WRS
Water Revival Systems

Greywater management and management of excess water in emergency situations

Swedish Red Cross

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Swedish Red Cross

GREEN RESPONSE

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Table of Contents

1 Introduction

The Red Cross helps people in need across the world and therefore operates under a broad range of environmental conditions. This implicates a considerable challenge when it comes to finding universally applicable solutions for wastewater management. Draining stagnant water that gathers from many sources in low points in the environment is often the biggest challenge. Drainage is often difficult or aggravated by clogging soils. In this report we will describe challenges and possible solutions for management of greywater in emergency situations.

In emergency situations different types of water are often mixed. Relatively clean Excess water from tap stands is for example often mixed with stormwater and greywater. In many cases even untreated black water (feces and urine) is mixed with other types of water. The contamination of other flows of water with black water poses a health hazard and also increases the total volume of contaminated water that needs to be treated and reduced.

There are three main pathways to lead water away from locations where it poses a risk; drainage, infiltration and evaporation. In emergency situations it is important to reduce the occurrence of stagnant water in proximity to living quarters. Stagnant water contributes to the spreading of diseases and can deteriorate the local environment due to smell and mud.

1.1 Notes

This reports main focus lies on temporary refugee camps with relatively short residence times in locations where more permanent solutions are impossible due to lack of infrastructure, potential impact on the environment or reluctant authorities and land-owners. The solutions presented in this report can often be constructed with locally available materials, are easy-to-adapt and require minimal maintenance efforts. For more long-term refugee camps there are other solutions for water management that may be more effective and suitable than the ones presented in this report.

This report focuses on greywater management but also describes general drainage of a site as well as what to consider when installing a tap stand, since both activities have implications for greywater management.

The solutions presented in this report are a selection from a wider range of available techniques. The selection and description of suitable techniques was performed by a team of experts consisting of Peter Ridderstolpe, Maja Granath and Tova Forkman (WRS), Caroline Gårdestedt, Sara Andersson and Tomas Ärlemo (Swedish Red Cross), Sahar Dalahmeh (Swedish University of Agricultural Sciences, SLU), Kim Andersson (Stockholm Environment Institute, SEI) and Per-Olof Johansson (Artesia Grundvattenkonsult AB).

To this report there is a number of related “How-to-do” flyers. They are suggested to be used during education and in the field when applying the techniques that are described in this report. It´s suggested to read the report before (and during) using the flyers.
Appendix (flyers):

1 Planning - Read me first
2 Main Drainage
3 Tap stands

4 Showers and laundry
5 Kitchen wastewater

2 What is greywater

Greywater is generally defined as household wastewater that does not come from a toilet and therefore does not contain as high levels of pathogens or nutrients as mixed wastewater. In general, it makes up 50% to 80% of a household's wastewater volume. In emergency situations, however, the contribution of greywater is considerably lower. The quantity of water needed for domestic use is context based, and varies with climate, the sanitation facilities available, people's habits, their religious and cultural practices, the food they cook, the clothes they wear, and so on. Water consumption generally increases with the dwellings proximity to the water source. The total basic water need for one person is calculated to approximately 15 liters per day.[1]

The quality, e.g. level of contamination, of greywater varies depending on habits and chemicals used. Greywater is generally divided into three different types: kitchen, bathroom and laundry. They have different characteristics:

- Kitchen wastewater contains high amount of fats, food residues and detergents, including high levels of salts and suspended solids. This is the type of greywater containing the highest level of oil and organic matter and therefore the water that is hardest to treat.
- Laundry wastewater contains soap products and bleach. It can also contain feces (from cloths and diapers) and chemicals from cloths. This type of water has the highest level of chemicals.
- "Bathroom" wastewater contains soap products and in many cases bleach as well as various by-products from showering, including trace amounts of feces. This type of water is often considered to have the highest quality among the three different greywater types.

2.1 What is greywater in emergency situations?

Due to low availability or even lack of bathroom facilities for individual households, it is more applicable to divide greywater in emergency situations into only two types:

- Wastewater from households that is mainly produced in the kitchen but with minor contributions from managing personal hygiene.
- Wastewater from laundry activities and showers ("bathroom" wastewater).

In emergency situations both types of greywater tend to eventually be mixed with other water flows.

2.1.1 Chlorine and other chemicals used

Widespread use of chemicals is common practice in emergency situations and several substances end up in water where they might be a concern for both health and the environment.

[1] SPHERE handbook https://spherestandards.org/handbook/ 2018-11-06

Bleach or sodium hypochlorite (NaOCl) is often used for treating drinking water and for general washing and personal hygiene. When sodium hypochlorite dissolves in water it forms hypochlorous acid (HOCl) and sodium hydroxide (NaOH). In high concentrations hypochlorite is caustic, and poses a hazard for both humans and biota such as microorganisms.

When used moderately, the caustic impact of hypochlorite on greywater is low and smaller amounts of residues and by-products can be taken care of by the environment. Typical by-products found in bleach contaminated water are free sodium ions (Na+). High concentration of sodium can potentially have a negative impact on soil structure and decrease infiltration capacity of receiving soils. Negative impact on soils peaks in situations where all water is evaporated, leaving all sodium ions bound to soil particles. As long as at least part of the water flow can be infiltrated sodium ions can be transported down to the groundwater or be kept in deeper parts of the soil.

The conclusion is that greywater cannot be treated onsite with little risk for human health or ecological impacts, as long as chlorine is used moderately and greywater infiltration is possible.

2.2 Challenges in emergency situations regarding greywater

Emergency situations and the accommodation of refugees in temporary dwellings pose severe challenges for wastewater management. Greywater management is often not prioritized in emergency situations because of the immediate need to treat wastewater from toilets first. However, greywaters in close proximity to living quarters and its high concentrations of organic matter, oil and chemicals, make it a hotbed for vectors of contagious diseases to thrive in. Treatment of greywater should therefore be given higher priority than it is today.

Uncontrolled and diffuse discharge of greywater results in mixing with stormwater and other excess water. When discharged and run-off water accumulate in depressions and other low areas it becomes stagnant. Stagnant water bodies are often contaminated by feces from livestock, wild animals and humans. It also creates a dangerous environment for children to play.

Below we describe a number of important and challenging parameters to be considered when planning for greywater management.

2.2.1 Climate/precipitation

In this report we focus on situations in areas with a warm climate (above zero degrees Celsius as the average annual temperature). Greywater management in colder climates requires other solutions than the ones presented here.

Precipitation is the climate parameter of influence for greywater management. High precipitation can cause problems draining water from areas where people live and therefore poses higher risks of stormwater mixing with greywater.

In dry climates on the other hand, lack of water is often a considerable challenge. In these situations, it could be of importance to manage greywater for re-use.

2.2.2 Space/Area available

Refugee camps are often densely populated and frequently even have more inhabitants than that were planned for, making effective and safe handling of greywater even more important. Finding suitable locations for greywater management without competing with house/tent areas is a considerable challenge when the demand for living quarters is high.

In more sparsely populated areas solutions for greywater management should focus on re-use of greywater.

2.2.3 Recipient: groundwater and surface water

In locations with close proximity to surface water recipients, such as natural lakes and rivers, one challenge is that greywater should preferably be treated before discharge to the surface water. Proximity to surface water does on the other hand provide the benefit of good drainage conditions and thereby low risk for stagnant water.

If the distance to the nearest surface water recipient is larger, other solutions for drainage are required. This report will present solutions such as irrigation, evaporation, evapotranspiration as well as enhanced infiltration.

In locations with high natural groundwater levels (1-2 meter below surface elevation) and soils with good infiltration capacity, greywater should be treated before it reaches and potentially contaminates the groundwater. This is the case especially when groundwater is used as a source for drinking water.

With lower groundwater levels or smaller infiltration capacity there is little risk for contaminating groundwater.

2.2.4 Infiltration capacity

Different soil types have different infiltration capacities. Clay soils for example have very low infiltration rate whereas sandy soils have relatively high infiltration rates. If the infiltration capacity of the local soil is high greywater and excess water can simply be handled by infiltration. However, to prevent the soil from clogging it is important to pre-treat the water before infiltration. This pre-treatment should primarily focus on reducing particles from the water by filtration.

If the infiltration capacity of the local soil is low or has been impacted by prior clogging it will be more challenging to dispose of water. Pre-treatment of greywater and subsequent drainage via surface flows will be required in order to prevent the occurrence of stagnant water bodies. Alternatively, efforts can be made to enhance or restore the infiltration capacity of the soil (see described solution in chapters below).

2.2.5 Topography

As water runs downhill following the path of least resistance, infrastructure such as tap stands, showers and laundry places should be planned to minimize the risk for flooding. In very flat areas it can be difficult to predict the course water will take and the construction of draining channels can be required to control flows and reduce the risk of flooding.

3 Guide for greywater management in emergency situations

The guide proposed below helps with the setting of priorities for greywater management in emergency situations, with the avoidance of stagnant water bodies as the main objective. Local conditions can vary greatly between different emergency situations, and the provided guide should not be regarded as tailored toward any specific set of conditions. It presents a general set of principles and important parameters to reflect upon when planning for greywater management.

The guide provides one section about planning greywater management and four specific section for different kinds of greywater:

1. Planning (Read me first)
2. General drainage
3. Tap stands
4. Wastewater from shower and laundry
5. Kitchen wastewater

Each section is also described in a separate information sheet, se annex one through five.

For sections two to five we have developed a four-step implementation order:

1. Source control
2. Pre-treatment
3. Treatment
4. End-use

3.1 Planning

The main challenge greywater poses in emergency situations is ensure sufficient drainage to avoid the collection of stagnant water. Stagnant water bodies contribute to the spread of diseases and unpleasant conditions for settlement (smell, mud, flies, mosquitos etc., see Figure 1). Drainage of water away from living quarters is to be prioritized and if possible, water should be treated and reused for example for irrigation.

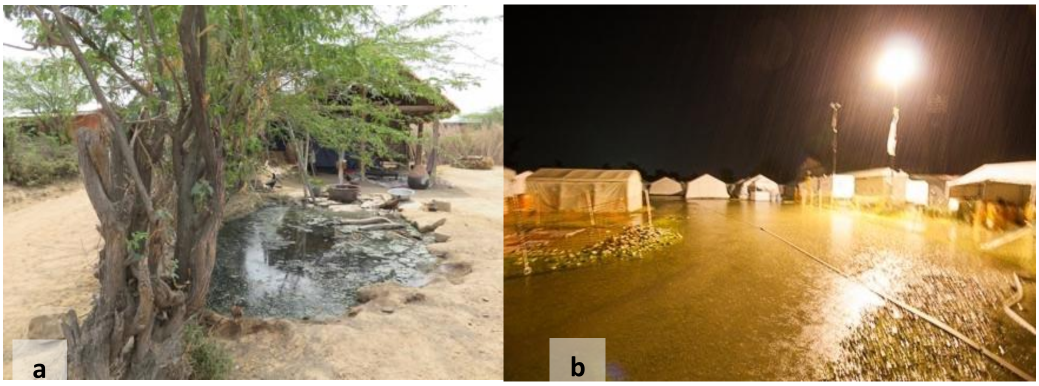

Figure 1a and 1b. Examples of problems with sitting water. Photo 1a: Caroline Gårdestedt 1b: Tomas Ärlemo.

Principle for planning

Evaluate the situation:

- How are greywater and excess water handled today?
- Are there problems with too much or too little water?
- Are there any problems with the water management today?

Evaluate the site: Examine the site in terms of topography, vegetation, soil properties etc. (Figure 2).

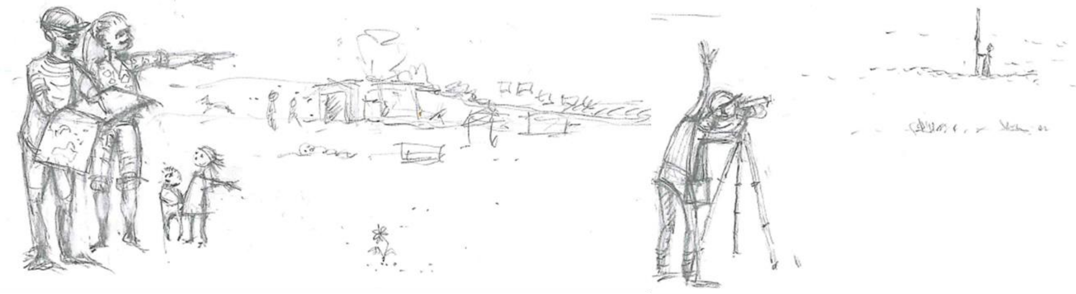

Figure 2. Examples on how to examine the topography at the site. By: Peter Ridderstolpe.

Examine the topography to get an overview of natural flow paths for water. Preferable, use a GPS. It is easier to examine a site when maps and GPS equipment are available but often characteristics such as contours and slopes can be judged with eyesight and common sense. Particular focus should be given to identifying depressions and low-lying areas prone to flooding. The presence of running waters such as streams and ditches will also provide clues as to how water drains from a site. Based on your observations, choose locations for tap stands, showers and laundry facilities that minimize the risk for water accumulating downstream.

Survey the vegetation present and evaluate if it can be used for irrigation with greywater. Maintaining available vegetation is desirable as it can be used to manage the flows of greywater and other excess water by evapotranspiration. If possible, also look for places where new vegetation could be planted.

Examine the soil properties and evaluate if there are sites that are suitable for the infiltration of greywater, preferably without infringing on locations needed for living quarters (Figure 3). If suitable locations for infiltration are found and to be used, it is of key importance to take measures that prevent deterioration of infiltration capacity such as clogging by particles or soil compaction by use of heavy machinery.

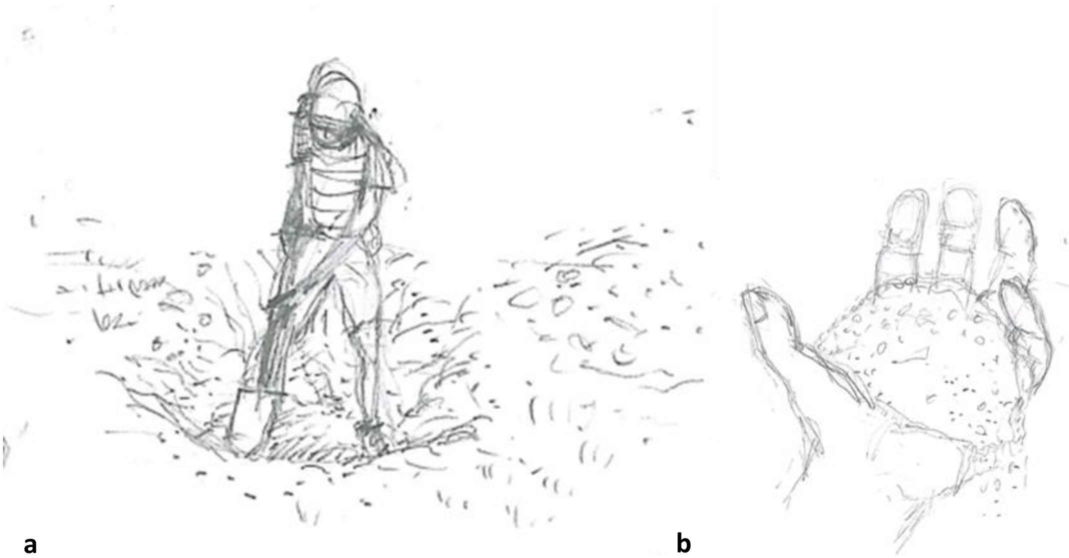

Figure 3. a) and b) Examples of examining the soil. By: Peter Ridderstolpe.

Sketching the systems: Sketch the different systems (after reading the other sheets), where is a good place for water management (Figure 4)?

Consider which water related facilities can be place in close proximity to each other. Combining drinking water taps, showers and laundry facilities in one and the same location facilitates easy and economic water transportation. Water facilities placed in near proximity to living quarters will be regarded as safer than those placed further away. Facilities that are regarded as unsafe may lead to diffuse discharge of water from living quarters that is harder to collect and treat.

Figure 4. Plan and sketch the system. By: Peter Ridderstolpe.

Consider the simplest construction but do make plans (and leave space) for future improvements such as (pre)treatment, sampling and follow up;

Construction phase:

- Establish the optimal location to dig major drainage arteries. See more detailed information below before excavation is started.
- Where to place the tap stand(s)? See more information below before placing/building the tap stands.

- Where to place the showers and laundry stands? See more information below.
- How to collect and treat kitchen wastewater? See more information below.

Follow up the plants and water management systems.

After the initial two weeks of operation systems should be inspected for flaws and potential improvements. Thereafter such inspections are to be repeated on a regular basis. Regular inspections should aim to identify problems, maintenance needs and potential improvements.

3.2 Main drainage

In emergency situations there is often no, or little, time for planning. Housings and shelters arise rapidly and often in a none-organized fashion. Sites, previously used for other purposes such as for example grazing or agriculture, are suddenly converted into densely populated areas. Trees are typically felled and other vegetation is damaged or removed. Tramping and heavy machinery during construction can compact the soil and have negative implications for infiltration capacities. Local and thereby diffuse discharge of wastewater from living quarters to areas with compacted soil can lead to the accumulation of stagnant water in direct proximity to living quarters (Figure 2).

Contamination of these accumulations of stagnant water with excrements from open defecations, malfunctioning latrines or livestock is inevitable, creating risks for infections. If stagnant waters become long-lasting (more than one week) they will produce repellent odors and provide excellent hatching sites for mosquitoes.

In situations where stagnant water occurs in close proximity to living quarters, finding appropriate solutions for greywater management is virtually impossible. Establishing a main drainage system for a site is therefore of key importance and a task that has to be done prior to the implementation of greywater management systems.

Figure 5. Accumulation of stagnant water in direct contact with living quarters after flooding in the absence of a main drainage system. Photo: Tomas Ärlemo

How to solve the problem?

Mapping the area: To understand the natural flow paths for water and make use of the local topography for drainage, surveying the landscape is necessary. In areas with distinct topography and slopes, determining natural flow paths will be relatively easy. In areas with flatter topography, however, run-off directions might not be as easy to establish by eyesight. In these cases, land survey equipment might be needed to determine natural flow paths.

Sites that have natural flow paths in several directions should be divided into several catchments using a topographic map or survey results. Natural flow paths for water, depressions and other low-lying areas as well as the final discharge points from the site should be indicated on the map.

Design the draining system: Plan your drainage system before the onset of excavation! Start with sketching out the location for the main branch (ditch) for each (sub) catchment Set out channel bottom elevations on your map at regular intervals along the channel. Make sure that a slope of at least 0.5% is achieved in all sections to secure that water can drain passively by gravitation alone. Try to estimate water flows during periods with heavy rainfall in order to estimate appropriate dimensions for your channel. Draw cross sections of your planned ditch along its path. As a rule of a thumb, a one m^2 cross section is able to discharge 1 m^3 water per second. In areas for slopes below 0.5% cross sections must be larger.

Implement: Sites without distinct topology will require a drainage system with a deep main branch. Excavation of deeper sections is preferably done with heavy machinery such as excavators. In the absence of such machines, digging may need to be done by hand. A hand excavation performed by a large number of people requires good organization and project managing skills.

However, deep running water in the direct vicinity of living quarters implies risks for inhabitants, such as drowning risks and mosquito reproduction. Wide ditches even require space that otherwise could be used for other purposes such as housing or crop production

A more appropriate draining system in an urban area is to build so called two leveled ditches (Figure 6). Building a two-leveled ditch can be made immediately or after some time. Some sections (deep and near dwellings) should be retrofitted as soon as possible. Other sections not so critical, can be left open.

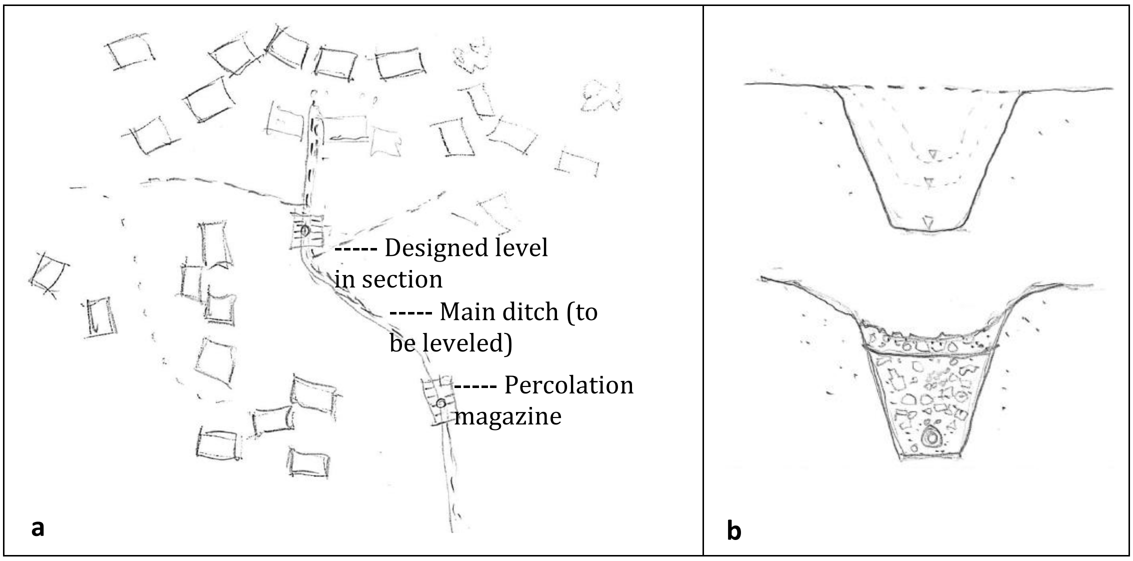

Figure 6. a) Drainage system from above. b) Cross section of an open ditch (above) and cross section of a two-leveld ditch filled with gravel (below). By: Peter Ridderstolpe.

Further improvements of drainage systems can be made by so called adding percolation reservoirs along the ditches. These reservoirs are widened sections of the subsurface ditch filled with stones or other hard, persistent and voluminous materials in order to create buffer volumes for retaining and infiltrating water. Preferably these percolation reservoirs are complemented with planted trees and other vegetation. Plants thrive in permeable soil and can take up nutrients and remove water by evapotranspiration.

3.3 Tap stands

The excess water running off from tap stands should be regarded as relatively clean. When mixing with stormwater and wastewater can be avoided this type of run-off could be a valuable resource for reuse.

If possible, place your tap stand on higher ground to allow for passive drainage of excess water. In situations with little or no topography, tap stand should preferably be placed on a raised platform to allow water to drain away. Drain excess water from your tap stand with a culvert or a small trench toward a nearby surface water recipient or a patch of vegetation for infiltration.

The principle sketch below (Figure 7), illustrates what to consider when planning a tap stand site. The steps are further described in the section below.

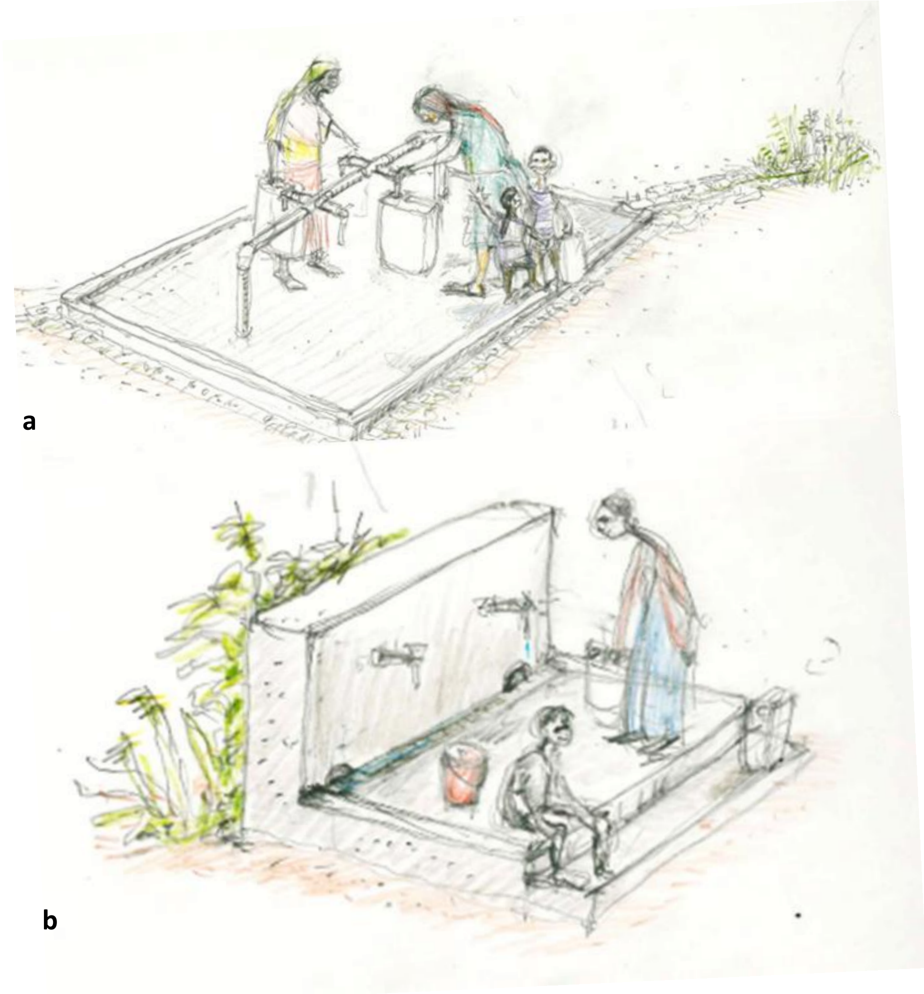

Figure 7. a) An eaxample of a tap stand where the water is collected in one corner and is lead to a small ditch with some vegetation. b) An example of a tap stand where the water is collected directly under the taps and lead to vegetation behind the tap stand. By: Peter Ridderstolpe.

Principles for tap stands:

1) Source control: Supply/use appropriate containers for collecting and storing drinking water to avoid contamination and water loss due to leakage. Inform users on the importance of not wasting or contaminating their drinking water supply.

2) Pre-treatment: If the excess water is to be reused for other purposes such as irrigation it must be collected and led away in a coordinated way. This easiest to assure when the surface under your tap stand has a clear low point toward which water will drain. The surface under your tap stand should preferably be constructed of impermeable materials such as concrete. Ideally the surface under your tap should have a raised board around its edges to prevent water from draining in an uncontrolled fashion. If solid materials are unavailable, you could construct a small drainage trench around the tap stand in order to control drainage. Graveled platforms as a surface under the tap can be covered with bricks or a carpet of bamboo sticks to provide more solid ground. Angle your platform and/or trench toward a low point in order to collect excess water and thus facilitate reuse.

Figure 8 a and b illustrate two examples of taps stand with appropriate drainage systems, Figure 9 a and b illustrate two examples of taps stands with poor drainage.

Figure 8.a) Good example of tap stand. Solid surface for the tap stand/pump to be based on, including a concrete channel that drain the water. Ideally the concrete would be designed with a small board. Photo: Caroline Gårdestedt. b) Good example of tap stand. Example of a tap stand with gravelled sides and a shallow channel to drain the water to bushes downstream the tap stand. Photo: Caroline Gårdestedt.

Figure 9. a) Bad example of tap stand. Unstable bricks and no path to drain the water. Photo: Caroline Gårdestedt. b) Bad example of tap stand. Placing the tap stand lower than the surrounding and no sustainable path to drain the water. Photo: Caroline Gårdestedt.

The examples of poor drainage around tap stand in Figure 9 a and b show how stagnant water collects adjacent to the tap stand and provides an environment for pathogens to develop/thrive in.

3) Draining and end-use: Make sure your water can drain from the platform under the tap stand by providing a gap in the surrounding board or an orifice with the platforms lowest point. Drain the water from the outlet preferably via a culvert or alternatively via a gravel filled ditch to the nearest surface water recipient, branch of the drainage system or to nearby vegetation on soil with good infiltration capacity. Excess water can also be used as drinking water recourse for domestic animals. Using a flexible hose for draining instead of a culvert or ditch provides the benefit of being able to alternate between various infiltration patches. Always make sure that the drainage system you set up is adapted to the local circumstances at your site! Further suggestions are provided in chapter 3.2 below.

Parameters to reflect on:

Climate/precipitation: Under conditions with high precipitation the board along the perimeter of the concrete platform is even more important for keeping excess water from tap stands apart from stormwater.

Space/Area available: Facilities that combine tap stands with laundry and showers should be preferred.

Recipient - groundwater/surface water: This type of water doesn’t have negative effects on either groundwater or surface water recipients unless it is mixed/contaminated by other types of water.

Infiltration capacity: If the infiltration capacity is poor, try to drain the water through a trench or a pipe to a nearby recipient or for irrigation.

Topography: Try to find a spot that provides a sufficient elevation gradient for water to drain passively. Avoid negative impacts on infrastructure placed downhill by choosing appropriate locations.

3.4 Showers and laundry

Showers and laundries tend to generate larger volumes of water that without proper drainage can results in the accumulation of water in stagnant pools, see Figure 10 a and b for examples of showers implemented without proper planning and Figure 11 for an sketch of a proper implemented shower.

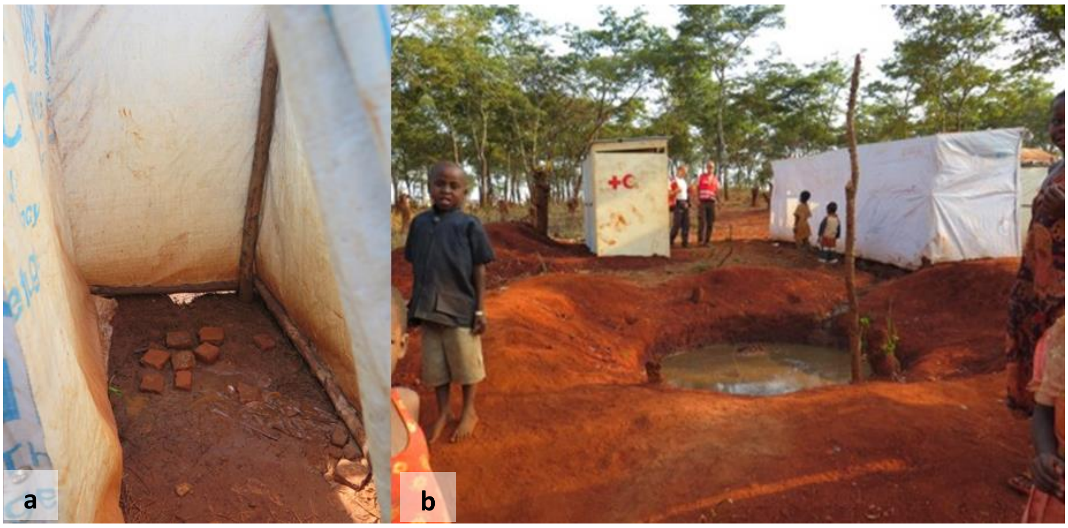

Figure 10 a and b. Two examples of inappropriate construction of showers. (a) the water is hard to collect, pre-treat and drain away from the shower cabin and the floor will become very "muddy", (b) poor example of an infiltration pit. Most likely the soil doesn't have good infiltration capacity or has been clogged because the lack of pre-treatment. Observe the presence of vegetation (trees) behind the showers in the right photo. It would probably have been a good idea to drain the water towards the grove instead. Photos: Caroline Gårdestedt.

Figure 11. An exemple of appropiate construction of showers. Notice that the water from the showers is collected in the back of the showers and lead in a ditch towards the tree. By: Peter Ridderstolpe.

Water from showers and laundries typically carries a high load of soap residues, fabric fibers, bleach, human hair and particles. Pre-treatment of this water before discharge to the environment is therefore important.

Management principles for water from showers and laundry facilities.

Source control and collection: Provide information and techniques for proper use of water and chemicals, so users won't overconsume water and detergents.

Just as for tap stands central collection of the water is of key importance for both treatment and coordinated drainage. Preferably water from all individual shower booths and laundry stations is collected separately before treatment and drainage. Central collection can easiest be accomplished by angling solid floors towards a low point, for instance in one corner, see Figure 12 for an example. Preferably the floors low point should be aligned with the locations natural topologic low point to facilitate passive drainage.

Figure 12. An example of a properly constructed laundry facility. Please observe that the facility in the picture lacks a pre-treatment step. Photo: Caroline Gårdestedt.

Pre-treatment: A first step in treating greywater from showers and laundry stations should be a simple mechanical filter to remove fabric fibers, hair and particles. A low-tech and easy to construct pre-treatment step can be constructed by using two containers (such as barrels or buckets) placed inside one another (Figure 13 a and b). The inner container should be filled with a filter matrix such as for instance biochar, zeolite, coir (coconut fibers), fine meshed strainers or other locally available porous material.

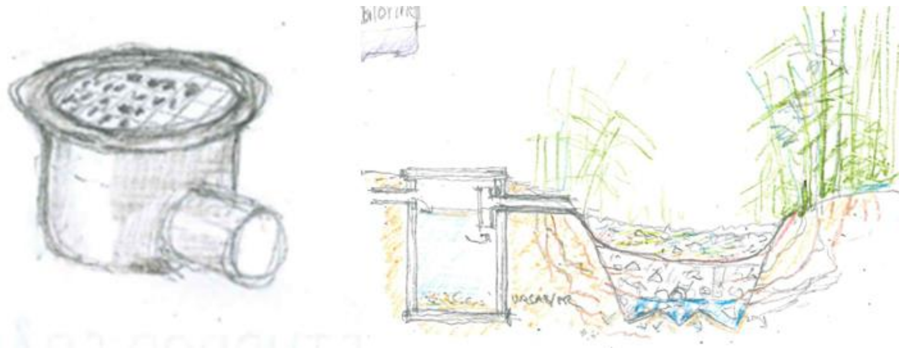

Figure 13. a) Example of a pre-treatment arrangement. b) Example of another type of pre-treatment arrengement and an exemple of treatment as well. By: Peter Ridderstolpe.

The filter should be placed with its inlet at the point where greywater is collected, slight lower than the outlet from the shower/laundry. The filters outlet should be placed a small distance above bottom level to allow for connection and passive drainage to either the next treatment step or a culvert or (gravel filled) ditch for disposal. To minimize the contribution of greywater to mixed streams of wastewater further downstream, additional treatment and subsequent infiltration should be given priority over simply leading filtered greywater away. The culvert or ditch from the filtering step should thus preferably connected to a treatment step (see below). If no treatment step can be constructed drainage to surface water recipients, branches of the drainage system or to nearby trees can be considered.

Treatment: Treatment should preferable consist of a biodegradation step in order to decrease bacterial and organic matter load. If site conditions are favorable (e.g. lush vegetation such as grass and trees or/and high soil permeability) sufficient treatment can accomplished by simple soil infiltration systems, such as infiltration pits or gravel trenches (Figure 13 b). Very often special efforts and technology must be allocated to support the biodegradation of organic matter. Such technologies can be constructed in different ways, some examples are presented below:

Since treated water can be regarded as relatively clean the outlet from the treatment step can be connected to a flexible hose that can be moved und thus supply water to different irrigation object. Always make sure that the drainage system you set up is adapted to the local circumstances at your site!

End-use: After pre-treatment and treatment the greywater is now considered as clean and can be discharged to the natural environment without concern. Passive run-off to a nearby surface water recipient should be preferred. If drainage to surface water is not feasible it should be either infiltrated to the groundwater or evapotranspirated by vegetation.

Parameters to reflect on

Climate/precipitation: Under conditions with high precipitation it is even more important to ensure proper drainage to avoid mixing of greywater with other flows of water such as stormwater and black water (sewage).

Space/Area available: Facilities that combine laundry facilities and showers with tap stands are preferable. Topology and flow paths to receiving waters should be taken into account. Adapt both the number and spacing of your facilities to population size and geographic extend of the camp. More facilities are required when the population is dense or when a large walking distance is to be covered. Both log cues at facilities and extended walking distances to them will contribute to people washing and showering at or near their dwellings, thereby increasing the risk for stagnant water and mixing of greywater with wastewater.

Recipient - groundwater/surface water: Even if pollutant loads in greywater from showers and laundries are much lower than in greywater from kitchens or black water (sewage), (pre) treat the water to prevent clogging of soils, ad odors or ameliorate environmental impacts.

Infiltration capacity: If the infiltration capacity of the local soils is poor, drain the water to a nearby surface water recipient or an irrigation site via a culvert or a trench.

Topography: Try to find a spot that provides a sufficient elevational gradient for water to drain passively. Avoid negative impacts on infrastructure placed downhill by choosing appropriate locations.

3.5 Kitchen wastewater

Kitchen wastewater is mainly produced by washing dishes after meals. Smaller contributions come from cleaning, washing and personal hygiene. Kitchen greywater is typically very rich in fibers and other particles from preparing and cooking food. Other typical constituents are detergents and oils and other fats. Bleach and other chemicals can often be found in the water.

The average family in a refugee camp produces around 50-80 liters per day. This wastewater is typically disposed of in buckets and other containers and simply poured out in the direct vicinity of the living quarters.

Challenges

Kitchen greywater that is poured out in the local surroundings may attract vermin such as rats and flies and contribute to the build-up of pools and puddles of stagnant water. If such stagnant water bodies become long lasting, they will provide excellent breeding grounds for mosquitos and thus raise risks for infections as a consequence. Inappropriate disposal of kitchen greywater thereby poses a severe health risk and negative impact on living standards for the residents. Figure 14 a and b illustrate two examples of poor handling of kitchen greywater. Figure 15 illustrate an example of proper handling of kitchen greywater.

Figure 14 a and b. Two examples of poor handling of kitchen waste water. Stagnant water collects directly adjacent to living quarters and causes problems with smell, mosquitos etc. Additionally they pose a drowning hazard to playing children. Photos: Tomas Ärlemo.

Figure 15. An appropriate construction to take care of kitchen greywater. By: Peter Ridderstolpe.

Principles for handling kitchen greywater

Source control: Inform the people about proper use of waters and chemicals. Water should be used efficiently to avoid waste of a scarce and valuable resource. Prior to washing up larger particles of leftover food, such as bones, should be removed and preferably composted. Providing every family with a strainer to filter their kitchen greywater is an easy way to reduce particle loads. Chemicals such as bleach should be used sparsely.

Pre- treatment. Before kitchen greywater can be reused for other purposes the majority of particles should be removed. A pre-treatment step prior to final treatment such as infiltration is extremely important and should always be implemented. The filters used for pre-treatment must be designed so that they are easy to use and maintain. Preferable the pre-treatment unit is built as a combination of mechanical and biological filters where particles are strained and consumed by biota. Such filters are called "mulch filter" (Figure 16 a-c).

Figure 16. a) Filter media (mulch) is contained in a bucket with holes drilled in its bottom. When clogged, the bucket is refilled with new or washed media. b and c) Mulch filter tower with a strainer above the mulch where organic matter is decomposed by micro- and macroinvertebrates. Sketch and photos: Peter Ridderstolpe.

If the local natural conditions are favorable simple mulch filter beds can be applied to remove and break down particles. The seepage water from the mulch beds can simply infiltrate the local soil. This technique avoids accumulation of stagnant water. The nutrients from infiltrated water can be a valuable recourse for growing trees and other plants.

Figure 17 illustrates the use of mulch filters as a technique for irrigation and infiltration. The mulch filter is designed with two layers, an upper part containing the mulch and a lower part that can retain a certain amount of water prior to infiltration into the soil. Preferably the two compartments are separated by a durable geotextile membrane that is permeable to water but not for particles. The geotextile should preferably have the capacity to strain all particles larger than 0.1 mm.

The mulch layer consists of a mix of porous materials. Carbon rich organic matter such as wood chips, coconut fibers or charcoal is blended with inert materials such as crushed bricks, pumice, gravel, or sand (no fractions smaller than 2mm) to offer a perfect matrix for straining particles and an environment for decomposing biota.

The mulch can be temporarily drowned (when applying water) but must then be allowed to drain from water to maintain filter capacity and keep the biota alive. When signs of clogging (smell, black mucus) occur the mulch has to “rest”, so that biota can recover. Alternatively, it may need to be removed and replaced. After a certain period of operation, the mulch “ages” by degradation of its organic material. Mulch that is “used up” can be washed and the more persistent material that remains can be reused as a basis for new mulch by adding new organic material. Used up mulch can also be used as a soil conditioner and make poor soils better suited for production of crops or trees.

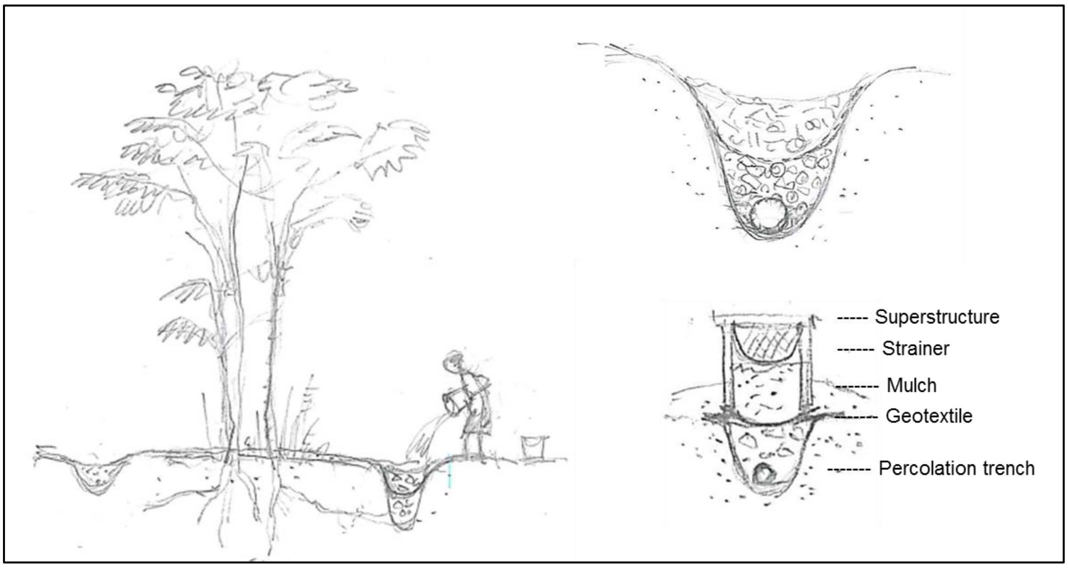

Figure 17. A mulch filter is designed with two compartments, an upper part containing the mulch and a lower one that can retain a certain amount of water prior to infiltration into the soil. By: Peter Ridderstolpe.

Treatment: As discussed above, greywater is relatively harmless and treatment should primarily focus on particle removal to prevent clogging of soils. Pathogens and harmful constituents occur in low levels and require no specific treatment step. Removal of particles means most of greywaters organic compounds must be removed. Failure to remove organic particles prior to infiltration will result in the occurrence of slimy and impermeable biofilms and subsequent clogging of the soil. The risks for clogging and subsequent occurrence of stagnant water are particularly high when water is loaded continuously to fine particle soils.

A biological treatment is always necessary to maintain infiltration capacity in soils. On sites with lush vegetation and permeable soils the vegetation present can be utilized as a biological treatment step.

However, in most cases special efforts and technologies to avoid clogging of the soil are required. Emergency situations often imply space limitations, lack of vegetation and soil compaction due to foot treading or the presence of clay. In these situations, we need to introduce special techniques to facilitate biological treatment. Such technologies typically involve artificial filter media. These filter media offer a large surface for straining and biodegrading organics in an oxygenated environment. An example how such a filter can be built is illustrated in Figure 18 a-d and Figure 19 a-c.

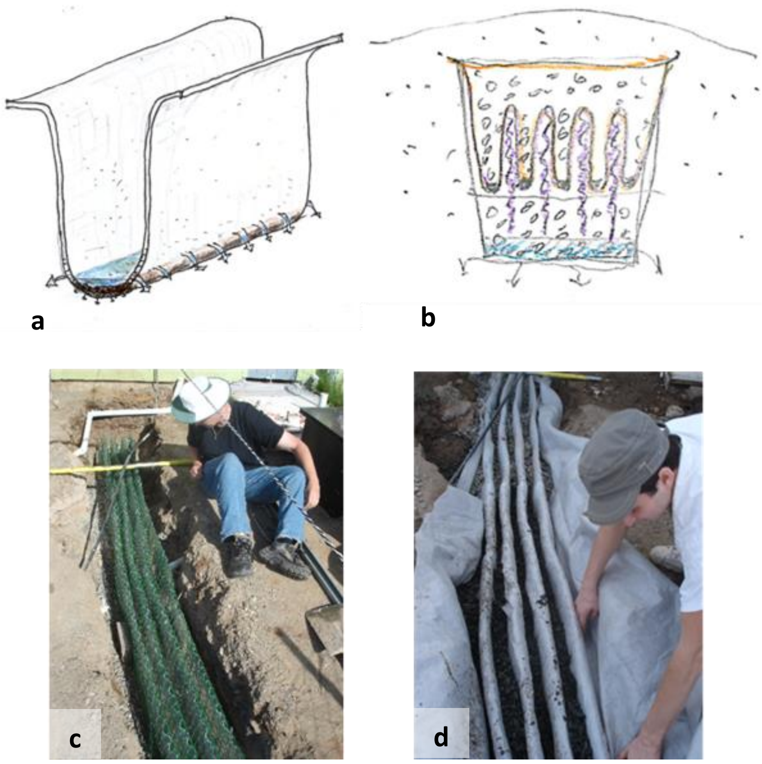

Figure 18. *Artificial filter for biological treatment. This technology makes it possible to infiltrate water even into also clayrich and compacted soils. a and b) The geotextile function as a biological filter where partcles area strained and decomposed. When constructed as a structure with valleys and ridges bacteria will clog the bottoms, thus water will be spread evenly along the whole structure. c and d) In a multi-convolution structure the filter surface can be widely expanded. This will secure efficient and long term perfomance. Sketches and photos: Peter Ridderstolpe.*

Figure 19. a) When BOD is removed from water it can be adsorbed by soil for infiltration or irrigation. This finas step is typically constructed as a long resorption trench. Normaly the reservoir is made of gravel but artificial media van also be used. b) If site conditions allow, a discharge system should be build to minimize clogging risks. c) Suitable solutions are drainage pipes prepared with coconut fibres or alternatively perforated corrugated pipes wrapped in geotextile membranes. Photos (a and b): Peter Ridderstolpe

End-use. After treatment water can be discharged to the natural surroundings, preferably by means of passive drainage to a nearby surface water recipient. In the absence of surface water recipients or when drainage poses severe difficulties, water should either be infiltrated to the groundwater table or be evapotranspirated by vegetation. The presence of vegetation is often vital for successful infiltration since plant roots improve soil permeability, biotransformation of pollutants and evaporation of water. One single tree is typically able to evaporate the kitchen greywater from a number of families.

Spatial requirements

Even though the volume of kitchen greywater produced per household is relatively small (50-80 liters per day) finding a sufficiently large central location for treatment often poses a challenge. Dimensioning principles for such locations depend on parameters, such as total volume, BOD[2] content of the water and the site-specific conditions such as topology and soil permeability.

In order to keep kitchen greywater systems as small as possible in densely populated areas, intrusion of stormwater is to be avoided. Treatment systems should on the other hand not be constructed to small either. This is particularly the case in climates with prolonged periods of precipitation and little or no evaporation. The example below gives an indication how a mulch filter resorption system should be dimensioned when a family produces 50 liters of kitchen greywater per day under conditions with poor infiltration and no evaporation.

Example. Dimensioning a mulch filter resorption system for one family/dwelling

- Amount of water 50 l/day
- SS 1000 mg/l => 50 g/d
- BOD 1000 mg/l => 50 g/d
- Infiltration rate = poor (10- 20 l/h with clean water)
- Evaporation rate = 0
- No possibility to discharge

Design for one dwelling (from criteria above)

<u>Mulch filter</u> designed for > 50% suspended solids (SS) and 25% BOD removal. This can be expected if the mulch filter volume is 15-20 l. The filter is encapsulated in a superstructure that also protects against high temperatures (>30˚C).

<u>Artificial media for advanced biological treatment:</u> Designed for 25 g SS/d and 37 g/BOD/day. An artificial filter constructed as in Figure 18 a-d (4 ridges 15 cm each high) increases surface area by a factor 10 compared to infiltration area of a simple trench. At the same time oxygen supply to the biofilm is enhanced greatly. Expected capacity for BOD-removal is in these conditions about 100 grams per m^2 surface area of the ditch. To be able to decompose 37 g of BOD a surface area of approximately 0.4 m^2 is required. Given a width of 0.3 m the required length for the trench would be 1.3 m. A simpler construction with a single wing of textiles would have to be considerably longer (4-5 meters) to accomplish the same surface area.

<u>Infiltration</u>: This is possible due to the pre-treatment and the BOD-removal in the artificial media. If BOD is not efficient removed, the soil will be clogged and unable to

[2] BOD, Biological oxygen demand is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material

adsorb water. In this example we calculate a BOD removal of 95-99% take part in the mulch and the artificial media. This means that we still have 10-50 milligrams of BOD per liter in the water. A certain clogging effect in the bottom and sides of the resorption trench is thus to be expected. Assuming long term adsorption rates of about 20 l/ d/m^2 approximately 2.5 m2 of infiltration area is required to dispose of 50 l/d. Constructed as a ditch with a mantel area of the percolation magazine of 0.5 m^2/m (0.25 m bottom, 0.25 m sides) we need a total length of the percolation magazine of about 5 m. As illustrated in Figure 18 c and d and Figure 19 a and b, the percolation magazine can be extended by for instance a draining pipe wrapped in geotextile or a prefabricated draining pipe with coconut fibers.

4 Read and learn more

The examples that are described in the report are, as mentioned, a selection from a wider range of available techniques. The selection and description of suitable techniques was performed by a team of experts consisting of Peter Ridderstolpe, Maja Granath and Tova Forkman Fahlgren (WRS), Caroline Gårdestedt, Sara Andersson and Tomas Ärlemo (Swedish Red Cross), Sahar Dalahmeh (Swedish University of Agricultural Sciences, SLU), Kim Andersson (Stockholm Environment Institute, SEI) and Per-Olof Johansson (Artesia Grundvattenkonsult AB). To learn more about some of the techniques we recommend to read following reports:

- Art, L. *Create an Oasis with Greywater.* 1994. Oasis Design CA 93105-9726
- Mundy-Castle, RP. *An investigation into the use of a mulch tower for low cost, low maintenance grey water treatment.* 2012. Final Report, University of the Witwatersrand, School of Civil and Environmental Engineering.
- Ridderstolpe, P. *Mulch Filter and Resorption Trench for Onsite Greywater Management - Report from a demo-facility built in Kimberly, South Africa.* 2007. WRS and EcoSanRes in co-operation.