no hygienic treatment is needed before, but a fence or a sign can be suitable for preventing people to get in contact with the material. If the toilet waste can be disposed of in some way without risking human health or the environment, for example a place far from a village without leakage to the ground- or surface water, little or no treatment is needed.

6 Conclusion

- There are several techniques that can be possible for sanitization of blackwater or other toilet fractions at ITS in Lebanon.
- The techniques that the group regarded as fulfilling the criteria the most were sanitization with urea/ammonia and open dry compost.
- All described techniques require some kind of transport. The type of vehicle suitable depends on the design of the collection containers, and on the local conditions at the specific site.
- A central, or semi-central treatment for waste from several households is easier to monitor, and to supply with the needed material and maintenance, e.g. urea, vorms or mixing. If analyzing of pathogen content or nutrient content is needed, that can be part of the maintenance, and carried out centrally for the whole village.
- The investment costs vary a lot depending on material used for the collection containers and for the treatment facility. If local material is used the cost can be reduced.
- Recirculation of nutrients, i.e. using the toilet fractions as a fertilizer on some kind of farming or forest is the best way to prevent the nutrients from leaking to rivers, lakes or the ground water. If just stored in a pile, eventually it will leak out to the environment.

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[24] Vinnerås, Björn; Researcher at the Department of Energy and Technology, Environmental Engineering Unit, Swedish University of Agricultural Sciences. 2016.

Appendix 1. Results from the workshop – ranking of important functions.

Most important functions (1)

- Decrease pathogens
- No harm product
- Protect waters
- Zero Waste (reuse of materials)
- Final destination??
- Low maintenance (easy to repair) and low energy consumption
- Consider cultural background and acceptance
- Inclusion of the community in the solution (community board)
- Access during all times a day
- Accepted from community and culture
- Simple and easily maintained technology
- No permanent infrastructure

Important functions that can be modified (2)

- Cost efficient
- Sustainable and long term solution
- Decrease produced volume
- Material needed from local market
- Collection and transport systems
- Robust system
- Build society community capacity

Desirable, but less important, functions (3)

- End product should be re-usable (handling)
- Source of income solution
- Decentralised solution
- Scale-wise, flexible

From the list of important criteria or functions made in the workshop, each participant then ranked the functions or criteria as follows: 1) most important functions listed, 2) important functions that may be modified and 3) desirable functions but less important. The list above is a compilation of the individual rankings.

Appendix 2. Results from workshop – evaluation of techniques

☺ Green marker: the technique seems to meet the criteria
😐 Yellow marker: the technique seems to almost meet the criteria
☹ Red marker: the technique does not seem to meet the criteria
😑 Black marker: more information is needed about the technique

Criteria/Techniques	Lime	Urea /Ammonia	Vermi-compost	Black soldier flies	Reed bed	Open dry compost	DRDO Bio-digester*
Health							
Decrease pathogens	☺☺	☺☺	☺☺	😑☺	☺	☺☺	😑😐
Environment							
No harm product	😑☺	☺☺	☺☺	😑☺	😐	😐☺	😐
Protect waters	😐☺	☺☺	☺		😐	☺☺	😐
Zero Waste (reuse of materials)	☹☺	☺☺	☺	😑	😐	☺☺	😐
Resource management							
Final destination	😐😐	☺☺	😐☺	😑☺	☹☺	☺	😐
Economy	☺☺	😐☺	☺😐	☹	😐☺	☺	☹
User aspects	☺	☺					
Low maintenance (easy to repair) and low energy consumption	☺	☺	☺😐	☹😐	😐☺	☺	☺
Consider cultural background and acceptance	☺	😐	☺	☹	☹☺	☺	☺
Inclusion of the community in the solution (community board)	☺	😐	☺	😐	😐☺	☺	☺
Accepted from community and culture	☺	😐	☺	☹	😐☺	☺	☺
Access during all times a day	☺	☺	☺	☹	☺	☺	☺
Institutional aspects	😐	☺	☺	☹	☺	☺	☹
Technical function							
Simple and easily maintained technology	☺	☺☺	☺😐	☹😐	😐	😐	😐
No permanent infrastructure	☺	☺☺	😐☺	☺☹	😐	😐	😐

*A technique currently evaluated by the Red Cross in Lebanon. Not described in this report.

Remark: The two groups put one marker each on most criteria. The number of markers is only due to how many groups that put markers on a single criterion, not a measure on how "good" the technique is regarded.