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WATER, SANITATION AND HYGIENE SECTOR

EMERGENCY TECHNICAL GUIDELINES FOR SUDAN

A MANUAL FOR FIELD STAFF
AND PRACTITIONERS



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people and skills for disaster relief

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Introduction

This companion manual is written to supplement but not replace existing WASH¹ manuals written by the Ministry of Health and the Drinking Water and Sanitation Unit of the Ministry of Water Resources, Irrigation and Electricity.

The Ministry of Health's (MoH) Manual for Environmental Health in Emergencies covers the following:

- Water Quality and Disinfection
- Sanitation – basic Excreta Management
- Solid Waste Management
- Vector Control
- Food Safety in Emergencies

The Drinking Water and Sanitation Unit (DWSU) of Ministry of Water Resources, Irrigation and Electricity has developed manuals for technical guidance for the following long term water supply and sanitation facilities:

- High Capacity Water Yard
- Low Capacity (Mini) Water Yard
- Hand Dug Well with Motor Pump
- Hand Dug Well with Handpump
- Drinking Water Distribution Network
- Water Treatment Facility
- Spring Development & Roof Water Harvesting
- Slow Sand Filtration
- Improved Hafir
- Improved Small dams
- Borehole with Handpump
- Household Latrines
- School Latrines
- Latrines for Rural Health Institutions

The premise of this manual is to provide a good grounding in emergency water supply for people working in the humanitarian sector in Sudan, principally providing an emergency supplement to the DWSU manuals. A second aim was to address gaps in the MoH manual, specifically around emergency excreta management options, hygiene facilities and wastewater disposal. Solid waste and vector control are already addressed in the MoH manual.

¹ *WASH - Water, Sanitation and Hygiene

Overview of this Guideline

The following sections 1 to 5 provide a basic overview of hygiene promotion and sanitation in emergencies

- Section 1 Emergency WASH Fundamentals
- Section 2 Hygiene Promotion in Emergencies
- Section 3 Emergency Excreta Management
- Section 4 Hygiene Facilities
- Section 5 Wastewater Disposal

Section 6 provides more detail on water supply in emergencies, covering

- 6.1 Emergency Water Supply Requirements and Standards
- 6.2 Water Source Selection
- 6.3 Water Safety Plans
- 6.4 Water Trucking in Emergencies
- 6.5 Rehabilitation & Operation and Maintenance of Water Supplies
- 6.6 Solar Pumping of Water Supplies
- 6.7 Emergency Water Treatment
- 6.8 Emergency Water Distribution

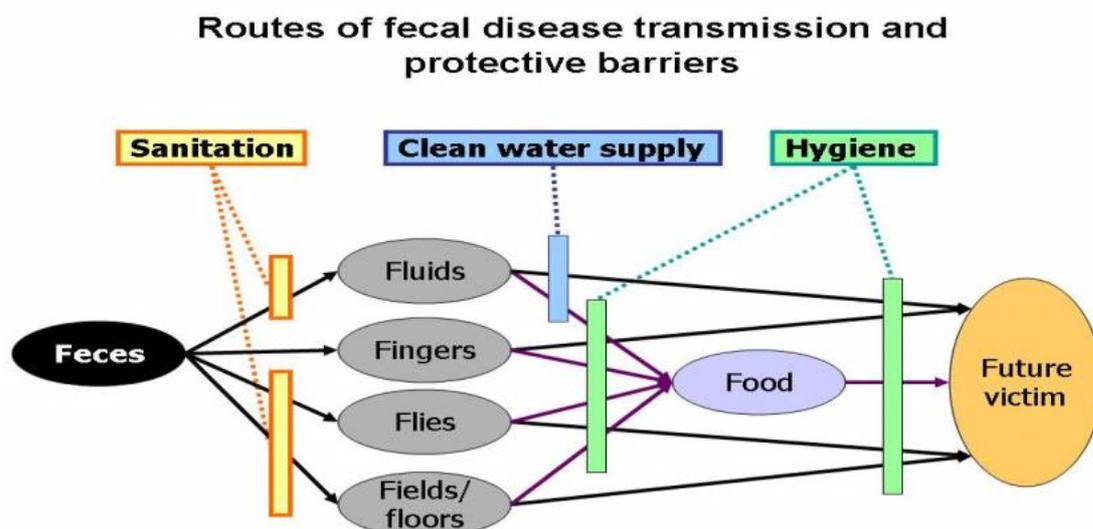
These sections provide a more in depth look at water supply in emergencies and should augment the longer term nature of the series of Technical Guidance Manuals on Water Supplies from the Ministry of Water Resources, Irrigation & Electricity.

1 Emergency WASH Fundamentals

Access to safe water and sanitation is a fundamental human right and is essential to any humanitarian response. The SPHERE Handbook states that: “the main objective of WASH programmes in disasters is to reduce the transmission of fecal-oral diseases and exposure to disease-bearing vectors through the promotion of:

- good hygiene practices
- the provision of safe drinking water
- the reduction of environmental health risks
- the conditions that allow people to live with good health, dignity, comfort and security.”

The main routes of fecal-oral transmission of diarrheal disease and the barriers to prevent or reduce this transmission are shown in the following diagram:



F-Diagram of Fecal-Oral Routes of Diarrhoeal Transmission

Water related classifications of transmission route:

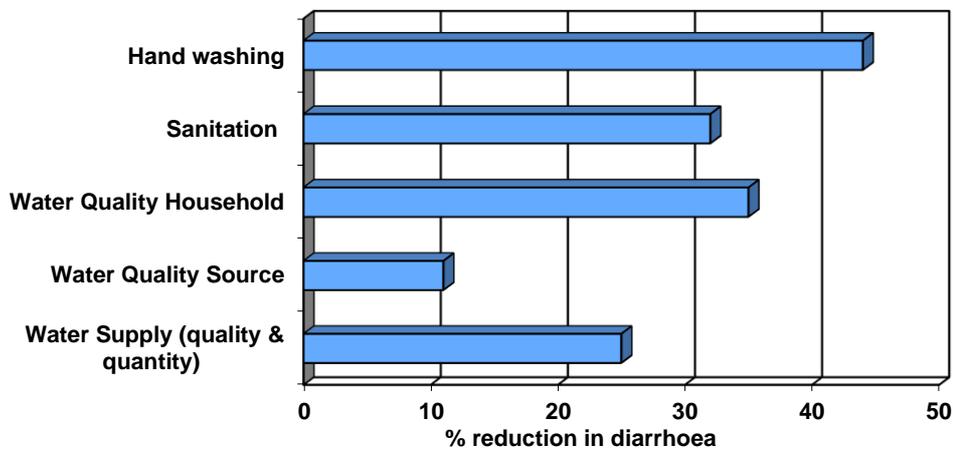
- **Water-borne** – diarrhoeas, dysenteries
- **Water-washed** – infectious skin and eye diseases
- **Water-based** – schistosomiasis, guinea worm
- **Water-related insect vector** – filariasis, malaria, river blindness, yellow fever
- **Soil based** (in addition to water related classifications) – ascaris worms

When water and sanitation systems are destroyed or disrupted by disasters, the likelihood of pathogens being transmitted through the chain increases. Protecting water sources,

installing suitable latrines, treating water and storing it safely, encouraging the use of latrines, hand washing with soap and the washing of food before consumption are all examples of aspects of WASH programming that act as barriers to transmission.

It is important that with the physical repairs and improvements to WASH facilities, good hygiene practices are also promoted to reduce the transmission of faecal-oral diseases. Hand washing (with soap and water) alone can bring about a 45% decrease in the occurrence of diarrhoea in emergency contexts (Fewtrell et al., 2005).

Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis, Fewtrell et al (2005)



2 Hygiene Promotion in Emergencies

Hygiene promotion activities will increase the likelihood of WASH facilities being accepted, used and maintained by the community. It needs to be initiated at the start of any emergency response to promote key behaviors to reduce diarrheal diseases and the scope broadened as the response develops.

The Sphere standard for Hygiene Promotion states that:

Affected men, women and children of all ages are aware of key public health risks and are mobilized to adopt measures to prevent the deterioration in hygienic conditions and to use and maintain the facilities provided

Hygiene Promotion Assessment, Planning and Implementation Steps

Step	Key issues/activities
<p>Step 1 Assessment Conduct rapid assessment to identify risk practices and get an initial idea of what the community knows, does, and understands about water, sanitation, and hygiene.</p>	<ul style="list-style-type: none"> • What is the current WASH situation? • Which specific practices allow diarrheal microbes/other diseases to be transmitted? Which practices are the most harmful? • Identify needs of vulnerable groups
<p>Step 2 Initial consultation Consult women, men, and children on contents of hygiene kit & possible locations and designs of latrines and bathing facilities for safety, privacy and usability</p>	<ul style="list-style-type: none"> • What specific hygiene needs do men, women, and children have e.g. sanitary towels, razors, potties?
<p>Step 3 Planning Select practice(s) and hardware for intervention (define objectives and indicators)</p>	<ul style="list-style-type: none"> • Which risk practices are most widespread? • Which will have the biggest impact on public health? • Which risk practices are alterable? • What can be done to enable alteration of risky practice?
<p>Step 4 Target Audience Define target audiences (this may be all the affected community with priority focus on those who care for young children) and identify stakeholders</p>	<ul style="list-style-type: none"> • Who employs these practices? • Who influences the people who employ these practices? E.g. teachers, community leaders, Traditional Birth Attendants etc.
<p>Step 5 Priority methods Define initial mode of intervention</p> <p>Determine initial key messages and channels of communication</p> <p>Determine advocacy and training needs for stakeholders</p>	<ul style="list-style-type: none"> • What mass media methods are available? E.g. 60% of people have radios but they are often used only by men • What methods do the target audiences trust? E.g. traditional healer, discussions at women's group meetings • Where/how can men and women be accessed? E.g. distribution queue, water point

<p>Step 6 Recruit and train Recruit/identify and start to train fieldworkers and establish outreach system</p>	<p>What capacity (systems, skills, and approaches) already exists in government/national NGOs?</p>
<p>Step 7 Implementation Begin implementation and continue assessing situation</p>	<ul style="list-style-type: none"> • Distribute hygiene kits • Emphasis initially on providing information and use of mass media e.g. radio spots, campaigns, and home visits by volunteers • Organize group meetings/interviews and discussions with key informants and stakeholders to initiate a more interactive approach.
<p>Step 8 Ongoing assessment Develop baseline</p> <p>Understand motivational factors/ refine key messages</p>	<ul style="list-style-type: none"> • Obtain quantitative data where feasible. • Carry out systematic collection of qualitative data using participatory methods (co-ordinate with others and be careful not to overwhelm communities with over questioning) • What motivates those who currently use safe practices? • What are the advantages of the safe practices? • What differences in need and priorities are there for vulnerable groups?
<p>Step 9 Monitor</p>	<ul style="list-style-type: none"> • Are hygiene kits being used/are people satisfied with them? • Are toilets being used/are people satisfied with them? • Do men and women feel safe when accessing facilities? • Are people washing their hands? • Is drinking water in the home free from contamination?
<p>Step 10 Implementation Refine communication plan Rapidly adapt intervention according to outcome of monitoring</p> <p>Continue training Continue monitoring</p>	<ul style="list-style-type: none"> • Emphasis more on interactive methods e.g. group discussions using mapping, three pile sorting etc. • Identify and train (with engineers) longer term structures e.g. committees

(Adapted from Hygiene Promotion in Emergencies, a Briefing Paper, Global WASH Cluster, 2007)

Steps 1 to 7 need to be done rapidly to ensure basic hygiene kits are distributed as soon as possible (see Annex 2.1 for basic hygiene kit details and also for a fuller list of hygiene materials that can be distributed, according to people's needs and preferences).

Include key initial hygiene messages such as:

- the importance of hand washing,
- no open defecation and safe disposal of child feces
- the need for water treatment at HH level

This can be disseminated quickly, using mass media and then expanded later as part of a phased approach.

It is important that vulnerable people are sought out and their views elicited proactively. They typically will have less of a voice and power in decision-making; they will have different needs in using WASH facilities and they are more vulnerable to violence and discrimination. Identifying who is vulnerable is important as different people will be vulnerable in different circumstances.

Not all individuals within a disaster-affected population have equal control of resources and power. People are, therefore, impacted differently on the basis of their ethnic origin, religious or political affiliation. Displacement may make vulnerable certain people who in normal situations would not have been at risk. Women, children, older people, persons with disabilities or people living with HIV may be denied vital assistance or the opportunity to be heard due to physical, cultural and/or social barriers. Experience has shown that treating these people as a long list of 'vulnerable groups' can lead to fragmented and ineffective interventions, which ignore overlapping vulnerabilities and the changing nature of vulnerabilities over time, even during one specific crisis

The SPHERE Project - Humanitarian Charter and Minimum Standards of Humanitarian Response 2011

It is also important that they are part of promotion activities, children especially can become strong proponents of behavior change once they understand the reasons why and how to change. Working with children requires staff who are background checked to ensure the children will be safe, and staff also need special training to make sure the activities are suitable and engaging to children of different ages.

For more details, see WASH Cluster materials on hygiene promotion:

<http://www.unicef.in/emergencies.com/downloads/eresource/docs/WASH/WASH%20Introduction%20to%20Hygiene%20Promotion.Tools%20and%20Approaches.pdf>

3 Emergency Excreta Management

Of primary concern, in the earliest stages of an emergency is the safe disposal of excreta to prevent or reduce the transmission of diarrheal disease. There has to be a balance between the very rapid setting up of excreta disposal facilities, with ensuring that the facilities meet people's need for privacy, dignity and safety whilst using them. In the earliest days of the emergency, the facilities are likely to be very basic and may not adequately cater for privacy and dignity. Through consultations with community leaders and with vulnerable groups, an understanding of the socio-cultural needs can help to improve the initial facilities or to underpin designs of more acceptable facilities.

Because of the additional costs of upgrading facilities at a later date, wherever possible facilities designed for the early stages of an emergency should consider issues related to privacy, dignity, safety and on-going operation and maintenance. Household latrines or latrines shared by 2-3 families maximum are much preferable instead of communal latrines, in terms of on-going operation and maintenance as well as safety of the users.

The following page has a decision-tree for excreta management with options for first phase emergencies, longer term emergency options and options for difficult soil or flooded areas.

Considerations for vulnerable groups – women and adolescent girls, elderly, children, disabled and people living with HIV/AIDS are outlined in section 2.

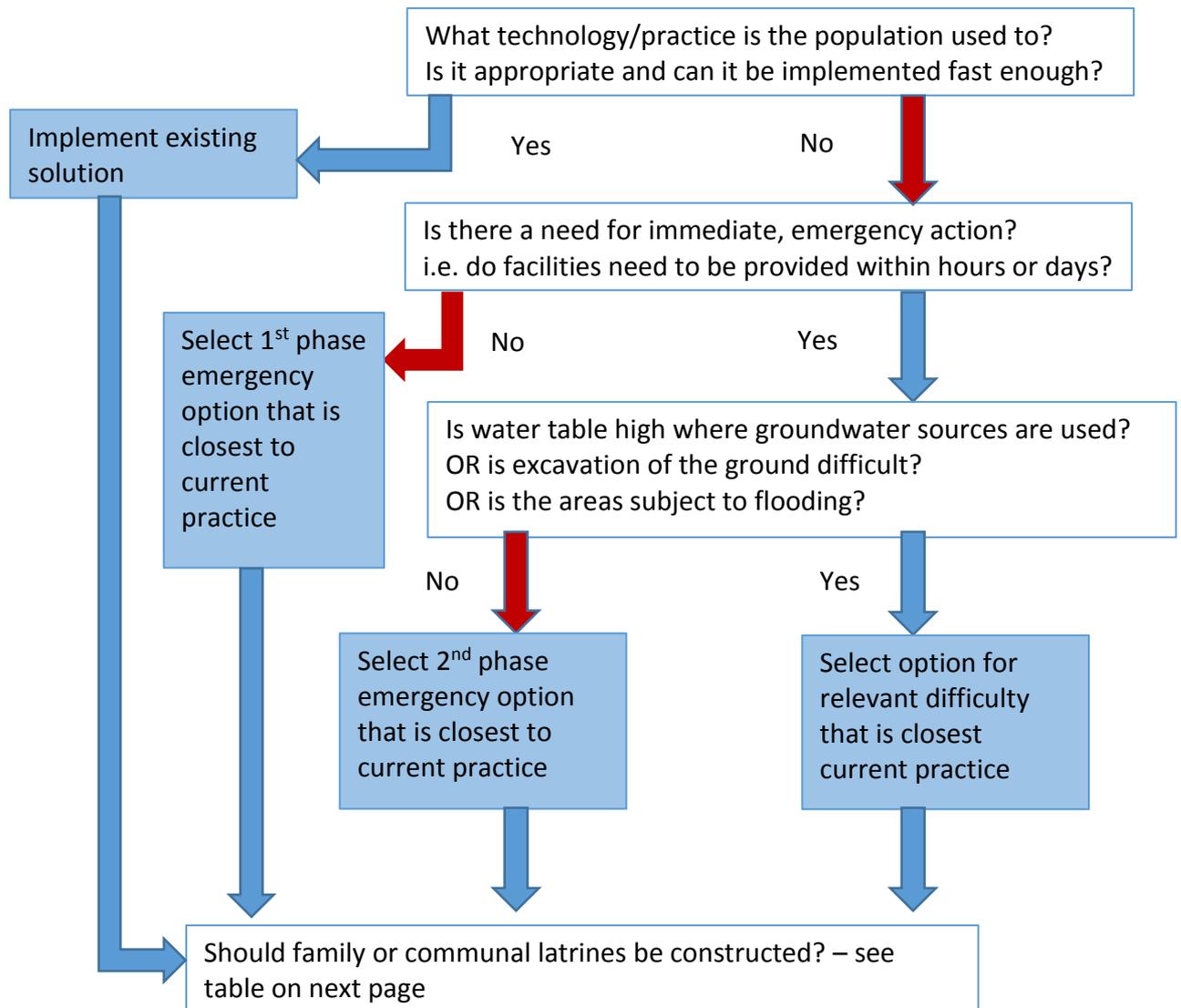
First phase emergency options are considered in detail in section 3.

Later emergency options for excreta management are discussed more fully in the Ministry of Health Manual – Technical Guidelines for Construction of Latrines.

Similar guidelines from the Ministry of Water Resources define latrines for schools and rural health centers – Technical Guideline and Manual for School Latrines; and Technical Guidance and Manual for Latrines for Rural Health Institutions

3.1. Management Decision Tree

(adapted from Excreta Disposal in Emergencies, P Harvey, 2007 WEDC Publications)



See 1st phase emergency options in following pages

For 2nd phase emergency options, see Ministry of Health Technical Guidelines for Construction of Latrines.

For latrines in high water tables, flooding or difficult soils, see Ministry of Water Resources, Irrigation and Electricity Manual on Household Latrines, figures 5 to 9.

For all options, handwashing facilities are needed close to the latrine with soap and water available (see Section 8 for more details)

Comparison of Communal and Family Latrines for Emergencies

Taken from Excreta Disposal in Emergencies, P Harvey, 2007 WEDC Publications

Factor	Communal	Family
Speed of construction	Can be constructed fast by well-trained and well-equipped team, although rate of construction limited by number of staff and equipment.	May take considerable time to train families in the initial stages, but large numbers of latrines may be built quickly.
Technical quality	Quality of design and construction easier to control but innovative ideas from users may be missed.	Potential for innovative ideas of users, but more difficult to ensure good siting and construction.
Construction costs	Use of materials can be easily controlled but labour must be paid for.	Construction labour and some materials free of charge; families may not have time or skills.
Maintenance costs	Maintenance, repair and replacement costs easier to predict and plan; staff required to clean and maintain facilities in long-term.	Users take responsibility for cleaning and maintenance but recurrent costs are less predictable.
Technical possibilities	Heavy equipment and specialized techniques may be used where necessary (e.g. rocky ground).	Families may not be able to dig in hard rock or build raised pit latrines where the water-table is high.
Cleaning and hygiene	Users do not have to clean latrines, but these are often dirty, and a greater mix of users increases the risk of disease transmission.	Latrines are often cleaner but many users may prefer not to be responsible for construction, cleaning and maintenance.
Access and security	Latrines may be less accessible and more insecure, particularly for women.	Latrines are often more accessible (closer to dwellings) and safer.
Development issues	People may lose or not acquire the habit of looking after their own latrine.	People keep or develop the habit of managing their own latrine.

Source: adapted from Adams, 1999

3.2. Basic considerations for vulnerable groups' use of latrines

It is vital that that the community participation is an integral part of selection, design and siting of latrines. Views of vulnerable groups, especially women and adolescent girls, the elderly, children, disabled people and people living with HIV/AIDS should be taken in to account. Similarly, cultural considerations are important to understand – how people use latrines, which groups can use the latrines that other groups use, who cleans latrines and how.

- Siting of latrines to minimize the risk of women and adolescent girls being sexually attacked, or not using latrines because of the fear of attack is important. Consider, where feasible lighting of latrine areas and routes to latrines as well as the surrounding camp areas. If lighting is only focused on the latrine blocks, men and boys can end up hanging around the women's blocks which will make women and girls feel less safe when using them.
- Separating communal male and female latrines is a must. Women, adolescent girls, men and adolescent boys should be consulted on whether they would prefer to have screens around their latrine units. Adding screens can increase the level of privacy and dignity for the users. Similarly make sure walls of latrines are built of materials that are robust, to prevent holes or slits occurring.
- Ensure all latrines have locks on the inside of doors, have hooks (a nail at least) to hang clothes or bags. Also a shelf in each unit can also allow the users to put down small items such as soap, a sanitary pad or cloth or a school book and pencil, while using the latrine, keeping these items off of dirty floors. Wherever possible also consider including a full length mirror in a block of latrines, in particular to enable women and girls to check their clothes for menstrual stains and for added dignity.
- Ensure women have a dignified way to manage their menstrual hygiene. This will be dependent on what materials they use for menstrual hygiene and the culture and taboos surrounding menstruation. They must be able to either dispose of menstrual hygiene materials or wash and dry them in privacy. Space to do this, with a water supply and soap when necessary is required.
- People with incontinence or their helpers will also need space or non-food items such as extra soap, rope and pegs, to wash and dry re-usable incontinence pads or materials.
- Build latrines for disabled people, with extra wide doors for access, space to manoeuvre wheelchairs or for a helper, with handles and bars to help a disabled person use the latrine. Raised seating will also help. It is vital though to talk to disabled people about how they use latrines and design accordingly. A blind person will have different needs than a person in a wheelchair or a person missing a limb. See the Compendium of Accessible Technologies from WaterAid for more details: <http://www.wateraid.org/what-we-do/our-approach/research-and-publications/view-publication?id=aff6d098-00f2-42e5-b9a0-22ec2b264a5e>

3.3. First Phase Emergency Options

3.3.1 Open Defecation Fields

For situations where there is an immediate need for excreta management for disaster affected populations and before latrines have been built, open defecation areas could be used only as an extreme short-term measure.

Set up a defecation areas surrounded by screening, with segregated sites for each sex. People should be encouraged to use one strip of land at a time and used areas must be clearly marked or shut off. It is also possible to use internal partitions to provide more privacy and encourage greater use.

Each defecation area needs monitoring and handwashing facilities with a water supply set up nearby. Strong hygiene messaging, sometimes backed up by monitors to reduce indiscriminate open defecation is important.

It is essential that defecation areas are:

- far from water storage and treatment facilities;
- at least 50m from water sources;
- downhill of settlements and water sources;
- far from public buildings or roads;
- not in field crops grown for human consumption;
- far from food storage or preparation areas.

Advantages: Rapid to implement; minimal resources required; minimizes indiscriminate open defecation.

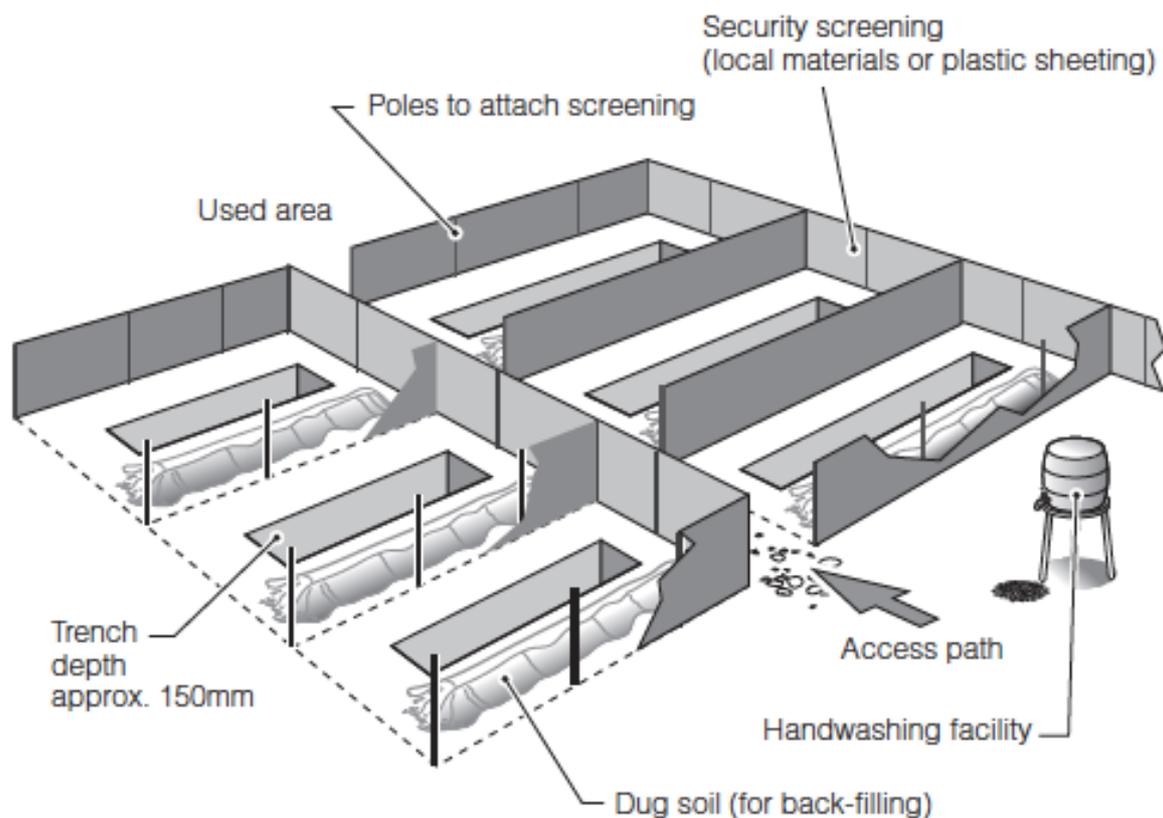
Constraints: Lack of privacy for users; considerable space required; difficult to manage; considerable potential for cross-contamination of users; better suited to hot, dry climates.

3.3.2 Shallow Trench Latrines

An improvement of defecation fields, where a shallow trench (150 to 250 mm deep) is dug in each strip of the defecation area. The area of trenches are screened off; separate male and female trench fields are set up. Management of the strips would mean that the trenches are used effectively and the bottom of a small part of the trench covered with excreta before a new part is made available for use. Rule of thumb suggests 0.25m² of land per person per day.

Advantages: Rapid to implement (one worker can dig 50m of trench per day); feces can be covered easily with soil.

Constraints: Limited privacy; short life-span; considerable space required.



Trench Latrines – from Excreta Disposal in Emergencies, P Harvey, 2007 WEDC Publications

3.3.3 Communal Deep Trench Latrines

These are often constructed in the early stages of an emergency where the soil is suitable. A large construction programme is required to ensure adequate numbers are constructed quickly. Many local laborers, working in teams to dig latrines with carpenters to set up the superstructure are needed; as are digging and carpentry tools.

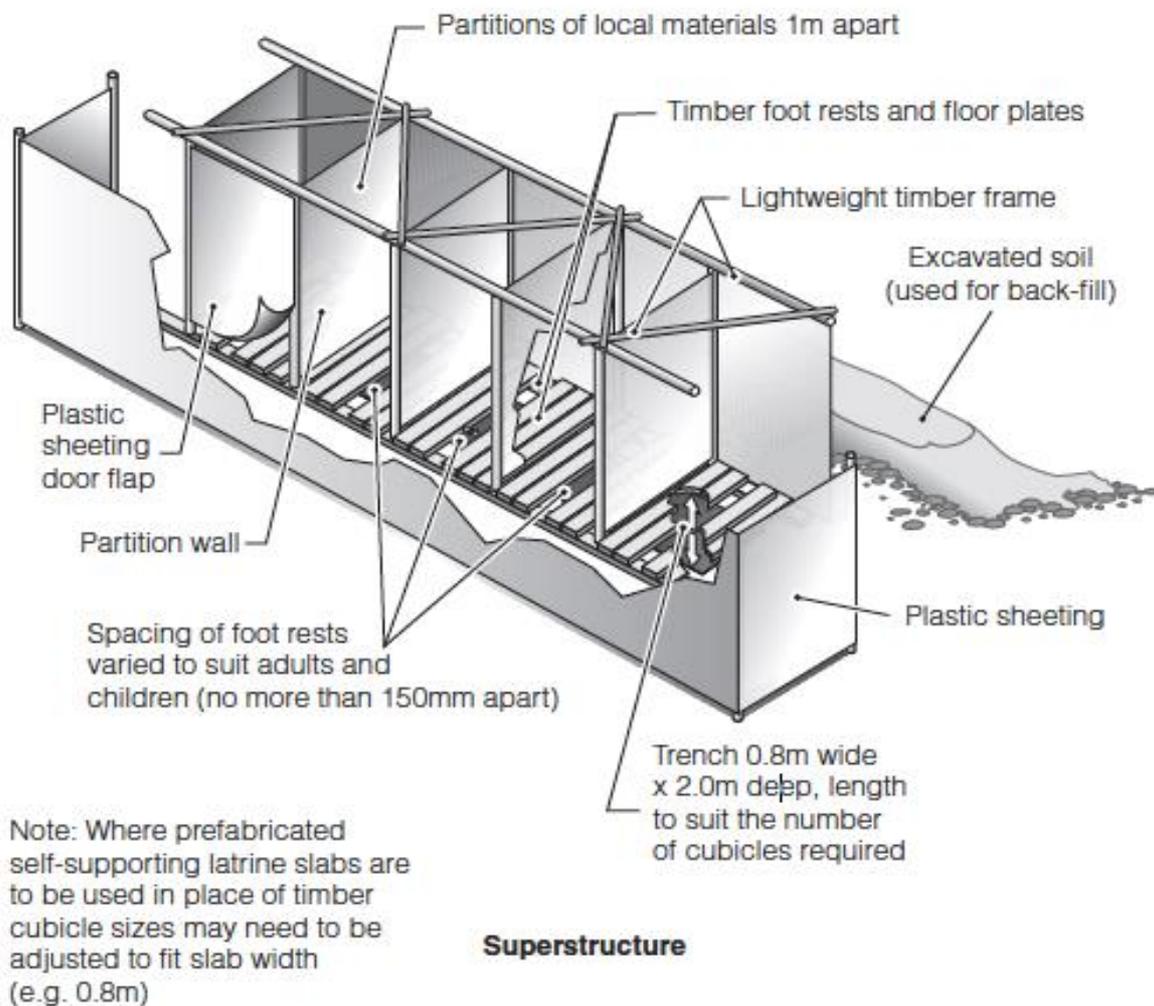
They are typically constructed in rows of up to 6 latrines over 1 pit. The latrine blocks need to be separated into male and female. Smaller holes and lower superstructure walls can be built for children, reducing their fear of using latrines. Vulnerable groups need to be consulted as to how they can access and use latrines with dignity.

The latrine slabs are often plastic slabs that humanitarian agencies have stocked regionally for emergencies. Otherwise planks can be placed across the pit with a gap in the middle between two planks, allowing people to defecate into the pit (See diagram below). The top 50cm of the pit should be lined, more if the soil is unstable. The superstructure can be made of plastic sheeting or local materials, built to ensure privacy.

Advantages: Cheap; quick to construct; no water needed for operation; easily understood.

Constraints: Unsuitable where water-table is high, soil is too unstable to dig or ground is very rocky; often odor problems; cleaning and maintenance of communal trench latrines are often poorly carried out by users.

See Annex 3.1 for Bill of Quantities



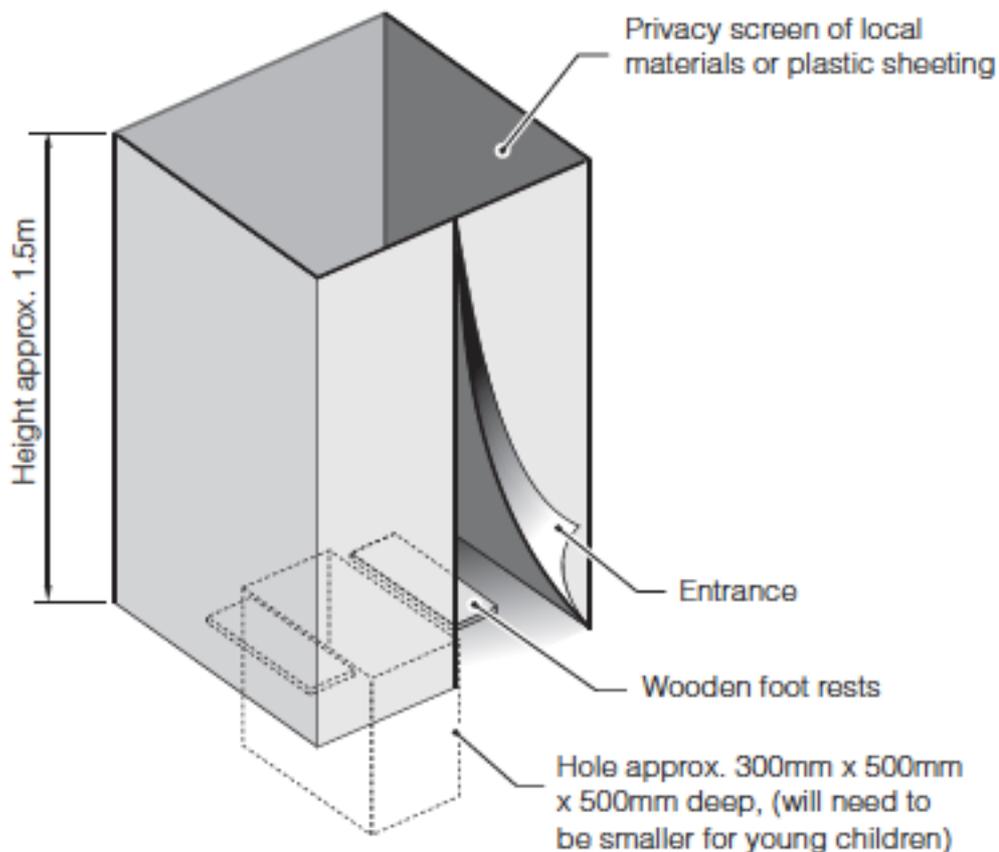
Communal deep pit latrines - from Excreta Disposal in Emergencies, P Harvey, 2007 WEDC Publications

3.3.4 Shallow Family Latrines

Where communities express a strong preference for family latrines, especially where there are difficult soil conditions – rocky soil or high water table, shallow family latrines can be an option. A shallow pit of approximately 0.3m x 0.5m x 0.5m depth may be excavated. Wooden foot-rests or a latrine slab (approximately 0.8m x 0.6m) can be placed over this, overlapping by at least 15cm on each side. This latrine is a short term measure only and should be filled in when the pit is full to within 0.2m of the slab. A simple superstructure for privacy can be made from local materials.

Advantages: Increased privacy; rapid to implement; reduced labor input from agency; allow people to actively participate in finding an appropriate solution.

Constraints: Community must be willing and able to construct family latrines; difficult to manage siting and back-filling of pits; large quantity of tools and materials required.



Taken from Excreta Disposal in Emergencies, P Harvey, 2007 WEDC Publications

3.3.5 Bucket Latrines

Where there is limited space and no other immediate option is feasible, it may be appropriate to provide buckets or containers in which people can defecate. Users must be willing to find this option acceptable for it to be effective. The buckets should have tight-fitting lids and should be emptied daily. Containers can be emptied into a sewerage system, a landfill site or waste-stabilization ponds.

Advantages: Defecation containers can be easily procured and transported; once containers are provided only the final disposal system need be constructed; can be used in flooded areas or where the water-table is very high.

Constraints: Many people find the method unacceptable; large quantities of containers and disinfectant are required; extensive education regarding final disposal is required; disposal it must be fairly close to homes to minimize transportation needs; containers may be used for alternative purposes.

3.3.6 Packet Latrines (such as Pee-poo bags)

In some emergency situations relief agencies have provided disposable packet latrines. These

are plastic packets (similar in appearance to a plastic bag) in which the user can defecate; the packets contain a blend of enzymes which assists the breakdown of the excreta, and must be collected safely and disposed of in a safe place. There are various commercial options available containing different chemicals to absorb liquids, aid organic decay and neutralize odors. Recent advances use biodegradable bags and state that the pathogens are neutralized after two weeks, allowing the bags to be disposed of in landfill.



Pee-poo bags (image courtesy of Peepoople)

Effective management of a system using packet latrines is crucial, and requires ongoing monitoring and appropriate hygiene promotion. Appropriate collection and disposal sites must be developed immediately and an active campaign initiated to inform community members. Basic consultation with the community is necessary before implementing such a system.

As the bags are normally fitted in a small container to use, they are not very suitable for the elderly, disabled, pregnant women. Other options such as a seated toilet over a bucket might be more suitable.

Advantages: Lightweight and easy to transport; may be used where space is severely limited or in flooded areas.

Constraints: Method may not be acceptable to affected population; final disposal site must be clearly marked, accessible and used.

3.3.7 Handwashing Facilities

It is vital that all latrines have handwashing facilities with water and soap nearby. The most effective is a tap connected to the water supply, with adequate drainage. This should be the long term option.

For emergencies, a raised water container, allowing a small flow of water (ideally via a tap) for handwashing will suffice if there is an attendant who will make sure the container constantly has water and there is soap. There are many options possible, some made locally. It is important that people do not dip their hands into the water, contaminating it for others and that there is drainage to prevent standing water and further disease transmission (e.g. of hookworm). See Annex 3.2 for diagrams. The soakaway is detailed in Annex 3.3.

4 Hygiene Facilities

Washing areas in camps for clothes and food dishes is necessary for basic hygiene. Through washing of clothes and personal hygiene, louse borne diseases such as typhus and relapsing fever can be almost eliminated (Cairncross & Feachem, 1983), other water washed disease transmissions are minimized, therefore it is important that the provision of wash slabs is backed up by hygiene promotion measures, especially the provision of laundry soap and clean water. Washing areas need to be positioned close to water supplies. See Annex 4.1 for details

When building communal latrines, shower blocks and washing slabs should also be constructed if space is available and with proper drainage and waste water disposal. Their design should promote privacy and incorporate wastewater design aspects. They should be built close to water supplies and for both females and males, screened blocks with toilets and washing facilities for clothes could be built. Women and adolescent girls should be consulted to see if they would like any modification for washing menstrual materials or need additional non-food items for this purpose. For example they may like some larger shower units to enable them to do private clothes washing inside the shower unit, or may like a washing slab within the screened unit. It is important to note that women and girls are often shy for other women and girls to know they have their menstrual period, so consultation is essential if the facilities may not be used. Covered waste bins for discrete disposal of menstrual materials (if applicable) should be made available inside the facility, but it is essential that a sustainable operation and maintenance system is in place for the management and disposal of such materials and that those who are to dispose of these materials know how to do so safely. See Annex 4.1 and 4.2 for details.

A screened latrine, shower and menstruation washing and drying area for women was a solution in Pakistan for dignity issues for women – see Annex 4.3 and 4.4 for details.



*Screened Latrine and Shower Block - Separate Units Provided for Females and Males
Photo credit: Sarah House/Oxfam-GB*

5 Wastewater Disposal

The lack of proper wastewater disposal and treatment can cause serious health risks including:

- Breeding of insect vectors (e.g. mosquitoes);
- Spread and multiplication of pathogenic agents, such as, cholera vibrios and schistosomonas, etc.;
- Chemical contamination of water (e.g. laboratory chemicals, detergents) and ecological disturbance / pollution of aquatic environments (ground and surface water);
- Production of noxious and corrosive gases;
- Flooded latrines will spread faecal pollution widely;
- In addition flooding can also result in wastewater and runoff water entering shelters and waste pits

In camps and rural areas, wastewater is normally from water collection, washing areas and showers, unless latrines overflow due to flooding or being overfull. Careful construction of latrines with ditches to divert rainfall and monitoring to ensure they are closed and filled in before overflowing will prevent this.

Grease traps are important to put in place after washing areas to minimize the flow of soap and cooking fats into soakaways. Otherwise the grease will clog up the pores in the soil surrounding soakaways very quickly and cause local flooding.

See Annex 5.1 for details of drainage designs.

6 Emergency Water Supply

6.1 Emergency Water Supply

The provision of water is a critical element of any emergency response and as part of a wider water, sanitation and hygiene programme is fundamental for survival in the earliest staged of a disaster. People affected by disaster, especially women and children, are more vulnerable to diseases related to poor sanitation and water supply and poor hygiene.

The provision of water by itself will not produce a marked reduction in the transmission of fecal-oral diseases or other water related diseases. The Emergency WASH overview will provide outlines of other WASH aspects and guidance manuals from the Ministry of Health concentrate in more detail on aspects of emergency sanitation:

- Environmental Health in Emergencies (including Food Safety)
- Construction of Latrines in Emergencies
- Solid Waste Management in Emergencies
- Medical Waste
- Water Chlorination

This guidance manual will concentrate on the provision of safe drinking water, but will also include references to sanitation and hygiene where necessary to ensure such linkages are there.

6.1.1 Water Requirements and Standards

The 2015 Draft WASH Sector Coordination Humanitarian Strategy has defined several contexts which would determine the affected population's water supply requirements, these are:

- New Internally Displaced People (IDPs) and new refugees;
- Disaster Affected populations (flood or outbreak especially) in first phase response;
- Permanent IDPs (settled for more than 5 years) and permanent refugees;
- Settled Communities and Returnees;
- Nomads: Moving nomads and settled nomadic tribes.

UNHCR has defined WASH indicators for refugees for the following emergency phases:

- Emergency phase – first three months of the emergency
- Transition phase – period above three months and under 1 year
- Long term phase – period above 1 year

The SPHERE handbook has 3 standards for water supply – access and quantity; quality and water facilities, these are:

Water supply standard 1: Access and water quantity

All people have safe and equitable access to a sufficient quantity of water for drinking, cooking and personal and domestic hygiene. Public water points are sufficiently close to households to enable use of the minimum water requirement.

Water supply standard 2: Water quality

Water is palatable and of sufficient quality to be drunk and used for cooking and personal and domestic hygiene without causing risk to health.

Water supply standard 3: Water facilities

People have adequate facilities to collect, store and use sufficient quantities of water for drinking, cooking and personal hygiene, and to ensure that drinking water remains safe until it is consumed.

A summary table of the water supply requirements for different phases and contexts can be found below. These water supply requirements are generally strongly related to the SPHERE manual and the same as the indicators in SPHERE, with some exceptions such as the minimum Free Residual Chlorine level (see the note at the end of the table). Where there is more than one indicator that relates to the specific issue (such as the maximum distance to water points from households for long term IDPs and refugees, both are presented):

Phase	Context	Water Requirement	Source of indicator
Emergency 0 – 3 months	New IDPs, new refugees, disaster affected populations	Water trucking 7.5l/person/day (refugees, 1 month only)	1,2,3
		Other water supplies at least 15 l/person/day	1, 3
		Maximum distance from water point to household 500m	1,2,3
		0 fecal coliforms/100ml sample water	1,3
		Free Residual Chlorine 0.2 mg/l at the household after 24 hours; and 0.5 – 1.0 mg/l at any point of distribution (tapstand, from a tanker or donkey cart) – both before and during an outbreak (see note at the end of the table)	4,5
		250 people/tap	1,3

		500 people/handpump 400 people/open well	3 3
Transition 3 months – 1 year	New IDPs, new refugees	Water supply 15 to 20 l/person/day Maximum distance from water point to household 250m (refugees, UNHCR), 500m (WASH Sector) 0 faecal coliforms/100ml sample water Free Residual Chlorine 0.2 mg/l at the household after 24 hours; and 0.5 – 1.0 mg/l at any point of distribution (tapstand, from a tanker or donkey cart) – both before and during an outbreak (see note at the end of the table) 250 people/tap 500 people/handpump 400 people/open well	1 1,2 1,3 4,5 1,3 3 3
Long term over 1 year	Refugees, IDPs	Water supply >20l/person/day Maximum distance from water point to household 200m (Refugees, UNHCR), 500m (WASH Sector) 0 fecal coliforms/100ml sample water Free Residual Chlorine 0.2 mg/l at the household after 24 hours; and 0.5 – 1.0 mg/l at any point of distribution (tapstand, from a tanker or donkey cart) – both before and during an outbreak (see note at the end of the table) 250 people/tap 500 people/handpump 400 people/open well	1 1,2 1,3 4,5 1,3 3 3

Phase	Context	Water Requirement	Source of indicator
Non-Emergency	Settled populations and Returnees	At least 15 l/person/day Maximum distance from water point to household 1500m 0 fecal coliforms/100ml sample water	3 2 3

		Free Residual Chlorine 0.2 mg/l at the household after 24 hours; and 0.5 – 1.0 mg/l at any point of distribution (tapstand, from a tanker or donkey cart) – both before and during an outbreak (see note at the end of the table)	4, 5
		250 people/tap	3
		500 people/handpump	3
		400 people/open well	3
	Moving Nomads and Settled Nomads	Maximum distance from water point to household 1500m	2

Source of Indicator:

- 1 –Sudan WASH Sector and Sudan Refugee Multi-Sector Refugee Response Strategy (August 2015 – December 2016) UNHCR
- 2- Draft WASH Humanitarian Strategy 2015, WASH Sector
- 3 – Manual of Environmental Health in Emergencies – Ministry of Health
- 4 – WHO Guidelines for Drinking Water Quality incorporating the first Addendum, 2017
- 5 – Sudan Drinking Water Safety Strategic Framework, 2017 (final draft)

Note on FRC:

During the process to develop the Sudan Drinking Water Safety Strategic Framework, 2017 it was agreed² to:

1. Maintain a free chlorine residual of 0.2 mg/l at the household level after 24 hours.
2. Increase the chlorine residual to leave at least 0.5-1.0 mg/l residual at public standposts in any hot climate condition, irrespective of outbreak or normal conditions, and to monitor the effects along the water chain to check: a) residuals in households, as well as checking b) the community acceptance of the chlorine taste/rejection levels; and then to adjust accordingly.

Guidance Notes from SPHERE

The quantity of **water needed for domestic use is context based**, and may vary according to the climate, the sanitation facilities available, people’s habits, their religious and cultural practices, the food they cook, the clothes they wear, and so on.

In a disaster, the priority is to provide equitable access to an **adequate quantity of water** even if it is of intermediate quality. Disaster affected individuals are significantly more vulnerable to disease; therefore, water access and quantity indicators should be reached even if they are higher than the norms of the affected or host population. Particular attention should be paid

² This update in level for FRC at distribution points is to take into account the hot climate and the high risk of contamination in Sudan from issues such as open defecation and old piped networks with intermittent supply. The changes have been based on recent learning from research in South Sudan and elsewhere. The recommendation has been discussed with WHO Geneva and it has been agreed that the increased levels are in alignment with the principles of the WHO Guidelines for DWQ 2017 with the main priority for chlorination to have a residual of 0.2 mg/l in the household.

to ensure the need for extra water for people with specific health conditions, such as HIV and AIDS, and to meet the water requirement for livestock and crops in drought situations. To avoid hostility, it is recommended that water and sanitation coverage address the needs of both host and affected populations equally

Queueing for more than 30 minutes is an indicator of insufficient water availability due to not enough water points or inadequate yields at water sources. This can result in people taking less water or not getting water from the water point but taking water from an unprotected source.

Even if a sufficient quantity of water is available to meet minimum needs, additional measures are needed to ensure **equitable access** for all groups. Water points should be located in areas that are accessible to all, regardless of, for example, gender or ethnicity. Some hand pumps and water carrying containers may need to be designed or adapted for use by people living with HIV and AIDS, older people, persons with disabilities and children. In situations where water is rationed or pumped at given times, this should be planned in consultation with the users including women beneficiaries.

For **livestock** needs, it is important to identify the water needs through assessment (see Livestock Emergency Guidelines and Standards, LEGS 2nd edition 2015 for details). For planning figures, the following can be used:

Cattle, horses, mules and large animals	20-30 litres per head
Goats, sheep, pigs	10- 20 litres per head
Chickens	10-20 litres per 100

(from WHO: How much water is needed in emergencies, Technical Notes On Drinking-Water, Sanitation and Hygiene in Emergencies no. 9 (2011))

SPHERE also defines water requirements for institutional and other users:

Health centres and hospitals	5 litres per outpatient 40-60 litres per inpatient per day Additional quantities may be needed for laundry equipment, flushing toilets, etc.
Cholera centres	60 litres per patient per day 15 litres per carer per day
Therapeutic feeding centres	30 litres per inpatient per day 15 litres per carer per day
Reception/transit centres	15 litres per person per day if stay is more than one day 3 litres per person per day if stay is limited to day-time
Schools	3 litres per pupil per day for drinking and hand washing (Use for toilets not included: see Public toilets below)
Mosques	2-5 litres per person per day for washing and drinking
Public toilets	1-2 litres per user per day for hand washing

	2-8 litres per cubicle per day for toilet cleaning
All flushing toilets	20-40 litres per user per day for conventional flushing toilets connected to a sewer 3-5 litres per user per day for pour-flush toilets
Anal washing	1-2 litres per person per day
Livestock	20-30 litres per large or medium animal per day 5 litres per small animal per day

6.2 Emergency Water Source Selection

Typical water sources in Sudan are as follows:

- Open wells,
- Closed wells with handpumps
- Closed wells with motorized pumps (submersible or with surface mounted motor)
- Hafirs (traditional or improved)
- Borehole with handpump
- Borehole with motorized pump (submersible or with surface mounted motor and/or solar system)
- Rainwater roof catchment
- Springs
- Surface water (rivers and lakes)
- Dams

6.2.1 Site Selection and Water Sources

Selection of water sources is often the most important factor in whether populations can reside at any one site for any length of time. Without the possibility of a reliable water supply that can provide the minimum amount of reasonable water quality, a site should not have people located there. Even if there is a possibility of a temporary solution, such as water trucking or a seasonal water source, it is important to ensure a longer term supply is possible. Once populations are settled on a site, even if it had been planned for a short period, it is likely they will be there for longer than anticipated. Sites with no permanent water supply, where people have self-settled, are very difficult to sustain in the long-term; the absence of a water supply has to be weighed against the real difficulties of moving them to a preferable site.

Adequate amounts of water need to be available to the population so that they need not walk more than 500m to collect it. They should also not have to queue for more than 30 minutes to get the water: an adequate number of taps (250 people/tap) and a minimum flow rate of 0.125 litres/sec from each tap should ensure this.

It is vital to set a defined maximum population a site can hold due to water supply considerations, based on the figures set out in 1.1 Emergency Water Requirements.

6.2.2 Identifying Water Sources

In identifying possible water sources for emergency use, the priority for investigation should be in the following order:

1. Existing water supply systems that are fully functioning – do they have spare capacity either for short or long term use?

2. Existing water supply systems that are not fully functioning – what needs to be done to repair these sources? How quickly can this be done? What is the capacity of supply if fully functioning?
3. Water sources that have not yet been exploited to provide a water supply – what needs to be done to make this supply drinking water? How quickly can this be done? What is the capacity of the source once functioning?

Method

1. For each settlement collect as much information as possible to determine the population's water supply needs and most suitable water supplies. For Water Supply Needs see Module on Water Requirements. A Checklist on water supplies information requirements can be found in Annex 6.1.

The following flowchart identifies a process for deciding the most suitable water supply in emergencies:

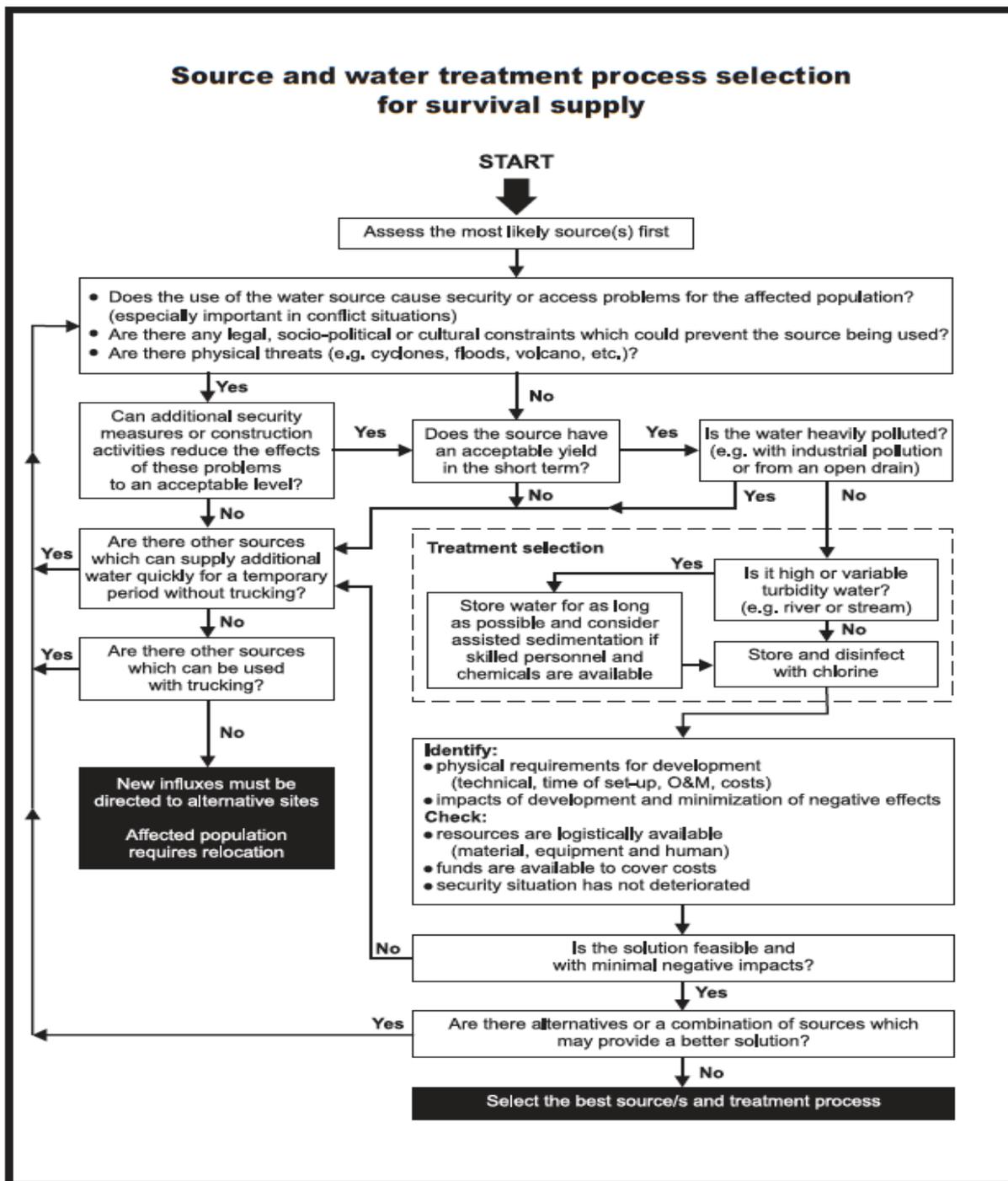


Figure from Emergency Water Sources: Guidelines for Selection and Treatment, S. House and R. Reed, WEDC 2004

2. Where possible draw a Catchment Map (see Annex 6.2 for an example) which is a useful method to show a range of issues, such as ownership, distance to settlements etc. for the water source and can identify major pollution risks.
3. For rural water supplies, carry out a sanitary survey to identify pollution risks for the source. Annex 6.3 has sanitary survey forms for most water rural supplies. These can be adapted for local conditions.

4. For larger water supplies, a sanitary investigation might be a better assessment of risk. A sanitary investigation form is in Annex 6.4
5. Follow the Flowchart to identify the most suitable source in terms of:
 - a. Security, access, political and socio-cultural considerations
 - b. Yield, both present short term and longer term/seasonal yields
 - c. Pollution risks and treatment options
 - d. Speed, cost and resources required for set up or rehabilitation of water supply system
6. A temporary quick solution such as water trucking is possible, but it is vital that longer term options are also identified (that might take longer to set up) and assessed. Water trucking should never be used in the longer term, as it is an expensive system that will easily break down and can rarely deliver enough water for the population's needs. See Module 6.4 on water trucking for more details.

6.3 Water Safety Plans

Rehabilitating water supply schemes will ensure targeted populations have access to adequate safe water to meet their WASH needs. This is rarely a first phase emergency option but will promote a good level of sustainability of water supply. Improved water sources can reduce the distance walked to collect water, enabling people to collect more water; allow them time for other livelihood activities; open economic opportunities for women; and enable children to continue schooling.

Water sources are often in poor condition because they have not been maintained. Increased population pressures can exacerbate the situation, putting greater stress on a poorly maintained system.

A key strategy for setting out priorities for rehabilitation and operation maintenance is Water Safety Planning (WSP). This identifies risks to health from the water source to household use of water and plans remedial and preventative measures to minimize those risks.

Alongside reconstruction efforts, setting up or supporting a water management committee to ensure operation and maintenance is key to a sustainable water supply.

6.3.1 Risk Management – Water Safety Plans

The Water Safety Plan approach is considered preventive risk management. Risks to drinking-water safety are identified, prioritized and managed to protect drinking-water quality before problems occur. Water safety planning also requires regular monitoring of control measures and checking of water quality. The WSP itself documents the process and practice of providing safe water at the community level, but dedicated implementation of the plan is key. The aim of employing a WSP approach is to consistently ensure the safety and acceptability of a drinking-water supply in a practical manner.

Where all risks cannot be immediately minimized because of limited resources, a WSP is implemented to make prioritized, incremental improvements over time.

Setting up and carrying out a WSP requires both time and genuine commitment at all levels among key members within the community. Water safety planning should be viewed not as a one-time undertaking, but as part of the day-to-day operation, ongoing maintenance and management of the water supply.

6.3.2 Key water safety planning principles

- Understanding and committing to achieving drinking-water safety are prerequisites to the implementation of any effective WSP.
- Water safety can be effectively and sustainably improved through the use of a preventive risk management approach.
- The WSP approach is meant to be flexible and adapted as needed.
- The greatest risk to drinking-water safety is contamination with disease-causing

microorganisms.

- Risks to the safety of drinking-water are best controlled using a multiple-barrier approach.
- Incremental improvements to the water supply system can be made over time, with the aim to eventually achieve water quality targets or objectives.
- Any (sudden) change in the local environment should result in investigative action to confirm that drinking water is safe or to provide information on how to undertake corrective actions.
- Any complaints about illness, taste, color or smell require follow-up to ensure that the drinking-water continues to be safe.
- Regular review of the WSP (including newly identified risks) is critical to ensure that water safety planning remains up to date and effective.

6.3.3 Water Safety Plan – 6 Tasks



Task 1 – Engage the Community

1.1 Engaging the community and assembling a WSP team are an essential means to:

- identify the community's ideas and needs about their water supply, through an inclusive process that considers women, men and children as well as elderly and vulnerable community members;
- work with local knowledge and experience in the identification, assessment and management of risks;
- identify resources within the community that can be called upon when needed;
- start discussions between the community and other stakeholders (government, NGOs, water service delivery and public health agencies) on the benefits and requirements of a well-functioning water supply;
- raise awareness of the role that community members can play in protecting and improving their water supply.

A successful WSP will have involved the community throughout the entire process and, ideally, is led at the community level.

1.2 Assemble a WSP team

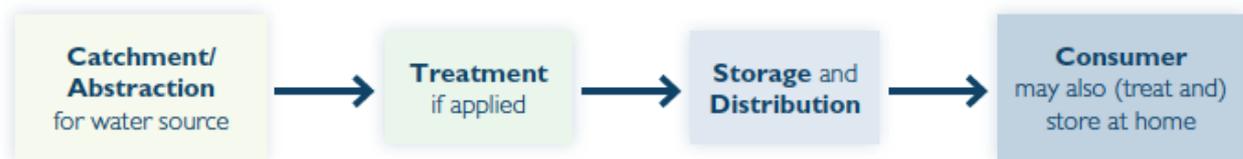
The WSP team will be responsible for developing, implementing and maintaining the WSP. The team is also needed to help the community to understand and accept the WSP approach. When choosing WSP team members, it is best to consult community leaders, such as elders, elected officials, Water User Committees and other persons who know the community well. Ideally, team members will have varying backgrounds. Individuals who have one or more of the following characteristics should be considered for team membership:

- is familiar with, and uses water from, the water supply, women and children will often be most familiar with the water supply as they will use it daily, it is therefore important that there are women in prominent roles in the water safety planning team, older children can also have a role in the Water Safety Plan Team. Ways of engaging younger children in the plan in ways that are relevant to them are important to ensure their needs are incorporated. They will also need someone to represent their views to the Water Safety Plan team and report back to the children of decisions and progress made.
- is responsible for the day-to-day operations of the water supply or has helped during construction or earlier repairs;
- has the authority to make decisions about spending money, training, recruiting staff and/or making changes to the water supply;
- has respect and trust of the community
- has the knowledge and capacity to identify potential risks to the water supply from the catchment to the consumer;
- is responsible for or has the capacity to help manage and prevent those risks;
- is influential and interested, at both the community level and at least one administrative level up, in representing water quality concerns and investment needs at the district level or higher.

If there is a Water User Committee set up, running well and respected by the community, there are good reasons to use this as the basis of a Water Safety Plan team. It is important to identify if they can take on the extra commitment and duties of a WSP team.

Annex 6.5 has details of skills useful in a large scale water supply WSP team

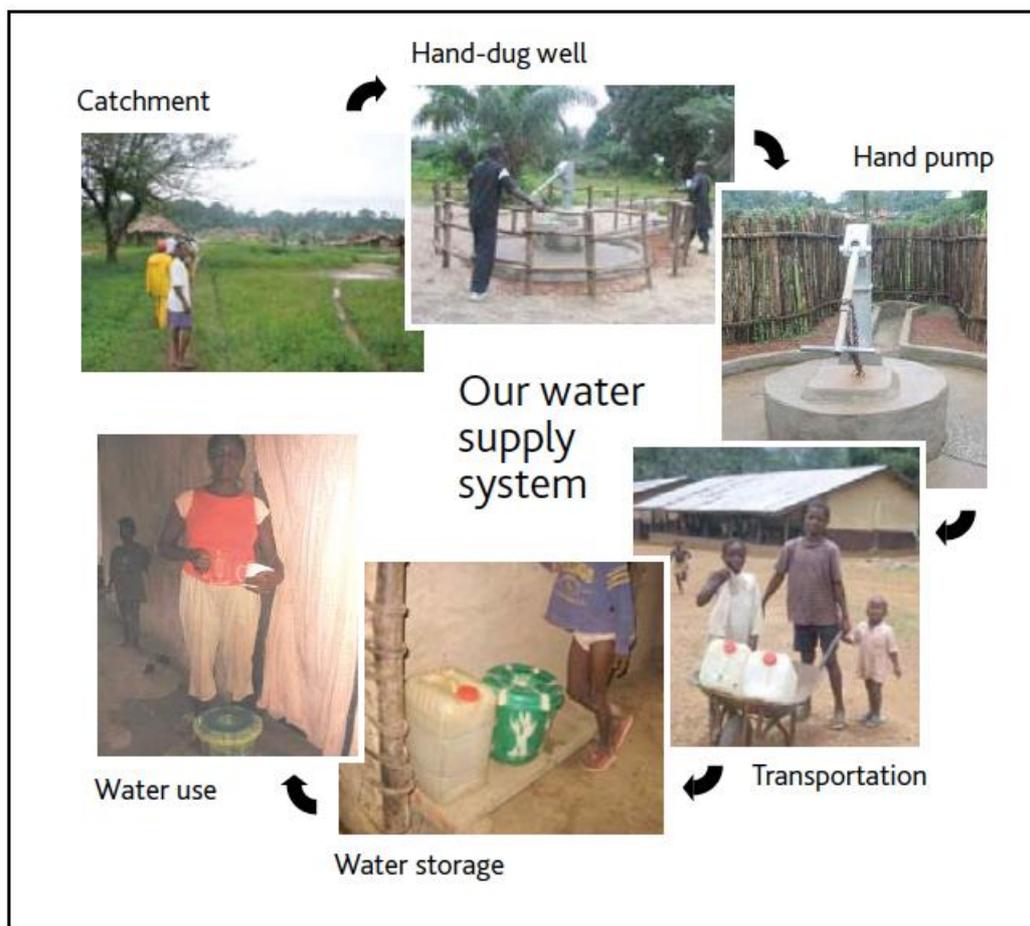
Task 2 - Describe the Water Supply



Components of a piped water supply system

Diagram from WHO: Water Safety Planning for small rural communities

A community water supply system may be made up of a number of connected components, as illustrated for a piped scheme above. Alternatively, a community may have several point water sources (e.g. protected springs, wells, boreholes, rainwater harvesters) serving tens or hundreds of households. The WSP team should check all of these sources and include them in the community WSP.



Picture from Tearfund: WSP for Communities

2.1 Draw a Map

This is done to understand what is in place. An easy way to do this is to make a map/flow diagram of the water supply, including relevant elements of the catchment area and the

community served. A great deal of information can be recorded and presented in a drawing. Such mapping of the community water supply from catchment to consumer is an essential part of the water supply description.

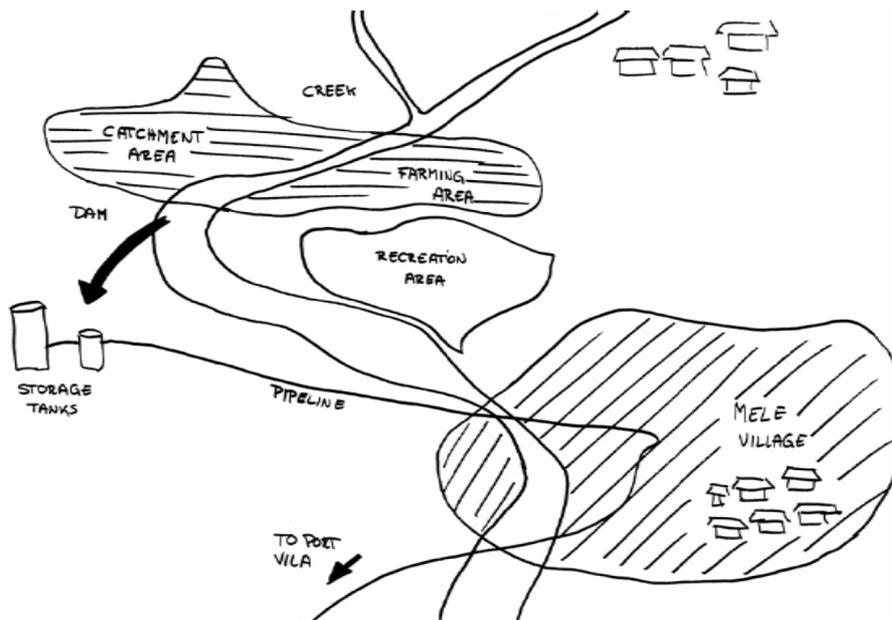
Maps should be sufficiently detailed to easily identify hazards to the water supply. Therefore, when a community water supply is made up of a number of connected components, it may be helpful to develop an overview map of the entire community supply as well as detailed maps/ schematics of each water supply component.



Photo from WHO: Water Safety Planning for small rural communities

For example, a catchment map should include human activities and land uses (e.g. agriculture, sanitation) that may contribute to microbial and/or chemical contamination of the water source, whereas a treatment map should provide details on the treatment processes used, where particular chemicals are added, etc.

Involving the widest range of people in mapping, especially ensuring the views of women, adolescent girls and children about where water points are situated and access to them in terms of their security is important.



Water supply system in Mele, Efate, Vanuatu
 Diagram from WHO: *Water Safety Planning for small rural communities*

2.2 Gather supporting information

Information needs to be gathered to describe the water supply and its management, including the various sources in use.

The type of information collected should include, but is not limited to:

- water quality standards;
- known or suspected changes in source water quality relating to weather or other conditions;
- land uses in the catchment and who are the riparian users (users of the land on river banks);
- treatment, distribution and storage of the water;
- who uses the water supply and for what purpose;
- who is responsible for operating the system and what education and training they received;
- what financial and human resources are available for managing and operating the supply;
- management procedures (e.g. operations, maintenance, inspection), if they exist;
- the legal ownership of land used and other properties in the catchment;
- details on existing sanitation facilities, including their location.

2.3 Check the map and water supply description

It is important for the WSP team to physically check the description of the water supply system through a walk or site inspection (e.g. by following the “flow of water” through the water supply system). Taking photos and reviewing related documentation can also be useful. The water supply map and description should be updated based on this check. This activity could also be conducted as part of 2.1 (drawing a map).

2.4 Discuss and identify community water supply objectives

The following questions can help in developing community water supply objectives:

- What do we want and need from our water supply?
- What are our current water supply and sanitation systems, and how are they operated?
- What problems are there with the water supply?
- Who is involved, and who should be involved, in ensuring that we have the water we need and want?
- What else, other than the water supply, is needed for a healthy and sustainable community?
- What other water supply aspects should/can be considered (e.g. other activities for which water is needed, such as fruit and vegetable gardening, growing rice seedlings for transplanting, domestic livestock)?

Using different forums for discussing these questions – school hygiene promotion clubs, different focus group discussions for women and men, key informant interviews with MoH and WES staff will all help to identify priorities.

Task 3 – Identify Hazards and Risks and existing control measures

3.1 Identify Hazards

Some hazards and risks will likely have been identified during the mapping process and during any visits to the water supply. This process allows for more discussion of those hazards that are less likely to be identified immediately:

- Besides identifying hazards affecting hardware, WSPs are concerned with social and behavioral risks. The effects of gender, vulnerable groups, children, conflict, security and, in particular, poor hygiene practices should therefore be discussed. Women and children will be aware of water points and routes to collect water where natural hazards and threats of violence are likely.
- The community should be aware of both existing and potential hazards, including seasonal or event-related hazards (eg flooding). As the community assimilates what can happen to their water supply, some members may helpfully be able to relate to things that happened in the past which affected their water quality.

The best way to go about this is to look at each part of the water supply from source to drinking water use in the house (the water journey) and identify the hazards and risks for each stage. Working with the WSP team – people willing to take time to investigate this, alongside experts (water supply staff, health workers etc.) will bring together local understanding of the geography, climate and culture with expert knowledge of water supply and health risks. Depending on how literate the community is, who is involved in the discussions and how well they know the water supply system and the risks, different methodologies can be used.

Problem Areas Hazard Mapping

Using pictures to illustrate the risks (open defecation, dirty water containers, animals drinking close to the water source etc.) might work well with people with little formal education. The pictures of possible risks can then be put on a picture or map of the water journey so that it is clear where the risks might occur.

Ways of engaging younger children in the plan: mapping the route they collect water, looking at areas that they are frightened to go when collecting water and drawing pictures of how they might be made safer is important to ensure their needs are incorporated.

Another way to identify the risks is by using a sanitary survey form – these can easily be modified for the particular situation. Sanitary Surveys are discussed in more detail in Annex 6.3 of Module 2: Water Source Selection.

3.2 Analysis of Risks

Looking at each part of the water supply journey, it is possible to quantify risks by giving a score from low to high (1 to 5 possibly) for the likelihood of a hazard happening, and doing the same for the impact or severity the hazard would have if it occurred.

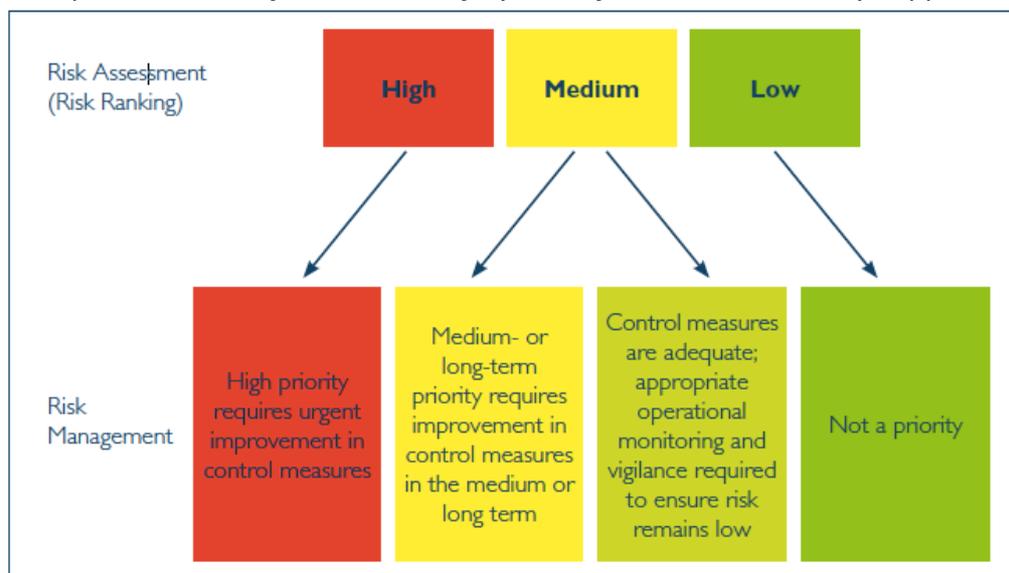
Multiplying the two together would give an idea of which are the biggest risks.

Descriptor	Description
Likelihood	
Likely	Will probably occur in most circumstances; has been observed regularly (e.g. daily to weekly).
Possible	Might occur at some time; has been observed occasionally (e.g. monthly to quarterly or seasonally).
Unlikely	Could occur at some time but has not been observed; may occur only in exceptional circumstances.
Severity/consequence	
Major impact	Major water quality impact; illness in community associated with the water supply; large number of complaints; significant level of customer concern; significant breach of regulatory requirement.
Moderate impact	Minor water quality impact (e.g. not health related, aesthetic impact) for a large percentage of customers; clear rise in complaints; community annoyance; minor breach of regulatory requirement.
No/minor impact	Minor or negligible water quality impact (e.g. not health related, aesthetic impact) for a small percentage of customers; some manageable disruptions to operation; rise in complaints not significant.

Example of scoring likelihood and severity of hazards from Water Safety Plans for Small Community Supplies, WHO

		Severity/consequences		
		No/minor impact	Moderate impact	Major impact
Likelihood	Likely	Medium	High	High
	Possible	Low	Medium	High
	Unlikely	Low	Low	Medium

Example Risk Matrix from Water Safety Plans for Small Community Supplies, WHO



Example Diagram to prioritize risks from Water Safety Plans for Small Community Supplies, WHO

With communities, this can be quite complex and it is easier to identify weak spots in the system through which contaminants could potentially enter the supply. Referring to the 'Problem areas' activity above, the facilitator should ask the community participants how they would prioritize any particular problems, and why they would do so. Agreement on the prioritization of particularly problematic or vulnerable areas should be sought, and the specific pictures to which they relate can be circled with a red marker pen.

Where existing risk control measures (such as fencing to keep animals away from the water source) are in place and working well, these can also be highlighted in a different color.

Task 4 – Develop an improvement plan

Having identified what are the priority risks for the water supply, the next step is to identify what control measures can be implemented easily to reduce the risks. This is again best done with the community and experts from the water supply organization and/or health workers discussing together to identify what measures are the most effective and what measures are easy to do. It is important to note how it will be done, who is responsible and when it should be done; costs are a useful input as well.

Hazardous events	Plan		Do		
	What	How	Who	When	Cost
Cattle and sheep can access the well and the immediate area around it, which could result in animal faecal matter entering the water supply	Exclude cattle and sheep from the abstraction area	Repair fencing around the catchment area	Mr W to arrange with local council work team	Repairs to be carried out February 2013	\$175 in materials
Access to water storage tank could result in bird/animal waste entering treated water	Eliminate potential for contamination at water storage tanks	Repair leaking covers, implement an annual inspection programme (to include all system tanks) and develop a suitable sanitary inspection form	Mrs X to develop sanitary inspection form and to carry out inspections; Mr Y to make repairs	Repairs to be carried out March 2013; begin developing sanitary inspection forms by March 2013, complete by August 2013; first annual inspection in January 2014	\$50 in materials
Contamination of treated water in household storage containers due to poor hygiene (e.g. hand dipping of cups)	Control potential for contamination at the household level	Develop and implement a consumer education programme (to include pamphlet distribution and information sessions at primary and secondary schools)	Mrs Z to develop and distribute pamphlets; Mr Y to present at schools	Begin developing pamphlets August 2013, complete by December 2013 Pamphlet distribution and school presentations to begin in January 2014	\$30 in materials

Example improvement plan, taken from from Water Safety Plans for Small Community Supplies, WHO

Again, working with prepared pictures of improvement measures can help with communities with low levels of literacy. A useful way of prioritizing what measures should be done is to look at what would be most effective and what would be the easiest to do.

	 (Easy to do)	 (In between)	 (Hard to do)
 (Very effective)			
 (Quite effective)			
 (Not very effective)			

Taken from Tearfund: WSP for Communities



Taken from Tearfund: WSP for Communities)

Task 5 – Monitoring the Water Safety Plan (and carrying out preventative maintenance)

The Water Safety Plan is nothing without it being implemented and monitored by the community. The monitoring and maintenance process must be clear, practical and easily understandable. Therefore, the community must be guided in drawing-up a design and format which they own, and which they can later adapt by themselves if they wish.

Monitoring and preventative maintenance have been grouped together so as to cause simple, preventative action to be carried out as routinely as observation and checking. This approach increases responsibility – the person who monitors a particular component of the water supply system is the same person who learns how best to maintain it, and who learns what the signs are that their maintenance is effective or not.

Explanation of the monitoring and preventative maintenance procedure follows on from the previous exercise of identifying what activities can be done to protect the water supply in the various stages of the system. It is useful to link the monitoring process with the question of ‘Who does what?’. This raises awareness of the responsibility on the community as a whole, and on specific members too. Monitoring then becomes personal and social, and it is typically at this stage that community ownership starts. Reporting progress to village authorities and/or local water supply officials periodically will help recognise the community’s efforts and encourage continued commitment.

In addition, the advantage ‘Who does what?’ is that it becomes natural and straightforward to consider the role of men, women and children in maintaining a safe water supply system. Hence, a gender-sensitive and inclusive monitoring and maintenance procedure can be drawn up.

Again how best to decide what is done and who does it depends on the community and how they can most easily understand the process. Tearfund’s process, with less literate communities, pictures can be drawn to represent the operation or maintenance or monitoring job to be carried out and then WSP team decide who in the community will be responsible for taking each action that they have identified. The name of the person is then written beneath the specific action-picture. The group also decide when that action will be carried out (taking account of the gender roles agreed earlier), and this too is written on the picture.

A table for monitoring and maintenance activities, suitable for literate communities is below, which comes from the World Health Organisation.

Hazard	Current control measures	Critical limits	Monitoring	Recommended further action
Pollution of ground-water with faecal matter	Provide good drainage around borehole; establish and train water users committees and pump attendants and design water source to be more than 30m away from OD area or latrine; ensure borehole located in area that can normally be accessed even during flooding	Diversion ditches: are flowing to within 100mm of ground level; have significant amounts of rubbish in them; show signs of wear or walls collapsing	What: Well inspection When: Weekly Who: Pump attendant	Clear out ditch; enlarge ditch; if significant collapsing occurs, have water users committee endorse cement-lining
Drought, causing borehole to dry up	Provide rainwater harvesting systems that can store water through some parts of the drought. Tanks marked with levels indicating estimated weekly water use according to household size	Rainwater storage tanks contain sufficient drinking water until rainy season	What: Inspect water level in rainwater tanks When: Weekly Who: Households	Households report low quantities to Water Users Committee
No water output from handpump	Water committees established and trained together with handpump mechanics to fix broken handpumps; support of local government to store the parts; standard Indian Mark II pumps supplied and installed to good quality standard.	Handpump must be working in optimal order (ie full expected flow); Pump attendant has essential parts (pump seals, foot valve, spare nuts and bolts, grease) in store	What: Check pump output When: Daily Who: Pump attendant	Purchase additional spares; call government technician/partner/DM Team for more serious maintenance issues
Pollution of ground-water with faecal matter from livestock	Water committees established with roles of completing boreholes with fencing and managing boreholes	Fences and hedges must be unbroken, and entry points must be closed at end of water abstraction period	What: Check fencing When: Daily Who: Pump attendant	Repair fences or hedging; remove faecal matter deposited by livestock, and sweep well-head area

6.4 Water Trucking in Emergencies

6.4.1 Rationale

The delivery of water by truck to populations is a very expensive and unsustainable option that should only be undertaken in the short term, where there is no other option. Sites should not be planned where a long-term water supply is unfeasible. Sites where people have self-settled, with no permanent water supply, are very difficult to sustain in the long-term; the absence of a sustainable water supply has to be weighed against the real difficulties of moving them to a preferable site. Water trucking operations will rarely provide adequate amounts for the populations' water needs and it is the most vulnerable people, with greater water needs, who will suffer most. The hygiene and health of the population are likely to deteriorate over time.

It also requires a great deal of monitoring to ensure the water is received by the people who need it most.

Where there are no better options to supply water, such as groundwater, treated surface water or an extension of piped water supplies, it is an appropriate solution to save lives and sustain livelihoods. It is not a standalone option, but it can provide time to plan and set up a more permanent and sustainable supply to replace it.

Justification for water trucking interventions:

- (1) People's lives and livelihoods are at risk because of a severe reduction in access to safe water, resulting in:
 - significantly more time spent collecting water from distant sources; and
 - a marked reduction in the amount used for drinking, cooking and essential hygiene
- (2) Attendance is significantly reduced or schools are closing because children and staff are forced to spend school hours collecting water, or tend to out-migrate without intervention;
- (3) There is heightened risk of epidemic resulting from a concentration of people;
- (4) There is no other short term solution, for example, by rapid repair or rehabilitation of local water points, or the rapid development of a new water supply scheme.

The context is very important, for example, the 'trigger' for water trucking in a peri-urban area would be quite different compared to a trigger used for pastoralist areas.

It is very rare to truck water to sustain livestock as the replacement cost of the livestock is usually lower than the cost of water trucking. They will also need fodder to survive, which if there is not enough water for drinking, it is unlikely that there is enough fodder. An awareness of the community priorities is also important as they might still use the trucked water for animals.

It is vital to have a defined exit strategy before starting any water trucking so that the water trucking does not drag on beyond what is essential.

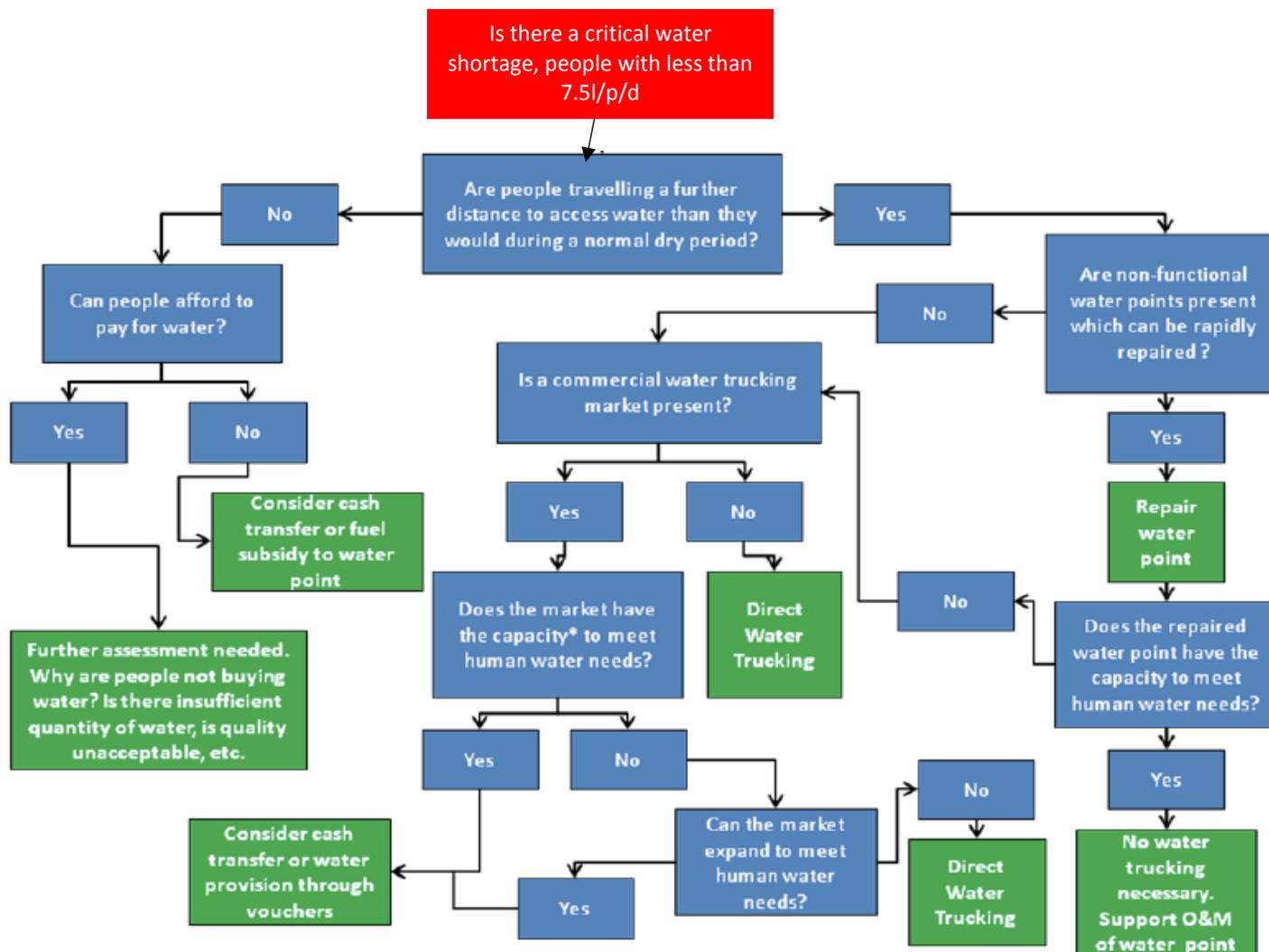


Figure 1 Decision tree for emergency provision of water.

*Capacity refers to: number, condition and capacity of water trucks available in the market; yield and expandability of water points to be utilized for water trucking; capacity of water trucks to access targeted communities. For further information on market capacity assessment, see the *Emergency Market Mapping & Analysis (EMMA) Toolkit* and the report *Water Trucking Market System in Harshin, Ethiopia* (see References section).

6.4.2 Quantities and Quality of Water for Trucking

It is extremely difficult to deliver enough water by truck to meet people's total water needs (SPHERE indicator of 15 liter/person/day). For this reason, the Sudan WASH Sector Humanitarian Strategy 2015 defines the indicator for water trucking as 7.5 liters/person/day for the first three months of an emergency. After this, water trucking is not considered an option in the strategy; if water trucking has to continue, the quantity should be reconsidered to reflect the longer term water demands of the affected population.

Water quality standards should be the same as for any other protected water source for large numbers of people (see Ministry of Health Environmental Health in Emergencies Guidelines), as it is a short-term measure, it might be permissible to relax certain of the longer term chemical water quality parameters, but the microbiological quality of the water is important. Therefore, the water needs to be chlorinated to provide a free chlorine residual of 0.5mg/l at the point of delivery.

Chlorination at filling station

If there is storage for clean water at the water filling point, chlorination can happen here, allowing for sufficient contact time. The amount of chlorine will need to be adjusted to allow for 0.2 mg/l at the household after 24 hours; and hence 0.5 – 1.0 mg/l at any point of distribution (tapstand, from a tanker or donkey cart) – both before and during an outbreak³. This means that the chlorine dose in the storage at the filling point for the tanker needs to be high enough that by the time the tanker has been filled and has reached its destination and empties its contents, there will still be between 0.5-1.0 mg/l FRC in the drinking water.

Chlorination in the water tanker

Allows for good contact time during transportation of the water. Some water tanker operators are reluctant for chlorination to happen in the water tanker as it they fear it would cause localized oxidation of their tankers when the chlorine is added. This depends very much on the materials, construction and condition of the tanks. Mild steel does oxidize, but minimally, so does stainless steel to a much lesser degree, the extent to which it does depends on the quality of the steel. As far as published evidence⁴ goes, short term exposure at low concentrations does not pose a risk to water quality but might possibly cause localized pitting

³ During the process to develop the Sudan Drinking Water Safety Strategic Framework, 2017 it was agreed³ to: 1) Maintain a free chlorine residual of 0.2 mg/l at the household level after 24 hours; 2) Increase the chlorine residual to leave at least 0.5-1.0 mg/l residual at public standposts in any hot climate condition, irrespective of outbreak or normal conditions, and to monitor the effects along the water chain to check: a) residuals in households, as well as checking b) the community acceptance of the chlorine taste/rejection levels; and then to adjust accordingly. This update in level for FRC at distribution points is to take into account the hot climate and the high risk of contamination in Sudan from issues such as open defecation and old piped networks with intermittent supply. The changes have been based on recent learning from research in South Sudan and elsewhere. The recommendation has been discussed with WHO Geneva and it has been agreed that the increased levels are in alignment with the principles of the WHO Guidelines for DWQ 2017 with the main priority for chlorination to have a residual of 0.2 mg/l in the household.

⁴ Effect of Chlorine on Common Materials in Fresh Water, Tuthill A et al, Materials Performance, Vol. 37, No. 11, pp. 52-56 (1998), NACE International;

Localised corrosion of stainless steels depending on chlorine dosage in chlorinated water. Mameng, S et al, Acom Magazine (2011), Outokumpu, Sweden, www.outokumpu.com

of the tank. Reducing the risk further is possible by venting of gases in moist areas: ensure that tanks have air vents open, especially when not completely full. This is not the same as leaving water tanker covers open, which could allow airborne contaminants into the water. If water tanker operators still do not want to transport chlorinated water, extra storage at the distribution point, allowing for sufficient contact time before distribution would work as well.

Chlorination at the distribution point

Chlorination can be done at the distribution point where Water Monitors add chlorine to the water as it is pumped from the truck to the local storage tank prior to distribution. The main difficulty is adding the appropriate amount of chlorine to the volume of water delivered: if the storage tank is not completely empty when the water is delivered or the amount of water delivered is not a complete full tank then the volume of water delivered needs to be measured and the amount of chlorine calculated to treat this volume. The water then has to be stored for 30 minutes contact time before distribution, which could frustrate people queuing for water.

Chlorination at the household level

This is typically accomplished through the provision of Aquatabs or a similar chlorine product which is capable of treating one 20-liter jerry can of water. This has worked where chlorination of water at the source was not possible or during major outbreaks of diarrhea. It is not always culturally acceptable and should be assessed before implementation. Chlorination at the water source or in the water tanker is preferred as chlorination at the household level requires additional activities and resources:

- Distribution of Aquatabs to households
- Sensitization on the use of Aquatabs (including safe use and storage);
- Post-distribution monitoring on proper use and chlorine residuals at household level.

6.4.3 Planning Water Trucking

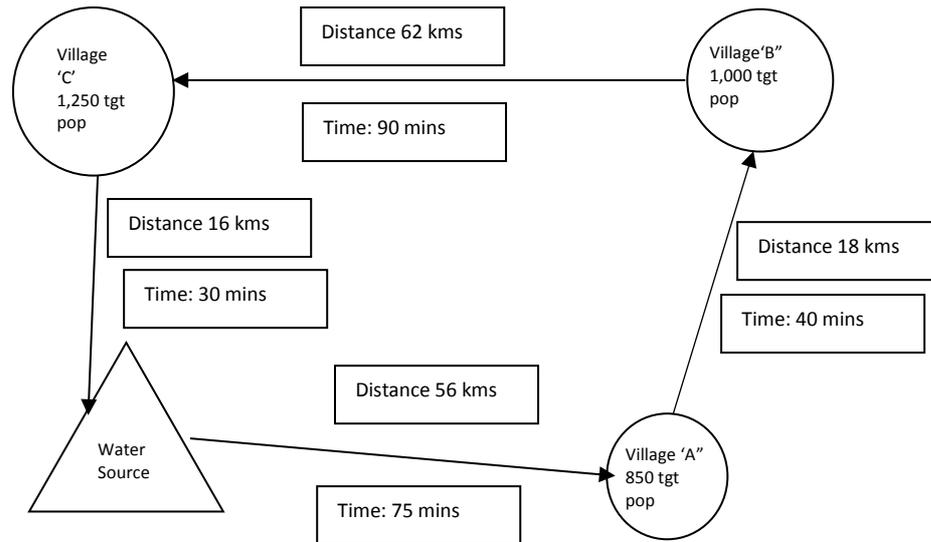
If water trucking is justified, the following information is needed to inform a plan:

- (1) Prioritised locations where water is needed – drop off points would typically be at the village level, serving the local community, health post and school. Locations should be fenced off and/or kept secure to ensure the safety of the drinking water and facilities. It is important to include women and children in the agreement of siting of drop-off points as they will not collect water if they feel insecure on their route, or at the water point;
- (2) The minimum amount of water needed at each drop off point per day, based on (as a minimum) 7.5 litres per person per day, and an accurate estimate of the local population that is critically short of water (the *target* population);
- (3) Available water storage, if any, at each intended drop off point;
- (4) A route map, indicating prioritised drop off points, distances, road conditions and travel times;

- (5) The location of operational water points that can be used to fill trucks, and their filling capacity (metres cubed per hour, based on the storage and pumps available). Filling of water trucks should not affect people living around water points;
- (6) Communications available in each village – landline, mobile phone, radio.

This information is best shown on a simple, schematic map. It does not have to be accurately scaled, as long as the information shown on the map is correct. An example is shown:

Schematic for Water Trucking Distributions



A water trucking plan can then be developed, taking into account the volume of water needed, travel time, fill-up time, drop-off time, the capacity of water filling points and truck volumes. Over time this can be adapted to make it more efficient and to reflect changing demands. The resulting plan is basically a day-by-day schedule, prepared for each truck. An example of a calculation outlining how long the water delivery will take is shown in Annex 6.6.

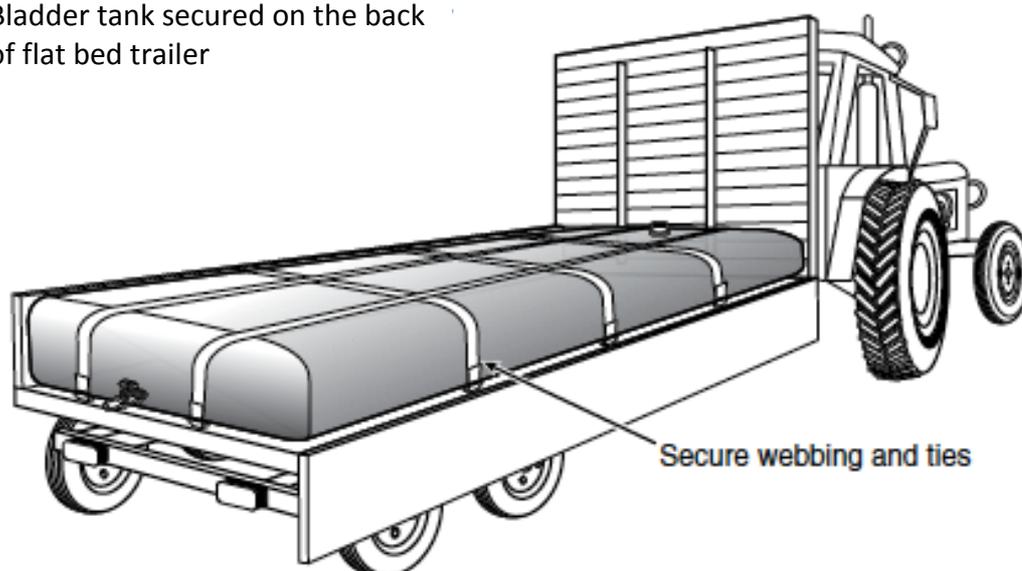
It is very important that the water users know when the water will be delivered. This means that the supply must be regular and when something disrupts this schedule, changes can be communicated to the users in good time.

6.4.4 Resources required:

Water Trucks or Trucks with Bladder Tanks

In an emergency, one of the issues is the availability of water tankers. Finding an adequate number that are roadworthy and that are safe for trucking water (were not previously a fuel tanker) is vital. Other options are flatbed trucks with plastic tanks or bladder tanks secured to the flatbed. Special water trucking bladders are available with internal baffles to minimize movement of water whilst the truck is driving. See Annex 6.7 for a checklist on water trucks. Water trucks should carry small pumps to speed up transfer of water.

Bladder tank secured on the back of flat bed trailer



From Engineering in Emergencies, J Davis and R Lambert, 2002 Practical Action Publishing

Distribution Points

A water storage tank with enough capacity to store water between water trucking trips for the number of users to draw 7.5/person/day. Consideration must be given to peak demand – typically people want to draw more water especially in the morning and also in the evening so there is greater volume needed at these times. The storage tank at the distribution point allows for effective use of the water truck, as it can pump water in to the tank and then leave directly, otherwise it has to wait whilst each user fills their water container individually. The storage tank has to be elevated at least 1 to 1.5m above the taps used to allow the water to flow by gravity.

Bladder tanks can be used for storage in the short term (but they are not very robust), other options are plastic roto-tanks or similar. The storage tank must be accessible for the water truck to deliver its water. It is a good idea to ensure the access and turning area (if needed) is well surfaced as over time it will get muddy and rutted.

A tap or tapstand (one tap per 250 people) is also required, a short distance from the tank, connected to the storage tank by a pipe (typically 32mm MDPE), allowing people to draw water. Drainage is needed around the tapstand to minimize health risks to the people collecting water, and to safely divert the overflow.

The water point must be secured, managed, monitored and maintained by community representatives, if there is an operational Village Health Committee (VHC) then a member of that can carry out these activities (see Section on Monitoring below for details)

Filling Points

The same measures apply to water filling points. Adequate storage at the filling point can help manage demand which is normally concentrated at particular times of day or night. Water filling points may also need policing, especially if truck operators are being paid per volume of water delivered rather than per day, irrespective of what they delivered. The needs of the local population who use the water source must also be safeguarded. And water truck operators normally sign (and pay for) the water they take, the money collected being used to pay for diesel and routine maintenance.

It is important that the organization operating water trucking

- (i) establishes a good relationship with the water point operator,
- (ii) assesses the condition of the water supply and
- (iii) ensures its continued operation, taking into account the increase in water demand, and the impact that increased pumping hours has on the pump and the generator in terms of consumables and spare parts.

If the filling point is a surface water source, then it is possible that a water treatment plant of some sort is required. To ensure effective chlorination of the water, the turbidity and pH need to be assessed and regularly monitored and where outside limits of effective chlorination (turbidity <5NTU, pH <8.5) then the water will need some level of pretreatment. This might only be storing the water overnight in a tank to reduce the turbidity, but then a second tank is required for chlorination as the addition of chlorine and stirring to ensure a thorough mixing would disturb the settled solids.

Good Access Roads

Water tankers are heavy vehicles and can quickly damage poorly constructed roads. Make an assessment of the roads before starting to use them and reinforce them if necessary.

Household level collection and Storage Containers

Each household must have adequate containers to safely collect and store the water. SPHERE indicators state each household should have 2 containers of 10 to 20 liters, one for collecting water, one for storing it. Smaller containers of 10 to 13 liters could be distributed for children collecting water.

6.4.5 Implementation and Monitoring

Water trucking usually contracted to one or more truck companies/owners. To get this right, it is important to coordinate with other organizations contracting out water trucking in the area to ensure clear and consistent conditions. When contracting out, consider the following:

- Base contract fees on the quantity and quality of water delivered not on operating time;
- Agree on a method for appraising contractor performance;
- Clarify responsibility for consumables such as the provision of fuel, insurance, maintenance, the wages of drivers, etc.;
- Frequent spot checks are useful, particularly at the start of a tankering programme.

Carefully monitoring the operation is absolutely essential. It is strongly recommended to use 'waybill' systems of monitoring. Such systems are based on a job card, which is maintained by the truck driver. These record, on a trip by trip basis, where and when water was collected, the distance travelled, and how much water was delivered to each drop off point. The card is countersigned by representatives of each village receiving water. The completed card is then checked and endorsed by an authorizing authority. If necessary, it can be used to inform spot (verification) checks.

One important aspect not to overlook is to ensure that water trucks have adequate local stocks of fuel. This may be included in the contract, or external too it. Either way, trucks should remain operational in the trucking area, without interruption caused by a lack of fuel.

If necessary, monitoring is helped by placing a field monitor with each driver. This person can also help loading and unloading, help with disinfection, and check water quality. It also helps ensure that the driver does not get lost, deal with breakdowns, or fall asleep on the road. The field monitor can also play an important role in verifying that the need for water remains, and report back important changes that may affect subsequent operations. The monitor also verifies that the driver delivers the amount of water to the village that is contracted. Finally, he or she can advise households collecting water, or Health Extension Worker, on issues of safe storage and water handling, including the proper use of household water treatment chemicals such as WaterGuard, Aquatab, Pur and Bishangari.

Reporting is an important part of monitoring – much of the information collected is vital to inform the coordination mechanism. Reporting systems and checklists are included in the later section on coordination.

Water trucking targeting settlements (free water)

This involves water trucking to established population centers which have no permanent water supply. In this type of intervention water tankers/trucks are directly contracted to deliver specified quantities of water to specified distribution points. The organization pays for the water (usually purchased from boreholes) and also pays for the transport (water tankers/trucks) to deliver the water. Water is provided at no charge to the beneficiaries. Regular focus group discussions with targeted beneficiaries are required to ensure that access is free.

Water Provision through Vouchers

Water provision through vouchers is an option that can be utilized in areas where a commercial water trucking market exists. Pre-printed cash vouchers are distributed to targeted beneficiaries, which are then redeemed with their normal water suppliers for a specified quantity of water. Vouchers can be single-use or multiple-use. Cash transfer payments are then made to the commercial suppliers against the submitted vouchers.

Advantages of a voucher system include:

- **Use of the existing commercial market** – by using the existing commercial vendors that the population normal utilizes, local water tanker businesses are supported and reinforced. Exit from the intervention is easier, as the commercial water tankers are still available in the area for those who would like to continue purchasing water.
- **Improved targeting** – in interventions where blanket targeting is not desired, only targeted beneficiaries are given vouchers. In a direct water trucking intervention, it is very difficult to ensure that only the targeted beneficiaries are the ones who are accessing the delivered water. In times where the voucher is either lost or stolen, a verification system can be put in place, by asking the targeted beneficiary one of their preset secret questions (e.g. case of Turkana targeted communities have three secret questions).
- **Cost Effectiveness** – voucher beneficiaries receive water at the current market rates. Direct water trucking interventions, in which NGOs directly contract a large number of water tankers, often times distort the market rates for water and drives up prices for those who would normally like to continue purchasing water.
- **Improved & Simplified Monitoring** – the number of vouchers collected shows how the water is being collected. The vouchers themselves can contain beneficiary information to further monitor individual collection of water. Monitoring of water quality (free residual chlorine levels) still needs to be fully monitored and must not be forgotten.
- **Increased Choice for the Beneficiaries** –beneficiaries can also choose how they want to utilize or distribute their water – give to family members, animals, neighbors, etc.

6.4.6 Coordination

It is vital to coordinate water trucking between organizations carrying it out. Reliable, up to date information on water trucking is an essential input for coordination.

Serial	Information Required – for each affected District	Remarks
	Target Village	Names and GPS coordinates
1	Volume of water delivered	m ³ , over reporting period
2	Population Reached	Both number and % of target population
3	No of trucks operational	Operation means on the ground, working, not just under contract
4	Average cost, SDG/m ³ /km	Includes cost of water
5	Water Source(s) used	GPS coordinates if possible
6	Water Source condition	State if maintenance support is needed
7	Water Safety	Whether or not all trucked water is chlorinated
8	Funding Source	
9	Expected end date	Due to funding limitations etc
10	Additional remarks	Reports of gaps, overlap, rainfall, etc

6.4.7 Exit strategy

For effective emergency water trucking interventions, there should be a concrete and well-defined exit strategy which has been planned before the beginning of any water trucking intervention and includes associated costs.

Different exit strategies exist for different locations of water trucking interventions. It can range from minor repair, rehabilitation, supporting the existing operation and maintenance structures, supporting the existing community's coping mechanism to new water scheme establishment, expansion from the existing schemes and considering rainwater harvesting structure development.

Effective exit strategies require longer time to address and water trucking projects should consider the timing related to exit strategy activities during planning.

6.5 Rehabilitation & Operation, and Maintenance of Water Supplies

Carrying out a risk assessment such as a Water Safety Plan (see Module 4) will help identify the measures that have to be taken to rehabilitate the supply, it will also help identify what has to be done regularly to maintain the supply. The risks identified will mainly be about contamination of the supply and a reduction in the amount of water being delivered but also should consider the structural integrity of the water system.

A useful tool to promote access to water points for more vulnerable groups is an Accessibility Audit (see Annex 6.8) where a child, pregnant woman, elderly or disabled person attempts to get to and use the water point and any problems or obstacles that prevent them or make it difficult are written down and photos or diagrams drawn to illustrate them. Identify what can be done to minimize or eliminate these. These adaptations then can be made to the water point.

It is useful to develop an O&M checklist format for each specific water source and technology – that can be completed by the operator or person responsible for maintenance. This helps to keep a track of when checks and maintenance have been undertaken and when it has been omitted. See Annex 6.13 for an example of an O&M checklist.

Water Supplies components and their rehabilitation, operation and maintenance

6.5.1 Wells

Rehabilitation

It is often better to rehabilitate existing wells than dig new ones as the ownership and management is already in place, there is or was a water source there and a large part of the work has been done – the digging and lining of the well. This might need to be deepened to reach the aquifer if it has lowered over time.

The majority of work to be carried out is likely to be:

- to reduce the likelihood of contamination of the water from either surface pollutants (surface water entering through cracks in the well apron), airborne pollutants (windblown fecal matter or feces from birds), or from shallow groundwater pollution (such as from nearby latrines);
- to improve the structural integrity of the well – lining some or all of the well will reduce well collapse but can also reduce pollution pathways;
- to increase the volume of the well, deepening the well is the easiest way to do this.

Establishing safety procedure

Technical Guideline and Manual for Hand Dug Wells with Hand Pumps for Field Staff and Practitioners (PWC, 2009) set out the following on Safety of Well Construction:

Before any work is initiated on the construction of a hand dug well, the implementing organization should be aware of the safety measures that will need to be taken. Careful preparation of the well diggers and their equipment is a primary importance in order to avoid accidents that may occur during hand dug well construction such as: lack of knowledgeable supervision, careless workers and work methods, tiredness and lack of concentration, faulty equipment, falling materials, collapsing soil, poisonous gases from pump engines, explosives and naturally occurring gases, incoming water, excessive dust, interference by casual onlookers, and animals and children playing on unattended well sites.

Proper safety measures need to be in place to mitigate the possible dangers that may occur during well construction. Some of these safety measures include:

- Ensuring that competent staff is supervising the construction,
- Agreeing on signaling arrangements between diggers and the surface,
- Ensuring that a minimum of four people work on a well at any one time and no person should dig alone,
- Providing safe and easy access to the well,
- Having available an additional standby method of well entry and exit,
- Protecting the hole when digging is in progress and making it safe when workers are not on site in order to prevent people, animals and materials falling in,
- Regular checking of equipment like ropes, ladders, tripods, lifting gears, buckets, pick-axe and hammer handles and heads etc,
- Providing and using essential safety equipment like safety helmets, protective footwear, gloves, and goggles. Goggles should be worn when breaking rock,
- Providing first aid training and equipment as part of the overall safety measures,
- Using safe and suitable dewatering equipment;
- No lowering of combustion engine, petrol or diesel-powered pumps into wells for dewatering as exhaust gases are heavier than air and will sink to the lower levels,
- Ensuring petrol or diesel engines are positioned downwind of the well site at ground level,
- Keeping onlookers far away from the excavation, and
- Securing the site during non-working periods, especially at night. Additional safety measures may be necessary depending on the situation.

Rehabilitate well linings

Under normal circumstances, a reinforced concrete lining of a well should age well, unless the construction of the lining was very poor, and small cracks can be repaired with mortar. Masonry linings must be carefully inspected, and the mortar joints checked to ensure sealing of the lining, especially the upper part.

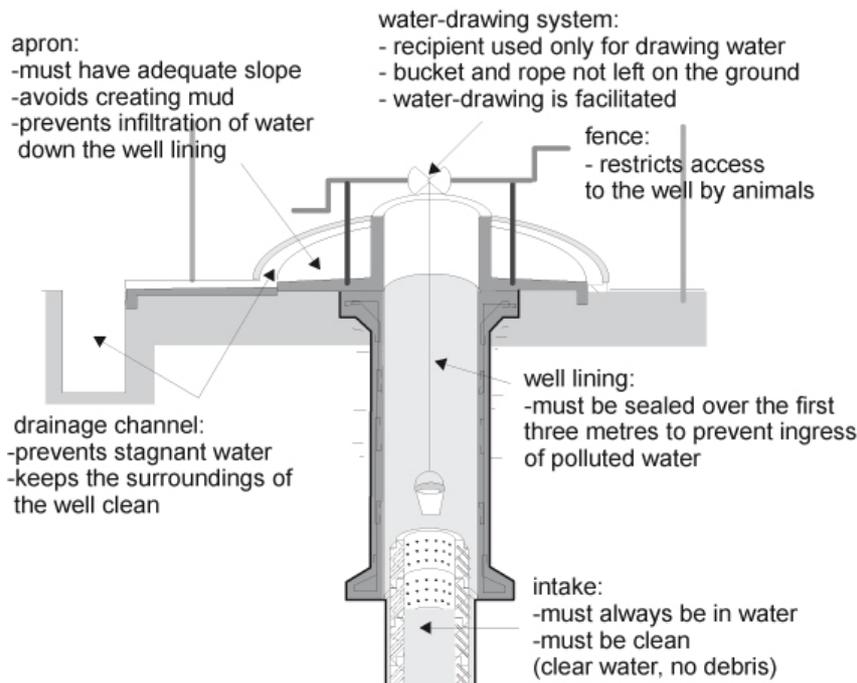


Diagram from Water, Sanitation and Hygiene for Populations at Risk, Action Contre la Faim

New well linings

If the sides of a well have collapsed, then it is possible to reline the well, typically with concrete, either reinforced concrete placed in-situ (built in the well) or precast rings lowered down the well and then earth backfilled afterwards. It might be possible to only line the part that has collapsed if the underlying rock is stable. The backfill around the concrete well rings should be brought up to 50cm below the top of the well and then topped off with concrete as normal for a well. It is very important to compact the backfill properly as subsidence due to later natural compaction will crack or destroy the wellhead.

Repairs to the wellhead and apron

The apron needs to be of a sufficient size to prevent easy ingress of runoff back into the well through the surrounding soil (Sudan Technical Guidelines and Manual for Hand Dug Wells with Handpump or Motorised Pump states the apron is to extend 1.5 to 2m from the edge of the wellhead). It also needs to be free from cracks, pay special attention to the joint between the well head (vertical walls of the well above the apron) and the apron for cracks.

Adaptations to the well head

To help children, women and people with mobility difficulties, a concrete pedestal about 45 cm high can be added to the apron to allow people to lift their water container half way and rest it before lifting it all the way up to their head or wheelchair.

Access to the well needs to be free from standing water or mud. If the access is too narrow (such as on stepping stones or a narrow path) then women or adolescent girls might be

harassed by men whilst on them and elderly and disabled people would find them difficult to access. An accessibility audit (Annex 6.8) would highlight this.

Deepening a well

Deepening a well normally increases the flow unless the bottom of the aquifer has already been reached.

Deepening wells near the sea can cause saltwater intrusion below the unconfined freshwater aquifer. Re-digging beyond this level should not take place to avoid risk of contamination of the well by salt water.

There are several options for deepening techniques, depending on the nature of the well:

- for masonry intakes, a column of pre-cast well rings of a smaller diameter than those already existing in the well can be sunk, or the masonry lining can be extended as re-digging progresses (shallow depths);
- for reinforced concrete intake-lining sections, an independent intake column is sunk inside the old lining;
- for existing independent intakes, re-digging is easy since it is sufficient to dig and add new well rings to deepen the intake column.

See Section 5 of Technical Guideline and Manual for Hand Dug Wells with Hand Pumps for Field Staff and Practitioners (PWC, 2009) for more details on well linings, apron and well construction.

Completion of a hand dug well

It should be noted that the Guideline and Manual for Hand Dug Wells has the following on completion of wells which should also be followed for rehabilitating wells:

When a hand dug well is completed, it must have the following components/parts:

- A sanitary seal at the surface to prevent pollution by surface water and seepage flowing into the well.
- A concrete apron and effective drainage which carries waste water away and does not leave pools of water around the well.
- A concrete cover slab with pump stand casted on it and a manhole sealed with manhole cover.

Cleaning/chlorination of a well

After disasters such as floods, high winds or conflict where the well is likely to have had accumulated large amounts of sediment or objects, it will be necessary to clean the well. Cleaning a well should also be an annual maintenance activity to be carried out by the community at the end of the dry season when the water level will be the lowest.

Emptying the well, if it is not too productive, may be carried out by hand using a bucket. In

the case of higher-yielding wells, pulleys and animal traction or a dewatering pump may be required. Chlorination of the well is set out on p 29 of Technical Guideline and Manual for Hand Dug Wells with Hand Pumps for Field Staff and Practitioners (PWC, 2009)

Operation and maintenance of a hand dug well

The daily, Monthly and Annual activities should include the following O&M activities:

(i) Daily Activities

- Check for any debris in the well by regular visual inspection
- Clean the concrete apron
- Clear the drains
- Check that the gate is closed

(ii) Monthly activities

- Replace the bucket and other parts as needed
- Check the concrete apron and well seal for cracks and repair them with cement mortar
- Record the water level with a rope-scale Village Health Committee
- De-silting of dug wells periodically as required

(iii) Annual activities

- Dewater the well and clean the bottom
- Inspect the well walls and lining and repair as needed
- Check the water level and deepen the well as needed
- Record the depth of water level & depth of well with a rope scale

O&M Resources for a Dug Well are as follows:

Unskilled labor is required for daily tasks. Semi-skilled labor (well caretaker) is needed to carry out weekly and monthly O&M tasks. Skilled labor (mason) is needed to work with the caretaker on yearly O&M tasks and to repair the concrete apron.

Materials and equipment include fencing, support posts, brush, digging and hand tools, cement, pulley and pulley shaft and bearings, and masonry tools to be provided to the caretakers.

6.5.2 Handpumps

Rehabilitation/repairs & operation and maintenance of handpumps

As handpumps are mainly made up of mechanical parts, then repairs or rehabilitating the mechanical part of a handpump are the same maintenance procedures. The National Standard for handpumps both shallow and deep wells and boreholes is the India MkII handpump and will be the pump detailed here. Maintenance can be carried out at two levels – minor repairs carried out at village level by a caretaker or Village Health Committee Member

and major repairs carried out by technicians from WES Rural Council Unit or similar.

Minor repairs

The repairing of hand pump which does not requires lifting of hand pump assembly is treated as minor repair. The minor repairs of hand pump may be made by a semi-skilled care taker or Village Health Committee (this type of repairing involves replacement of handle nut & bolts, repairing of chain, bearing etc.)

Major repairs

The repairing of hand pump which involves raising of the hand pump rods and cylinder is treated as major repairs; this type of repair is not likely to be made by local VHC and will be carried out by Rural WES Units.

See Annex 6.9 for details of India MkII Handpump in hand dug wells maintenance schedule and Annex 6.10 for details of India MkII Handpump in borehole maintenance schedule
See Annex 6.11 for disassembly, inspection and reassembly of hand pump

Adaptations to handpumps

After carrying out an accessibility audit (see Annex 6.8), specific changes to the handpump might include adapting the handle, lengthening it or adding a T at the end for easier use by children or people in a wheelchair.



Photo courtesy of WaterAid/Jane Wilbur

6.5.3 Boreholes

Borehole performance

It is important to monitor the yield of the borehole over time, a drop of about 10 to 15% of yield needs to be investigated further and rehabilitation should be carried out before the yield has decreased by 25%. The performance of the borehole can be investigated thoroughly by checking the following:

- i) Static water level
- ii) Pumping rate after a specific period of continuous pumping
- iii) Specific yield after a specified period of continuous pumping
- iv) Sand content in a water sample after a specified period of continuous pumping
- v) Total depth of the well
- vi) Position and depth of the screens in the well
- vii) Efficiency of the well
- viii) Normal pumping rate and hours per day of operation
- ix) General trend in water levels in wells in the area
- x) Draw down created in the production well because of pumping of nearby wells.

Causes of failure or reduction of yield of a borehole

The borehole might fail to inadequate design, faulty construction and operation or lack of timely maintenance. The main causes for source failure are:

- Incorrect design: for instance, use of incorrect size of screen and gravel pack, wrong siting of well site resulting in interference.
- Poor construction e.g. the bore may not be vertical; the joints may be leaky, wrong placement of well screen, non-uniform slots of screen, improper construction of cement slurry seal to prevent inflow from Saline aquifer.
- Corrosion of screens due to chemical action of water resulting in rupture of screens.
- Faulty operation e.g. over pumping, may causes the rupture of screen casing due to piping action of water, poor maintenance.
- Adverse aquifer conditions resulting in lowering of the water table and deterioration of water quality.
- Mechanical failure e.g. falling of foreign objects including the pumping assembly and its components.
- Incrustations due to chemical action of water.
- Inadequate development of wells.
- Placement of pump sets just opposite the screens, causing entry of silt by rupturing screen slots.

Monitoring of silt coming out with water during pumping from source

Indication for silting

- (i) Appearance of fine silt with water is an early indication of silting.
- (ii) Reduction in depth of bore well
- (iii) Reduction in yield of bore well.

Causes for silting

- (i) Over pumping.

- (ii) Improper sitting of casing pipe and/or screens.
- (iii) Improper jointing of casing pipes.
- (iv) Placement of pump sets just opposite the screens.
- (v) Poor development of bore wells.

Suggestions to overcome silting

- (i) Periodical inspection of bore well.
- (ii) Additional length of casing pipe and/or pump pipe may be inserted in the case of improper bore well assembly installation.
- (iii) Flushing of bore well.
- (iv) Re-development of bore well
- (v) Replacement of pump sets with proper duty condition, with respect to the safe yield of the tube well.

Rehabilitation/repairs and operation and maintenance of boreholes

(Adapted from: Operation and Maintenance Manual for Rural Water Supplies, Ministry of Drinking Water, Government of India, 2013)

Issue	Probable Cause	Maintenance/Rehabilitation
Silting	Over pumping, reduction of yield, improper sitting of casing pipe etc.	<ul style="list-style-type: none"> • Inspection of the borehole to assess the performance of yield. • Replace the pump-set to match its proper duty-condition with the yield of the borehole. • The appearance of fine silt with water is also an early indication of silting. • Further pressing of the whole pipe assembly in the case of shallow casings will arrest the silting. • In the case of hard rock borehole, flushing with compressor from the bottom will arrest/remove the silt
Decrease in Yield	Adverse seasonal conditions, clogging of pores, parallel exploitation in the neighboring well, sinking of new well in close proximity.	<ul style="list-style-type: none"> • Periodical flushing is essential for free flow of water • Adhering to strict spacing norms to avoid interference of pumping wells. • Removal of silt and clay through chemical/acid wash
Drying up (very low yield) of bore well	-As above-	<ul style="list-style-type: none"> • Periodical flushing, • Hydro-fracturing etc. • Resetting the depth of the pump • In case of defunct even after flushing it can be used as recharge well
Mechanical Failure	Falling of foreign objects, pump assembly etc.	<ul style="list-style-type: none"> • Mechanical devices to lift the objects. • Bore hole camera can also help inform the cause and remedy. • Removal of silt and clay through chemical/acid wash. • Sometimes re-drilling may also prove to be successful • In case no remediation it is possible the borehole may be utilized for recharge

Failure of screens	Corrosion or encrustation to screens	<ul style="list-style-type: none"> Removal of incrustation through Acid wash Replacement of screens with stainless or PVC
Salinity	Overpumping or water depletion	<ul style="list-style-type: none"> Monitoring of water salinity through time and seasons

See Annex 6.9 for Maintenance Schedule for a borehole fitted with a handpump and Annex 6.12 for the Maintenance Schedule for a borehole fitted with a motor pump.

Re-development of boreholes

Without proper supervision at the time of construction full development of the borehole might not be done, resulting in constant inflow of fine sand particles and choking of the filtering media and strainers. Such boreholes need re-development.

Re-development of a well involves the removal of finer material from around the well screen, thereby enlarging the passages in the water-bearing formation. It increases the porosity and permeability of the water-bearing formation in the vicinity of the well. It stabilizes the formations around the well screen so that the well will yield sand-free water. Re-development increases the effective radius of the well and, consequently, its yield.

The most common method to redevelop a borehole is to use compressed air – surging and pumping with a compressor to flush out the fine material.

6.5.4 Pumps

Manufacturer's recommendations

Pump manufacturers always provide a manual for the operation and maintenance of their pumps. The instructions in these manuals, including the recommended maintenance schedule, should be the first point of information and should be followed. The instructions will include greasing, oil inspection, checking of voltage at power source, adjustments and repairs.

If during inspection a defect is found, it should be repaired immediately. The operator should pay attention even to small defects, and not wait for them to worsen, as these could cause other parts or units to fail, resulting in larger damage and costlier repairs.

Pump/borehole information

Each pump and borehole should have the following information:

Station or Borehole No:	
Location	Coordinates
Date Filled	
Borehole or Source Data	Pump data
Well Casing Diameter Type:	Type:
Well Depth:	Brand Model:
Well SWL:	No. of Stages:

Specific Capacity: Water Quality: Year Drilled: Driller: Remarks:	Pump Setting Depth: Column Assembly Size: Discharge Head (m): Supplier: Remarks:
Motor Data	
Type: Brand/Model: Rated HP @ rpm: Volts/Amperes: Hollow Shaft Diameter: Year Installed:	

Pump log

A log of hours run, fuel or power consumption, flow readings etc. should be kept by the pump operator and recorded daily.

Date	Time Started	Tie Stopped	Pressure Reading	Flow reading		Power*		Remarks
				Start	Final	Start	Stop	

* If a generator is used then Power could be changed to fuel consumption

Pump operation

Pumps will normally work automatically, starting and stopping with low and high level pressure switches. To stop the pump manually, it is important to carry the following instructions:

- 1) Gradually turn the discharge valve until it is only about 1/4 open. Do not close the valve suddenly, as sudden shut-off could create back pressure and flow surges.
- 2) Use the "Stop" push button to stop the motor.
- 3) Totally close the discharge gate valve to prevent possible back flow.

Pump troubleshooting

The pump manufacturer or supplier will provide a pumping curve graph which is used to evaluate the pump's actual performance. The following are also indications of pump problems:

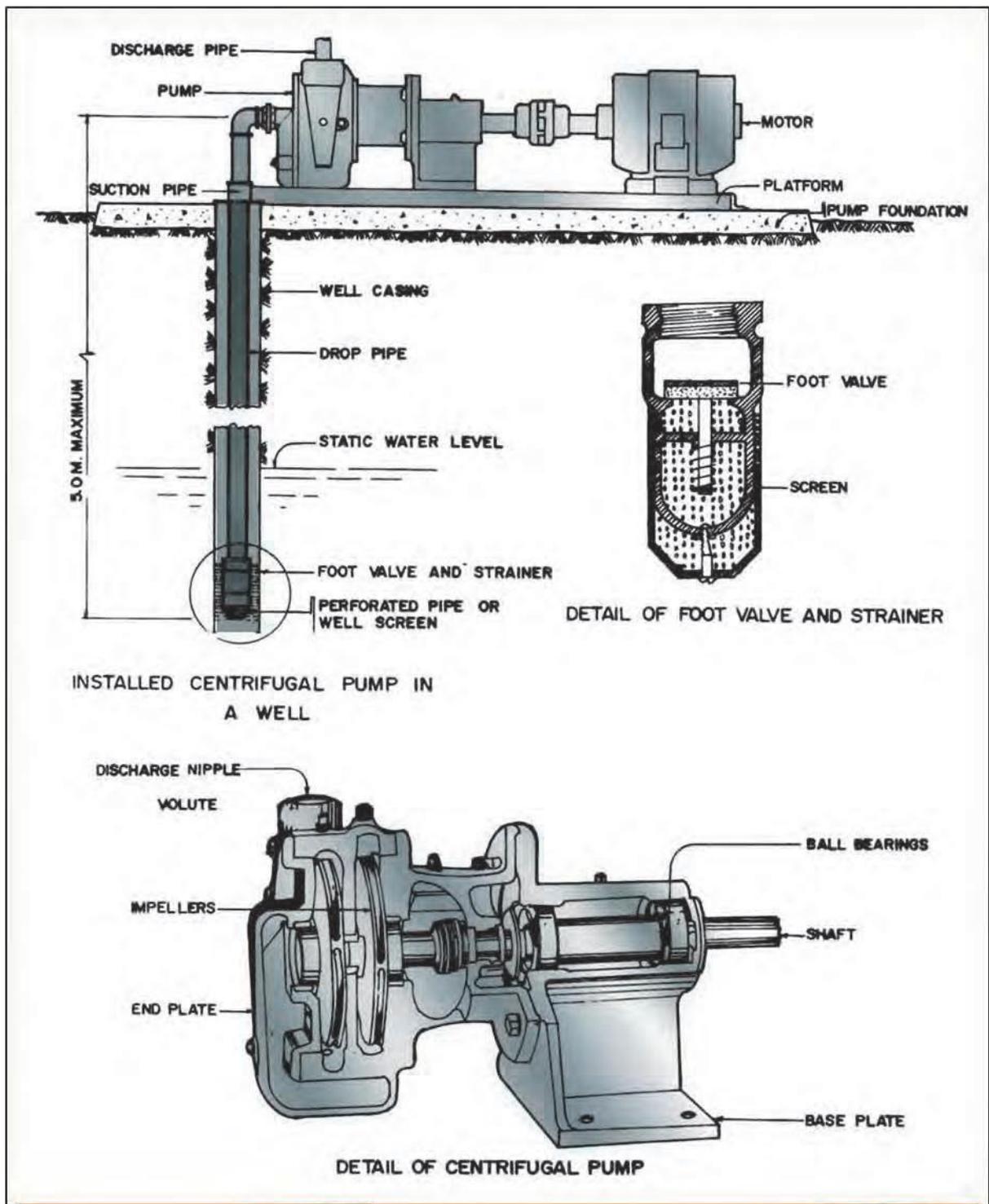
1. Excessive heating of the motor;
2. Noisy bearings;
3. Increased oil consumption of the motor;
4. Excessive vibrations;
5. Change in amperage or voltage load;
6. Cavitation noise or other unusual noise;

7. Presence of cracks or uneven settlement of the pad or ground around the pump.

Specifics for centrifugal pumps

Operation:

1. Before starting the motor, make sure that the discharge gate valve is closed.
2. If the pump is not self-priming or has defective suction line or foot valve, add priming water. Priming displaces the air in the suction line or drop pipe of the pump with water.
3. Allow the pressure to build up, and then slowly open the discharge valve. Doing this slowly avoid water hammer, which could destroy the pipes and valves.
4. Start the pump motor.
5. After the pressure has built up, slowly open the discharge gate valve. In case the pump has been primed with water, waste the water pumped during the first 1-2 minutes by opening the drain valve.
6. Make a routine check for faults in the operation of the system (abnormal noise, vibration, heat, and odor).



From: Rural Water Supply Operation and Maintenance Manual, World Bank, Philippines, 2012

Maintenance & repair

Lubricate all moving parts on the regular schedules, using the lubricants recommended by the supplier. The following are specific actions to remedy centrifugal pump problems.

a. Low pump efficiency

If the pump performance tests reveal that the pump is operating at significantly lower

efficiency, the pump should be pulled out, inspected and repaired or reconditioned. This work is best referred for servicing to the manufacturer or a pump repair specialist.

b. Packing adjustment

The water flowing through the stuffing box should be maintained at a level just enough to prevent overheating. The gland nuts should be loosened or tightened one-quarter turn only to allow the packing to equalize against the pressure.

c. Checking and adjusting misaligned head shaft

Pump vibrations could indicate a misalignment of the head shaft. This can be checked by the following procedure:

1. Remove the motor dust cover, motor head nut and key, and take out the motor drive flange.
2. Check if the head shaft is concentric with the motor hollow shaft bore.
3. If needed, adjust by using shims.

Other common problems are shown in the table on the next page:

Common problems in operating centrifugal pumps

Trouble	Likely Cause of Trouble	Remedy
Pump Motor fails to start	Blown fuse or open circuit breaker.	Replace fuse or reset circuit breaker.
	Motor or starting switch out of order.	Inspect /repair. Refer to equipment supplier or experienced mechanic or electrician.
	Break in wiring.	Repair circuit wires.
	Stuffing box may be binding or tightly packed	Check packing by manually rotating shaft. Loosen packing nut just enough to allow a slow seepage of water and free the shaft.
Pump runs but delivers no water	Scale or sand in the impeller.	Open pump and remove scale by acid treatment and/or sand.
	Pump lost first priming.	Repeat priming. Follow manufacturer's priming instructions.
	Pump repeatedly loses priming due to leaky drop pipe or suction pipe.	Pull out drop pipe and seal the leaks.
	No water at source due to overpumping	Reduce pumping rate or deepen the well.
	Collapse of well casing or screens	Replace with new one. If diameter of old casing is large, insert new casing inside the damaged casing. Consult driller.
Pump runs but delivers only a small amount of water	Clogging of well screens	Surging or acid treatment. Consult driller.
	Well not yielding enough water.	Do pumping test or deepen the well.
	Air leaks in suction pipe.	Pull the drop pipe from the well & seal leak/s.
	Incrustation or partial clogging of well screens.	Surging or acid treatment. Consult driller.
	Impeller is worn out or lugged with scale or trash.	Open the pump and clean/replace impellers.
Noisy Pump	Foot valve may be obstructed.	Clean foot valve.
	Bearing or other working parts of pumps are loose or need to be replaced	Tighten or replace defective parts.
	Pump motor is loosely mounted.	Tighten mounting.
	Low water level in well.	Reduce pumping rate.
	Presence of air in suction line.	Repair air leaks.

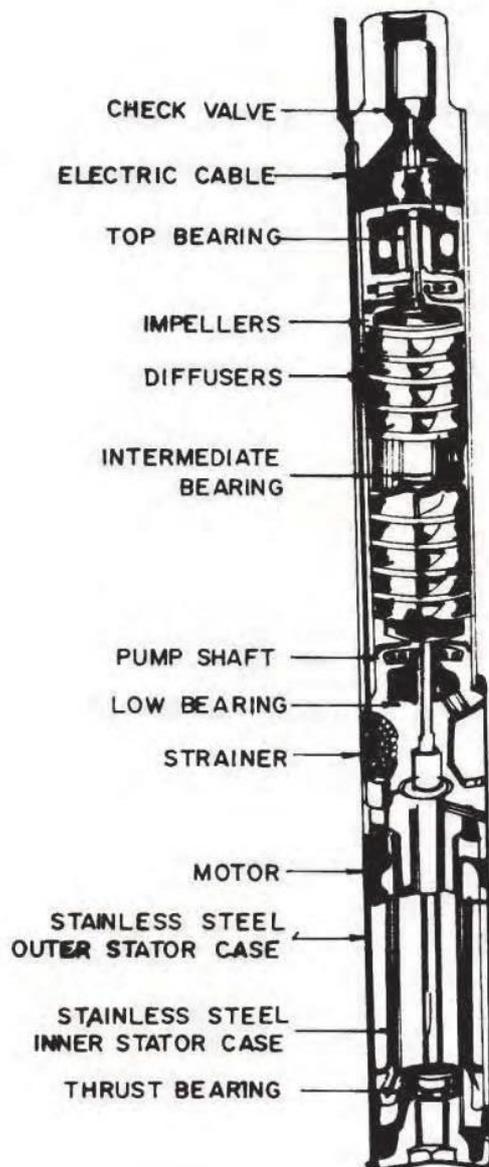
From: Rural Water Supply Operation and Maintenance Manual, World Bank, Philippines, 2012

Submersible pumps

Operation:

Submersible pumps may be operated manually with a switch located above ground level or automatically with a pressure switch, electrodes or float control devices.

Submersible pumps should always be operated below the water level. The pump should be installed higher than the well screen to prevent pump break suction which will lead to a burned pump motor.



DETAIL OF SUBMERSIBLE PUMP

From: Rural Water Supply Operation and Maintenance Manual, World Bank, Philippines, 2012

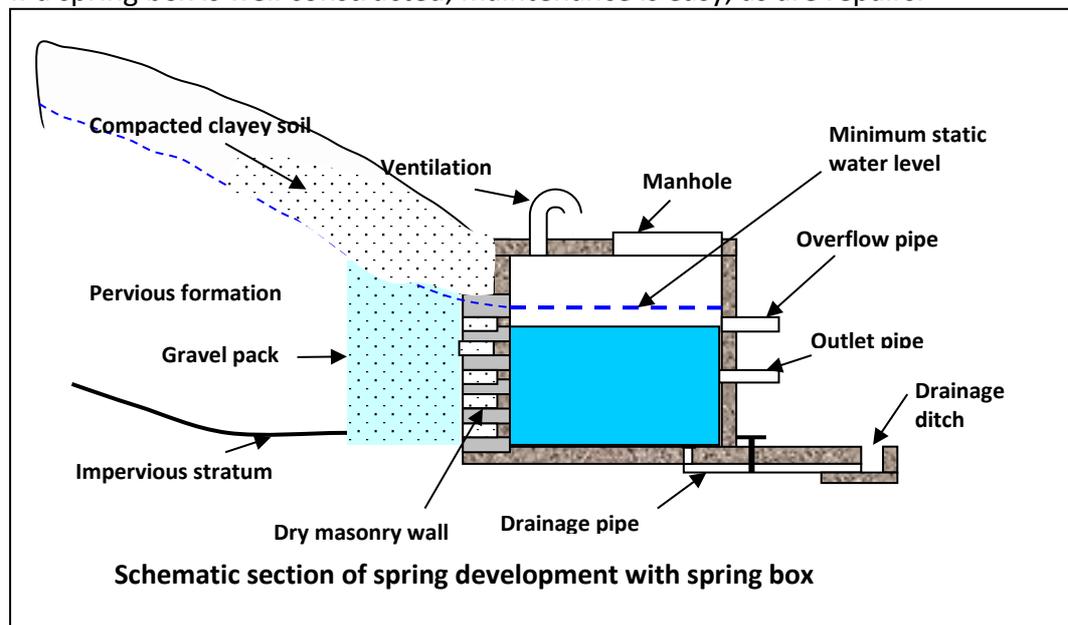
Maintenance of submersible pumps

Trouble	Likely Causes	Remedies
Pump motor fails to start	Motor Overload	Overloaded contacts close automatically. Check cause of overload.
	Low voltage	Check voltage.
	Blown fuse, broken or loose connections	Check fuses, relays, electric condensers and all electrical connections.
	Motor control box not in proper position	Ensure box is in right position.
	Damaged cable installation	Locate and repair the damaged cable.
	Cable, splice or motor windings may be grounded or wet.	Check the ground by using an ohmmeter. If grounded, pull out the unit and inspect cable and splice. Cut the unit loose from the cable and check each part separately using an ohmmeter.
	Pump stuck by corrosion or abrasive	Pull out pump, examine and remove foreign matter.
Pump runs but delivers little or no water	Pump not submerged	Lower the unit into the well or replace by a smaller capacity pump
	Discharge pipe may be leaking	Examine discharge line by pulling out one joint at a time.
	Check valve may be clogged or corroded	Pull out pump and clean or replace check valve
	Pump badly worn-out by sand or abrasive	Replace pump. Clean well thoroughly of abrasive before putting the new unit in.
	Strainers or impellers clogged with sand or scale	Pull out pump unit and remove the scale/sand.
	Scaled or corroded discharge pipe	Replace pipe.
Pressure valve fails to shut	Switch may be defective or out of adjustment	Adjust or replace pressure switch.
	Discharge pipe may be leaking	Raise unit one pipe joint at a time until leak is found. Repair leaks.

From: Rural Water Supply Operation and Maintenance Manual, World Bank, Philippines, 2012

6.5.5 Spring box maintenance

If a spring box is well constructed, maintenance is easy, as are repairs.



Taken from Technical Guideline and Manual of Spring Development and Roof Water Harvesting, MIWR, Sudan, 2009

Basic repairs to spring boxes

Fault	Repair
Crack or leak	Plug crack or leak with Portland cement mortar.
Damaged overflow and screen vents.	Replace damaged screen with a new one.
Clogging of drainage canal	Clean drainage canal from all obstruction and check its slope.
Dilapidated fence	Replace all worn-out posts and repair fence.
Reduction of spring discharge due to clogging	Clean the "eye" of the spring

Spring maintenance

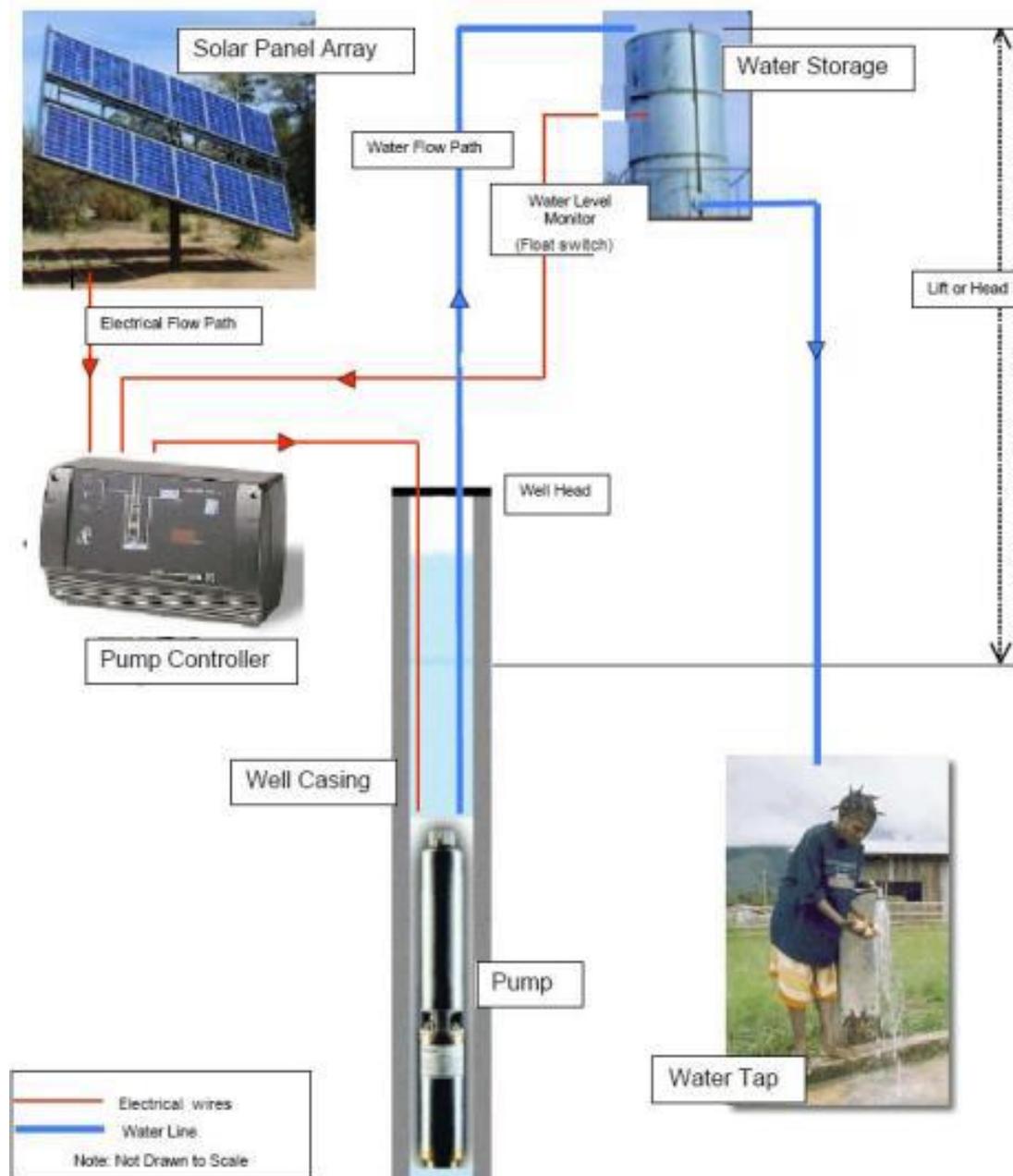
1. Water quality should be checked at least once a year, more often if needed.
2. The uphill diversion ditch should be inspected to ensure that it is not eroding and that it is adequately diverting surface runoff away from the spring box.
3. For hillside collection boxes, the uphill wall should be periodically inspected to ensure that it is not eroding and its structural integrity is maintained.
4. The animal fence should always be kept in good repair. If animals are allowed to get close to the spring, they could contaminate the water and ground surrounding the spring, and cause the compacting of soil, which in turn could lead to decreased flow rates.
5. The cover should be checked frequently to ensure that (a) it is in place and watertight (b) water is not seeping out from the sides or from underneath the spring box, and (c) the screening is in place on the overflow pipe.

6. If the concrete sides of the spring box are damaged, they will need repair. Drain the spring box. If it has a drain pipe and valve use these. If the box does not have a drain pipe or if the leaks are below the water level of the drain pipe, you must siphon the water out. If the volume of water is too great for a water hose to siphon the water out, you will have to use a water pump. Mix an appropriate amount of water and concrete. Trowel the concrete onto the spring box's cracks and damaged areas on both the inside and outside of the box. Ensure the water level in the box is kept below the newly patched concrete to keep water from damaging it, which usually takes 5 to 6 hours to cure.
7. Once a year, the system should be disinfected and the sediment removed from the spring box. Drain the spring box. Remove any sediment from the box and wash the interior walls with a chlorine solution. The solution for washing the spring box should be mixed at a ratio of 10 L water with 0.2 L chlorine bleach. Wear protective clothing and equipment such as gloves and safety glasses when dealing with chlorine. After the spring box has been cleaned, 100 mg/l chlorine should be added directly to the water in the spring box, followed by a second application after 12 hours these consecutive applications should provide for adequate disinfection. If possible, water samples should be analyzed periodically for contamination.

6.6 Solar Pumping

6.6.1 Introduction

Solar pumps are seen as a long-term replacement for fuel-powered pumps as they are typically more cost-effective, require less operation and maintenance and are more environmentally sustainable. They are designed for a future water demand of up to 25 years (includes population growth for 25 years) and pumps, solar arrays and electronics have a lifespan of about 10 years before needing replacement.



A schematic of a typical solar pumping set up for a borehole and water tank (from: Solar Pumping Systems (SPS) Introductory and Feasibility Guide, Green Empowerment, 2007)

The advantages and disadvantages of various pumping options are set out below.

	Advantages	Disadvantages
Hand pumps Link	<ul style="list-style-type: none"> • local manufacture is possible • easy to maintain • low capital cost • no fuel costs 	<ul style="list-style-type: none"> • loss of human productivity • often an inefficient use of boreholes • low flow rates
Animal driven pumps	<ul style="list-style-type: none"> • more powerful than humans • lower wages than human power • dung may be used for cooking fuel 	<ul style="list-style-type: none"> • animals require feeding all year round • often diverted to other activities at crucial irrigation periods
Hydraulic pumps (e.g. rams) Link	<ul style="list-style-type: none"> • unattended operation • no fuel costs • easy to maintain • low cost • long life • high reliability 	<ul style="list-style-type: none"> • require specific site conditions • low output
Wind pumps Link	<ul style="list-style-type: none"> • unattended operation • easy maintenance • long life • suited to local manufacture • no fuel requirements 	<ul style="list-style-type: none"> • water storage is required for low wind periods • high system design and project planning needs • not easy to install
Solar PV	<ul style="list-style-type: none"> • unattended operation • no fuel costs • low maintenance • easy installation • long life (20 year) 	<ul style="list-style-type: none"> • high capital costs • water storage is required for cloudy periods • repairs often require skilled technicians
Diesel and gasoline pumps	<ul style="list-style-type: none"> • quick and easy to install • low capital costs • widely used • can be portable 	<ul style="list-style-type: none"> • fuel supplies erratic and expensive • high maintenance costs • short life expectancy • noise and fume pollution

Comparisons of Pumping Techniques (from Solar (PV) Water Pumping, Technical Brief, Practical Action, 2010)

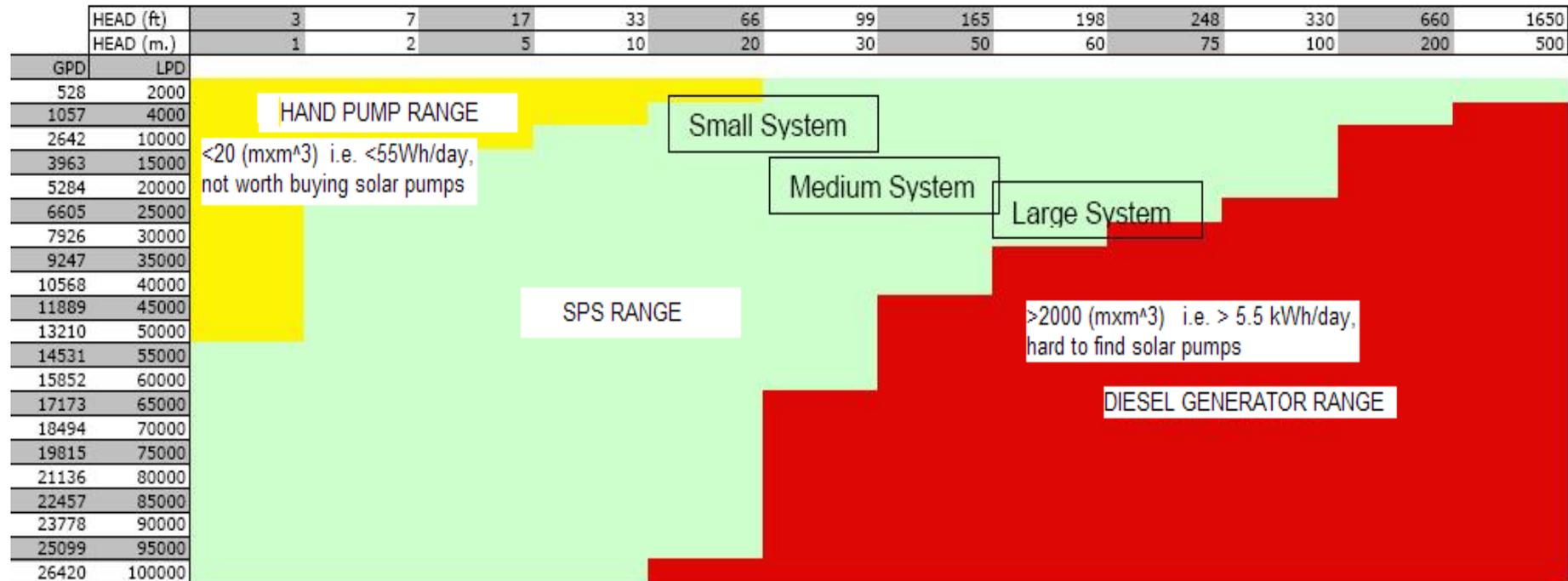
For larger installations, solar powered pumps are less effective than fuel powered ones. As a rough guide, multiplying the head (m) by the demand (m³) will give an indication of the effective range of a solar powered pump. As it is a rough guide, the friction losses in the pipe can be ignored:

Hydraulic duty = head x demand

If hydraulic duty < 20 then handpumps are the most effective solution,

if hydraulic duty > 2000 then a diesel generator powered pump is more effective.

6.6.2 Effective Solar Pumping Range



(from: Solar Pumping Systems (SPS) Introductory and Feasibility Guide, Green Empowerment, 2007)

6.6.3 Community Participation

As this is a long term measure, that can have a lifespan of 25 years or more, it is vital that the community is involved from the start in the planning, siting, management and operation and maintenance of the solar water supply. A survey and assessment should be conducted among the village health committee (VHC), leaders and households to determine if the villagers will be willing to embrace the technology (Annex 6.14 has a checklist for community participation). The assessment should consider local skills, materials, and labor in order to estimate how the community could be involved in the installation, operation, and maintenance of the system. Also important to assess the availability and cost of spare parts and skills for O&M – whether WES at State level can take this on, whether it is done by the private sector and if so, how this would the fee structure cover this. It is also generally a good idea for the community representatives such as the VHC to visit an existing community with a solar supply to discuss how an existing system is operated, managed and paid for. It is vital to plan this with the local WES officials so that the system relies on technologies that WES agrees with.

Solar-powered water supply systems are gaining ground in developing countries, but rarely are they installed without the funds and supervision of NGOs. There are significant upfront costs and community training required for the successful implementation. NGOs will usually be involved in the initial phases of the project including design, installation, and training needed to operate and maintain the systems.

Community ownership is key to the longevity of the system. The community should have a strong sense of ownership in it. There needs to be a tariff system set up to pay a water system manager in the village and to maintain and upgrade the system as needed. The NGO needs to arrange the training of villagers, such as representatives from the VHC to install the system and to understand its basic operation and maintenance.

6.6.4 Security

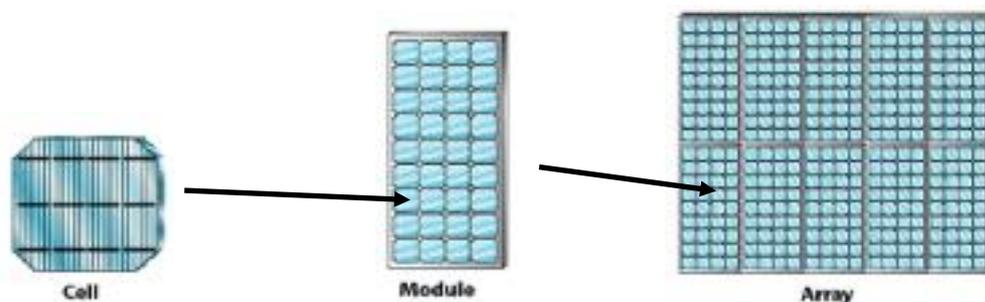
Another important aspect to consider is security. Can the PV array be secured properly or will it be stolen or vandalized? It is obvious that without a functioning PV array, a SPPS is worthless. The PV array is one of the most expensive components of the system (~50-75%) and should be protected from theft, vandalism, and livestock. It is important to conduct a security survey, looking at the risks in siting a solar system in the village and weighing them up against the cost of the system. As part of the agreement with the community to install a solar system, an agreement with all the stakeholders about who is able to use it and for what purposes; where will it be sited to ensure equitable access; and who will manage both the system and the money from tariffs is important to set out.

It is strongly recommended that provisions be made to put a fence with a lockable gate around the array. The fence needs to have enough set-back that it does not cast a shadow on the array.

6.6.5 Components of a Solar Powered Pumping System

Solar (Photo Voltaic) Cells

When light falls on the active surface of the solar cell, the electrons in it become energized, in proportion to the intensity and spectral distribution (wavelength distribution) of the light. When their energy level exceeds a certain point a potential difference (or voltage) is established across the cell. This is then capable of driving a current through an external load. Typically photovoltaic cells are about 15cm diameter and connected in series to get the desired voltage and then these strings of cells are connected in parallel to increase the current available. This produces typically a group of 30 cells which are then protected by a glass front and a metal or fiberglass back and sides to make one module or solar panel. These panels or modules may be connected in series or parallel to increase the voltage and current, providing the required solar array characteristics that will match the load.



from: Guide to Solar-Powered Water Pumping Systems in New York State, New York State Energy Research and Development Authority (NYSERDA)

All modern, commercial photovoltaic (PV) devices use silicon as the base material for the solar cell. There are three types of PV used commercially:

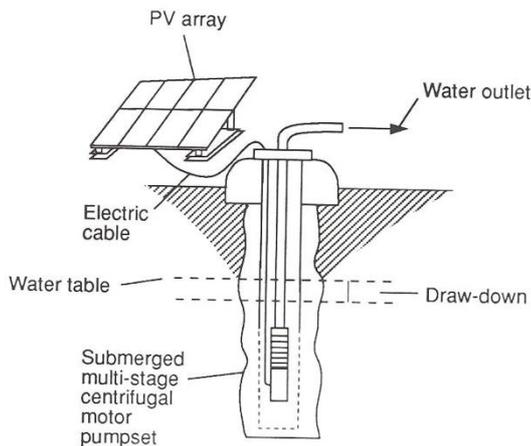
- Mono-crystalline cell modules: the highest cell efficiencies of around 15% -18% are obtained with these modules;
- Multi-crystalline cell modules. The cell manufacturing process is lower in cost but cell efficiencies of only around 15% are achieved;
- Amorphous silicon modules. These are made from thin films of amorphous silicon where efficiency is much lower (10% - 12%) but the process uses less material. The potential for cost reduction is greatest for this type and much work has been carried out in recent years to develop amorphous silicon technology. Unlike mono-crystalline and multi-crystalline cells, with amorphous silicon there is some degradation of power over time.

An array can vary from one or two modules with an output of 10W or less, to a vast bank of several kilowatts or even megawatts.

- **Flat plate arrays** fixed at a tilted angle and facing towards the equator, are most common. The angle of tilt should be approximately equal to the angle of latitude for the site. A steeper angle increases the output in winter; a shallower angle - more output in summer. It should be at least 10 degrees to allow for rain runoff.

- **Tracking arrays** follow the path of the sun during the day and thus capture more sun. However, the increased complexity and cost of the equipment rarely makes it worthwhile.
- **Mobile (portable) arrays** can be of use if the equipment is required in different locations such as with some lighting systems or small irrigation pumping systems.

Pump



(from: Solar Pumping Systems (SPS) Introductory and Feasibility Guide, Green Empowerment, 2007)

Solar (Photo Voltaic) power can power several different types of pumps, the most typical ones are small **submersible multistage centrifugal** pumps which are reliable, can start at low torques and can be matched to the solar array without electronic controllers, they are however not very efficient.

They can run on alternating current AC which require batteries (costly and more likely to be stolen), an inverter and a larger solar array to run. They can also run on direct current, DC. Older DC motors have carbon brushes to supply electricity to the motor which need replacing (by pulling the pump out of the hole) every 2 years. Newer DC motors for centrifugal pumps are brushless and use electric circuits to supply power to the motor. Both inverters and batteries significantly reduce the efficiency of an Solar Powered Water Supply. Batteries along with the charge regulator can produce a power loss of up to 25% of the total array output. If plenty of water storage is available, the batteries may not be necessary. The initial cost of an efficient DC pump (designed for PV power) is usually greater than an equivalent AC pump and AC pumps are often more easily available. It is usually better to pay the extra initial cost and use a DC pump.

Positive displacement helical pumps



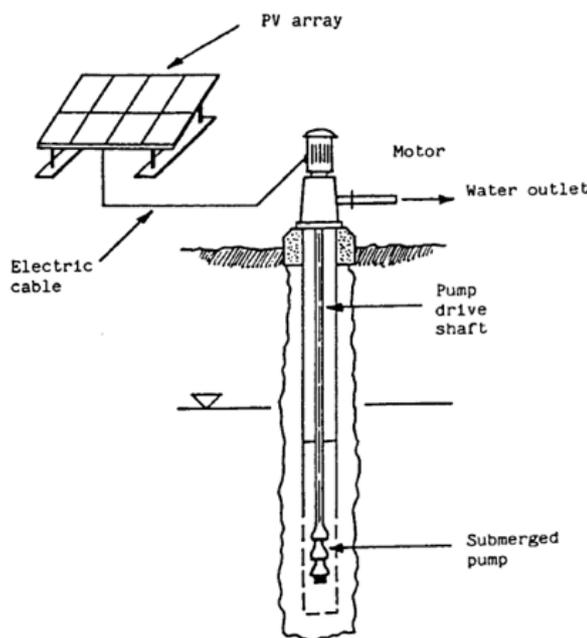
(from: Solar Pumping Systems (SPS) Introductory and Feasibility Guide, Green Empowerment, 2007)

Positive displacement helical pumps have the best efficiency and the smallest PV panel for

the same specs of water delivery volume pressure and head. They have low rotational speed. The pump is made up a metal helical rotor which rotates in a rubber casing. Suitable for bigger heads. A Mono solar pump will slow down when it is cloudy, but because it has no minimum speed (unlike a centrifugal pump) it will keep delivering water.

Submerged pump with surface mounted motor

Solar Pumping Systems (SPS) Introductory and Feasibility Guide, Green Empowerment, 2007



The main advantage is the easy access to the motor for maintenance.

The low efficiency from power losses in the shaft bearings and the high cost of installation has been disadvantages. In general this configuration is largely being replaced by the submersible motor and pumpset.

Sizing the pump is very important, as the cost of the solar panels is typically between 50 to 75% of the total cost, a more efficient but more expensive pump will reduce the number or panels and hence the total project cost.

A good sub-system (that is the motor, pump and any power conditioning) should have an electrical to hydraulic efficiency of around 70% using positive displacement pumps; centrifugal pumps

might only have an efficiency of 20%.

Pump Controller

The pump controller is a highly specialized item and can vary significantly between pump manufacturers. It is also called a linear current booster. It is therefore important to match the controller to the pump and use the same supplier for both. The purpose of the pump controller is to regulate and match the flow of DC electricity from the solar array to the needs of the pump. The pump controller also contains the recognition components for the storage tank floatation switch and the low-well switch. The controller should be expected to last approximately 10 years.

Storage Tank

The storage tank should have enough volume to hold three to five days' worth of average demand. This is not only to account for peak demands, but primarily to compensate for nights and cloudy days, especially when other backup systems (such as storage batteries) are not used. It will also be raised to a height that allows for gravity flow to the taps.

Additional Components

There can be several additional components to a SPPS that can enhance the performance of the system or add backup energy reserves:

Batteries

Deep-cycle batteries can be used as a power backup. They are recharged during the day through the PV array and drained at night or during cloudy days. The batteries should be lead-acid so they can be trickle charged indefinitely once they reach full charge. The pump controller is usually installed after the batteries. The addition of batteries requires a charge regulator between the batteries and the PV array. The charge regulator needs to monitor the battery voltage to prevent over-charging because the DC solar energy fluctuates throughout the day. It is also recommended to install blocking diodes before the charge regulator. A diode in the system should prevent the PV array from draining the batteries in low light conditions.

Low Well Switch

In low yield wells, where the drawdown of the well exceeds the pumping capacity, the addition of a shutoff switch is needed in the well to keep the pump from running dry. Some pumps advertise they can run dry without damage to the pump, but allowing any pump to continually run dry is a bad idea. Ideally, the pump should shut off when the water level gets within 0.5m of the pumps intake to reduce air intake and turbulence. Most pumps come pre-installed with a safety shut-off switch, but it is important to check when procuring that this is the case.

Sand Shroud

A sand shroud may be needed around the intake zone of the pump. Sand shrouds are recommended for use in wells that have high sediment loads or that were not properly developed. They are particularly recommended in open boreholes which are not screened through the saturated zone of the well. The pump manufacturer can usually provide a compatible sand shroud.

6.6.6 Demand

The output of a solar pumping system is very dependent on good system design derived from accurate site and demand data. It is therefore essential that accurate assumptions are made regarding water demand/pattern of use and water availability including well yield and expected drawdown. Domestic water use per capita tends to vary greatly depending on availability.

SPHERE suggests an emergency supply of 15 liters per person per day, the Sudan WASH Sector and Sudan Refugee Multi-Sector Refugee Response Strategy (August 2015 – December 2016) suggests for long term refugees who have been in the camp for over a year, a supply of more than 20 liters a person a day is required. WHO guidelines aim for a per capita provision of 40

to 50 liters per day for domestic use only. Most villages have a need for combined domestic and livestock watering which will require much greater amounts of water (see Module 1 Water requirements for more details of both domestic and livestock requirements).

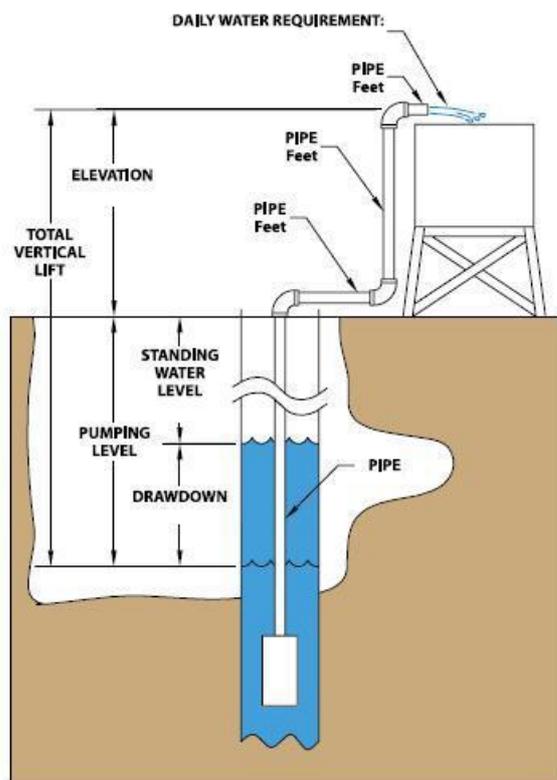
If there are irrigation requirements, they will depend upon crop water requirements, effective groundwater contributions and efficiency of the distribution and field application system. Irrigation requirements can be determined by consultation with local experts and agronomists.

6.6.7 Design

Several water source parameters need to be taken into account and where possible measured. These are the depth of the water source below ground level (standing water level), the height of the storage tank or water outlet point above ground level and seasonal variations in water level. The drawdown or drop in water level after pumping has commenced also needs to be considered for well and borehole supplies. This will depend on the ratio between pumping rate and the rate of refill of the water source, and should be measured and/or provided by those who drill the borehole. In addition, there is usually a seasonal variation in the water level, and a long term trend in the water table level dropping.

This will give the total static head (or total vertical lift) of the supply, added to this would be any friction losses in pipes and fittings to between the pump and tank to give the total dynamic head (TDH). These friction losses are usually calculated as equivalent pipe lengths, or for initial design costing calculations can be taken for short lengths of pipe as 10% of the total static head which should give a conservative estimate of friction.

Solar Pumping Systems (SPS) Introductory and Feasibility Guide, Green Empowerment, 2007



Having got a clear idea of both present and future demand, it is important to size the system for maximum efficiency, this depends on the amount of sunlight available to fall on the solar array.

At this point, a solar pump manufacturer would give you good advice on the size of pump, controller and number of panels needed in the array. Generally, these are matched by the manufacturer to produce the most efficient solar pumping system, it is worth getting quotes from more than one supplier. Providing them with details of the static head (m), total dynamic head (m), demand (m³/day) and the position of the site (latitude and longitude) should be enough for them to give you a quote. One of the biggest factors is the type of pump and pump controller used, different types will

have efficiencies that vary from 20% to 70%, which obviously affects the calculations immensely.

It is also worth working out the calculations for a specific pump (once you have an idea of that pump's efficiency) yourself as a check, an example is in Annex 6.15.

Obviously the solar array has to be pointing in the best direction, both horizontally and vertically to catch the most solar energy. Depending on where the site is latitudinally (how far north or south from the equator) the amount of peak sunlight will vary. Various websites can be used to get a good idea for the number of hours of peak sunlight.

A good website is the European Commission's JRC Photovoltaic Geographical Information System webpage for Africa & Asia :

<http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?map=africa&lang=en>

The calculations are well set out, and you can change the variables to get a good idea of what you might change in terms of slope of the solar arrays to get the optimum result. See Annex 6.16 for details on how to fill in the webpage.

Example Results for Khartoum

Fixed system: Inclination=17 deg., orientation=0 deg. (Optimum at given orientation)				
Month	Ed	Em	Hd	Hm
Jan	4.76	148	6.59	204
Feb	4.94	138	6.98	196
Mar	5.44	169	7.93	243
Apr	5.00	150	7.32	220
May	4.60	143	6.75	209
Jun	4.38	131	6.39	192
Jul	4.12	128	5.94	184
Aug	4.10	127	5.89	183
Sep	4.56	137	6.61	198
Oct	4.68	145	6.82	212
Nov	4.70	141	6.70	201
Dec	4.64	144	6.45	200
Year	4.66	142	6.69	203
Total for year		1700		2440

Ed: Average daily electricity production from the given system (kWh)

Em: Average monthly electricity production from the given system (kWh)

Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m²)

Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m²)

6.6.8 Maintenance

This is dependent on being maintained (kept clean and securely mounted) and protected from strong winds, lightning and hail storms, and falling objects such as tree branches. The solar

pumps should be expected to last about 10 years. The other electronics and controls should be designed to last at least 10 years with little electrical maintenance. The overall lifetime of the complete system should be designed and maintained to last 25 years taking into account the community's future growth projections. The system should be inspected at least once per week checking the pumping rate, operation of controller, condition of PV modules, tanks, wires, and pipes (for leaks/corrosion).

See Annex 6.17 for Maintenance Schedule

6.7 Emergency Water Treatment

6.7.1 Water Quality

Water quality is a vital factor in reducing the incidence of diarrheal disease, along with the promotion of handwashing, safe excreta disposal and provision of sufficient amounts of water. Water quality is defined in terms of microbiological, chemical and physical parameters. In the early phases of emergencies, microbiological contamination, leading to diarrheal disease, is the most important to eliminate through disinfection. Highly turbid water (a physical parameter) will prevent effective disinfection. Some chemical parameters are important for long term health but generally not considered in first phase emergencies unless an assessment suggests these would be a high risk (e.g. through existing health concerns or identification of chemical pollution risks such as nearby industries). The relative risks of short term use of chemically contaminated water needs to be balanced with providing populations with an adequate amount of water.

The Ministry of Health's Manual of Environmental Health in Emergencies and WHO's Guidelines on Drinking Water Quality provide guidance for long term effects on health, some of these, especially the chemical parameters, are less relevant for short term use of water. The table below compares water quality parameters from the Ministry of Health guidance for emergencies and the SPHERE manual indicators and guidance for emergencies:

Water quality Parameter	Ministry of Health Environmental Health Guidelines in Emergencies and Sudanese DWQ standards	SPHERE Handbook, WASH Chapter
Microbiological quality:	<ol style="list-style-type: none"> (0-10) <i>E.coli</i>/100ml of water considered good (10-100) <i>E.coli</i>/100ml of water considered contaminated More than 100 <i>E.coli</i>/100ml of water is considered very contaminated it is better to be chlorinated and if there is no chlorine should be boiled 	<p>There are no faecal coliforms per 100ml at the point of delivery (0 <i>E.coli</i>/100ml of water)</p> <p>For piped water supplies, or for all water supplies at times of risk or presence of diarrhea epidemic, water is treated with a disinfectant so that there is a free chlorine residual at the tap of 0.5mg per liter.</p> <p>If any fecal coliforms are present the water should be treated. However, in the initial phase of a disaster, quantity is more important than quality</p>
Physical Quality:	<p>Physical quality:</p> <ul style="list-style-type: none"> Turbidity not more than 5 NTU No odor No taste Should be without color 	Turbidity is below 5 NTU
Chemical quality:	<p>Monitoring chemical indicators mentioned above for drinking water according to Sudanese standards.</p> <ol style="list-style-type: none"> Arsenic Fluoride Iron Manganese Nitrate 	<p>No negative health effect is detected due to short-term use of water contaminated by chemical (including carry-over of treatment chemicals) or radiological sources, and assessment shows no significant probability of such an effect. Where hydrogeological records or knowledge of industrial or military activity suggest that water supplies may carry chemical or radiological health risks, those risks</p>

	6. Total dissolved solid 7. Hardness 8. pH	should be assessed rapidly by carrying out chemical analysis. A decision that balances short-term public health risks and benefits should then be made. A decision about using possibly contaminated water for longer-term supplies should be made on the basis of a more thorough professional assessment and analysis of the health implications.
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Table 1: Comparison of water quality parameters from the Ministry of Health guidance and the SPHERE manual indicators and guidance

Hardness or Total Dissolved Solids (TDS) can also be measured as it could indicate a high level of salts in the water and make it taste salty.

6.7.2 Emergency Priorities

At the very first stages of an emergency, water quantities are more important than good water quality; the SPHERE handbook states:

In many emergency situations, water-related disease transmission is due as much to insufficient water for personal and domestic hygiene as to contaminated water supplies. Until minimum standards for both quantity and quality are met, the **priority should be to provide equitable access to an adequate quantity of water even if it is of intermediate quality**, rather than to provide an inadequate quantity of water that meets the minimum quality standard.

Treatment at source (bulk water treatment) or treatment at household

In emergencies, an early decision is whether treatment is best carried out at or near the source, in a centralized treatment plan (bulk treatment) or at point-of-use (household level). Advantages and disadvantages are set out below.

	Advantages	Disadvantages
Bulk water treatment	<ul style="list-style-type: none"> ✓ Can supply to large numbers of people ✓ Can provide drinking water quickly ✓ Can control water quality ✓ Can monitor changing water needs 	<ul style="list-style-type: none"> ○ Often communal therefore low levels of ownership ○ Not useful for dispersed populations ○ High O&M inputs ○ Water can be contaminated post-supply
Household water treatment	<ul style="list-style-type: none"> ✓ More cost-effective ✓ Less risk of contamination post treatment ✓ Private ownership = more control for householders & 	<ul style="list-style-type: none"> ○ Water quantity not addressed ○ Training needed for effective use ○ More difficult to supply large numbers of people ○ Limited control on effective use

	<p>more sustainable (if appropriate to situation)</p> <p>✓ Good for dispersed populations</p>	
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Table 2: Comparison of Bulk and Household Water Treatment Options

The most important considerations in emergencies are:

- Density of populations – with dispersed populations or small numbers of people, bulk water treatment is not a good option;
- Pace of response – the need for a quick response will favor bulk water treatment, unless populations already are able to effectively use the type of household water treatment and do not require training in its use.

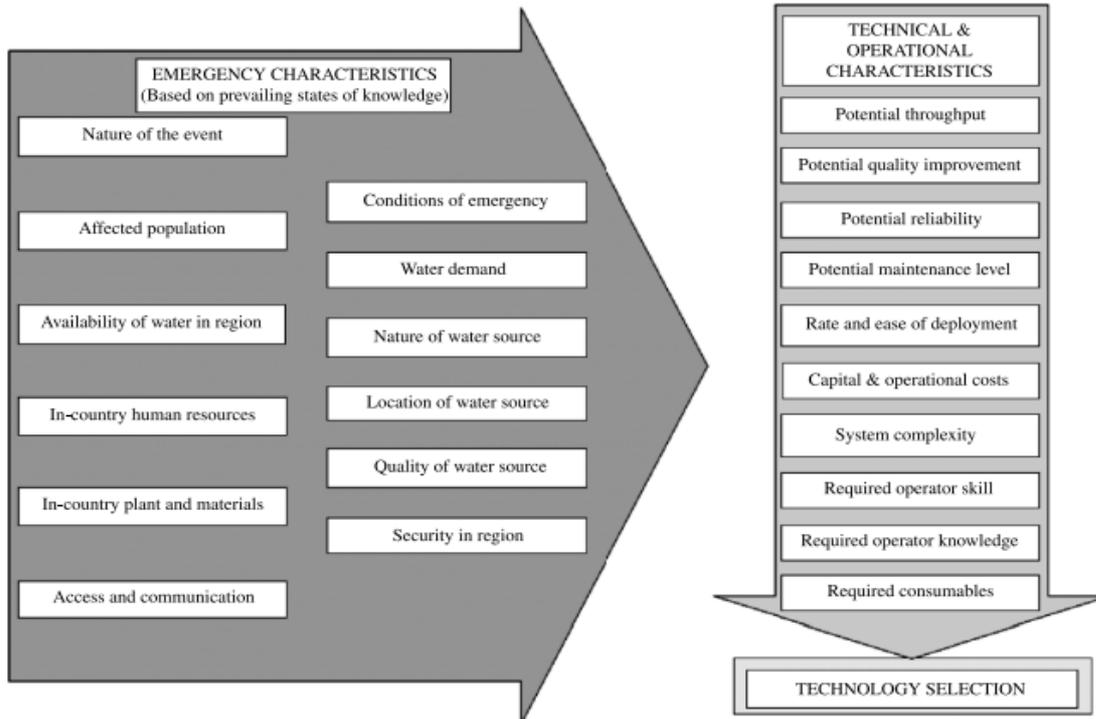
The following sections explain bulk water treatment in more detail, the later section details household water treatment.

6.7.3 Bulk Water Treatment Methods

Bulk water treatment – the process of treating water centrally and distributing it, is carried out when there is a need for a speedy response and where there are large numbers of people requiring water, in densely populated areas. The provision of water to large displaced people camps often uses bulk water treatment.

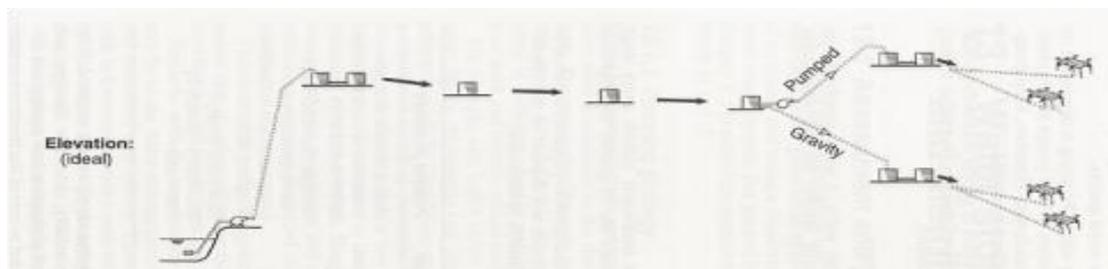
Similarly, mobile treatment plants can be set up very quickly to supply smaller populations affected by rapid onset disasters or who are not likely to stay in one place long.

The factors determining which type of treatment to use are outlined in the diagram on the next page. Decisions are typically also influenced by the type of water treatment technology available and the experience and capacity of the organization deploying it.



Factors affecting water treatment technology selection – taken from *Problems of treatment process selection for relief agency water supplies in an emergency* Andre Steele and Brian Clarke, *Journal of Water and Health*, 2008, IWA Publishing

A typical bulk water treatment set up is shown below:



Stages	Water abstraction and pumping	Raw water storage	Pre-treatment (such as roughing filtration)	Coagulation / Flocculation / Sedimentation or Sand filtration	Chlorination	Storage	Distribution

Adapted from *Engineering in Emergencies*, Davis and Lambert, Practical Action Publishing, 2002

Figure 1: an overview of bulk water treatment methods

Chlorination is detailed first as this is always carried out for large/dense populations, other treatment methods are there to reduce turbidity to ensure effective chlorination.

Chlorination – see MoH Manual of Environmental Health in Emergencies for more details

The Ministry of Health states it is important to chlorinate water for emergency populations if:

- Water is trucked to the population;
- There are large numbers of people, or densely populated areas;
- There is a safe drinking water resource but the water is transported by donkey cart and containers;
- There is no safe solid waste disposal system;
- Unorganized residential areas or camps;
- Watery diarrhea is prevalent in the area;
- The area is close to an area with a diarrhea epidemic.

Chlorine is the normal disinfectant used in emergencies. Treating water with enough chlorine will kill off the pathogens in the water and allow residual free chlorine to form in the treated water. This then can disinfect pathogens from recontamination that might happen during collection, household storage and use. There are no other easily obtainable disinfectants with the residual effect. Chlorine does not kill off all pathogens at doses that are acceptable to people's taste though: cysts, eggs of protozoa and helminthes are resistant to chlorine at all but very high doses and contact times. Nevertheless, chlorine is a very effective, easily obtainable and easy to use disinfectant.

Key factors to ensure chlorine is effective are:

- Turbidity of water – large amount of suspended solids in the water will 'hide' the pathogens from the chlorine. The turbidity should be less than 5NTU (MoH and SPHERE);
- pH of the water – the pH range for effective chlorine disinfectant is 6.5 to 8, outside of this, a higher dosage of chlorine or a longer contact time between the chlorine and water is required;
- Temperature – the water temperature needs to be between 10 and 20°C, or a longer contact time is required.

Higher doses of chlorinate in water can be leave an unacceptable taste for populations unused to chlorinated water. This might lead them to use other water sources with inferior quality or to worry that the water has been tampered with.

Disinfection is discussed further in the Ministry of Health Manual of Environmental Health in Emergencies, and covering especially:

- Different types of chlorination;
- Preparation of a 1% chlorine solution for carrying out disinfection;
- Chlorine dosage and carrying out disinfection using chlorine;
- Disinfection of wells.

Refer to the new FMOH chlorination protocol being developed in 2017/18 for more details.

Processes and Measures to reduce turbidity

Especially with surface water, the turbidity of the water can be the biggest barrier to effective chlorination. Therefore, reduction of turbidity to 5 NTU is often an important pre-treatment before chlorination. The use of some other treatment methods (filtration methods especially) with chlorine will also reduce the presence of protozoa and helminth eggs which chlorine is less effective in killing.

Below is a table outlining the main treatment methods, with those in grey used more often in humanitarian emergencies. Ceramic candles and membrane filtration are included, even though they are a household or health center treatment option. Ceramic candles are discussed in more detail later in this module. After that, several measures to reduce turbidity are explained, including physical measures such as intake structures which have not been included in the table.

	Natural sedimentation	Assisted sedimentation	Ceramic candles	Membrane ultra / nano filtration	Slow sand filtration	Rapid sand filtration (assisted with coagulant)	Chlorination (with normal concentrations used for potable water)
Turbidity	1 (long waiting time)	3 (rather long waiting time to reach very low turbidity)	3 (rapid clogging, frequent cleaning)	3 (rapid clogging, frequent backwashing)	2 (max 30 NTU, need for roughing filters)	3 (up to 300 NTU)	0
Bacteria (+/-0.1-20 μm^*)	1 (long waiting time)	1	3	3	2 to 3	0 (1 if assisted with a coagulant)	3
Viruses (+/-0.01-0.25 μm)	0 to 1 (long waiting time)	1	2	3	1 to 2	0 (1 if assisted with a coagulant)	2 (some viruses will survive)
Protozoa & Helminth eggs (+/-1-100 μm)	0 to 1 (long waiting time)	1	3	3	3	3	1
Salt	0	0	0	1	0	0	0
Colour, odour and taste	1	1	1	2	2	2	1
Remarks	- not often used due to its low efficiency	- turbidity reduction in emergency. -post rapid sand filtration desirable -post-chlorination compulsory	-small production -staff houses -small health structures -domestic treatment	-rather fragile -expensive -post-chlorination recommended	-slow production -small health structures -post-chlorination recommended	-camps -health structures -post-chlorination compulsory	-camps always -recommended in health structures -domestic treatment -remnant effect

In grey: the treatment procedures most commonly used by aid-agencies, often in combination with other methods
0: no impact, 1: low impact, 2: medium impact, 3: high impact - * μm = micron = 10^{-6} m

Table 3: Summary of main bulk water treatment methods used in emergencies. From *Public Health Engineering in Precarious Situations – Médecins Sans Frontières, 2010*

Physical measures – Intake and pre-treatment

- Designing the water intake to reduce turbidity (such as an infiltration gallery – see Annex 6.18 for details) - this could take time to construct so is rarely a first phase emergency action
- Placing the intake in the most suitable point of the water source. An intake in a lake that is several meters from the shore and neither resting on the bottom nor floating on the top will take less turbid water from the lake.

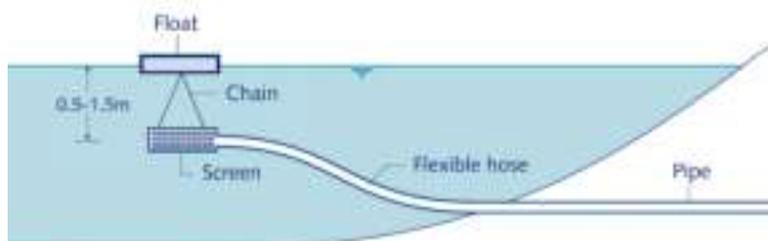


Figure 2: Floating Inlet in lake to reduce turbidity

From: First Draft of UNHCR WASH Manual, Tools and Guidance for Refugee Settings, UNHCR 2014

- Natural sedimentation – (see figure 1) allowing enough storage time in tanks for the sediment to settle out from the raw water, see 3.2.1.2 from Technical Guideline for Slow Sand Filtration System by the Ministry of Water for more details. If, when assessing the water quality, more than 80% of sediment settles in a clear 2 litre bottle in less than 30 minutes, it is likely that natural sedimentation is feasible.

Chemical measures – Coagulation and Flocculation

- adding a coagulant to the brings suspended particles together into flocs or large clumps, making them settle faster as they are larger and have greater density. Coagulants also neutralize the mild electro-repulsive forces between particles, allowing them to join together more effectively.

The process of coagulation and flocculation is carried out either in:

- bulk water treatment
 - as a pre-treatment to reduce turbidity before chlorination or
 - as a pre-treatment before rapid gravity filtration (which becomes inefficient with turbidities >300NTU) and then chlorination
- household water treatment
 - as part of a combined flocculent/disinfectant in packet form added to raw water

In emergencies, the coagulant is typically one of three types: aluminum sulphate (alum), ferric chloride or a polymer of some sort, the advantages and disadvantages of each are listed in the table

Product	Advantages	Disadvantages
Aluminium sulphate	<ul style="list-style-type: none"> • crystallised (sometimes lumps) • often available on the field • not expensive • no expiry date • often known by national counterparts 	<ul style="list-style-type: none"> • available only at low concentration (w/w*: 17 - 18%) • mainly usable within a pH-range of 6.0 to 7.4 (T.B. 2.10) • rather difficult to dissolve
Ferric chloride	<ul style="list-style-type: none"> • crystallised (but also available as a liquid) • high concentration (w/w*: 60%) • usable in a wide pH-range of 5.0 to 9.0 (T.B. 2.10) • not expensive at purchase • no expiry date (stable, even dissolved) • easy to dissolve • no (IATA) air transport regulation 	<ul style="list-style-type: none"> • rarely available on the field • importation needed • water might turn yellowish • corrosive • granules absorb very quickly humidity, becoming a wet paste or a solid block when dried out again (resulting in difficulties to prepare a mother solution)
Polymers	<ul style="list-style-type: none"> • extremely good coagulants / flocculants • usable in a very wide pH-range of 4.0 to 9.0 (T.B. 2.10) • normally little amounts needed <p>* w/w: weight for weight</p>	<ul style="list-style-type: none"> • often low concentration available • dosage can be difficult • rarely available on the field • importation needed • not stable during long period • possible (IATA) air transport regulation • possibly expensive

From *Public Health Engineering in Precarious Situations – Médecins Sans Frontières, 2010*

Table 4: Comparison of common coagulants

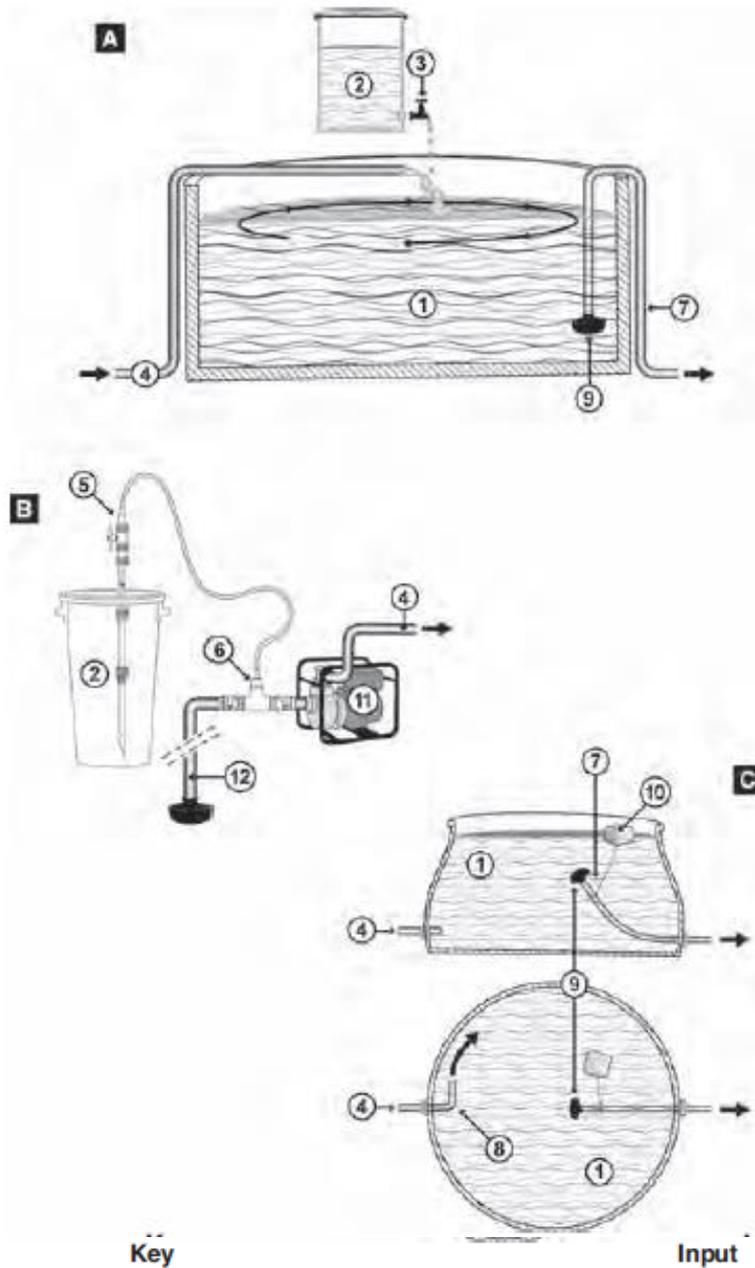
Unless another option is imported by an agency, alum is typically used as it is readily available. Correct dosing of alum coagulant can be determined empirically by carrying out Jar Tests (see Annex 6.19 for details). It should be noted that the most common coagulant used in Sudan in 2017 is Poly Aluminum Chloride (PAC) which has replaced Aluminum Sulphate which was previously more commonly used.

The coagulant is added to the water and requires rapid mixing to ensure it is effective and then slow mixing to form the flocs and allow the flocs to settle without being disturbed. The mixing can be done in a couple of ways:

Diagram A) Coagulant dropped into the raw water at the inlet of the flocculent tank where the turbulence of the water ensures mixing, the slow turning of the water in the tank encourages the formation of flocs;

Diagram B) Coagulant injected into the suction side of the pump by an inline doser, the rapid mixing occurs in the pump housing, flocs then form in the pipeline to the tank and in the tank as the in it water turns slowly. The inline doser allows for a better dosing of the coagulant so that it can be added proportionately to the filling of the tank

Diagram C) The settlement tanks should be at least 1m high to ensure an adequate amount of water is drawn off the top above the settled flocs on the tank bottom.



Key

Input

A. Drop-drop system and retrieval from open rigid reservoir

B. Suction Side Dosing (SSD) system

C. Water delivery to (for SSD system) and retrieval from open reservoir

1. Reservoir filling with water
2. Coagulants recipient
3. Valve / tap of the coagulant's recipient
4. Delivery pipe
5. Suction Side Dosing (regulation valve / flow meter)
6. Connection Suction Side Dosing system to pump
7. Retrieval pipe for the treated water
8. 90° elbow
9. Strainer on retrieval pipe
10. Floater
11. Motor pump
12. Suction hose with strainer

- Reservoir (pool or onion type)
- Plastic 20 l jerrycans or 120 l jar
- Construction materials / tools for the platform
- Suction Side Dosing system
- Pipes, T-pieces and valves
- Coagulant (solution)
- Motorised surface pump and accessories (kit)
- Floater
- Sticks and some rope to prepare the cross that avoids that the floating retrieval pipe descends too deep

From *Public Health Engineering in Precarious Situations – Médecins Sans Frontières, 2010*

As the settlement time of the flocs can be several hours, it is typical to have at least two tanks running in parallel so that when one tank's flocs are settling, the other tank is emptying to the chlorination tanks, this will also allow for cleaning of the tanks to get rid of the buildup of flocs over time.

This system, if using emergency kit from aid agencies can be quick to set up: the MSF flocculation kit can be set up in less than half a day, using an inline doser and union tanks for settlement. Oxfam kit, with steel sheet and a rubber liner tanks (see Annex 6.20 of Distribution Module for details) will take longer – up to 3 to 5 days to set up (depending on the number of tanks) as the tanks take between ½ to 1 day to build.

Filtration – Pressurized sand filters

Emergency water filtration is usually done through agency specific emergency water treatment kit, using pressurized sand filters. These are combined with other processes, typically coagulation and flocculation (as filtration of the larger flocs is easier than sediment), activated carbon (for taste issues) and chlorination. The water treatment mobile units are relatively small scale with a maximum output of between 3 to 5,000litres/hour, with high capital and operation costs and the need for skilled operators. Nevertheless, they can be rapidly deployed and set up and are a strong first phase emergency option.

Depending on how turbid the water is, they will need regular cleaning through backwashing (pumping a small volume of treated water back through the sand filter to dislodge the sediment or flocs from the filter media). Backwashing is a frequent process so two filters are usually run in parallel so that one is cleaned whilst the other operates.

See Section 8.5.2 of the Ministry of Water Resources Technical Guideline and manual of Drinking Water Treatment Facilities (2009) for more details on pressurized sand filters. See the next section in this module for how the pressure filters are incorporated and used in mobile water treatment units for emergencies.

Filtration – Slow Sand Filters

Slow sand filters can be used to reduce the turbidity and pathogen load of water in longer term emergencies, see the Ministry of Water Resources Technical Guideline and manual of Slow Sand Filters (2009) for more details. Oxfam has produced a slow sand filter kit, using its steel sheet and rubber liner tanks – see Annex 6.20 for more details.

Filtration – Membrane Filtration

Membrane filtration have modules with membranes typically with a nominal pore size of around 10^{-7} m, preventing the passing of bacteria, helminthes, protozoa, cysts to 99.99% or more, viruses are also significantly reduced. The water is passed through the membrane at low pressure (about 3m head) and requires an initial turbidity or around 50NTU to work efficiently (a pre-filter might be needed to reduce turbidity to this level). Turbidity is reduced from 50NTU to about 0.1NTU. The membrane surfaces are agitated and backwashed to clean.

For emergency use, it is vital to chlorinate after membrane filtration, to ensure residual disinfection.

The SkyHydrant model as used by Oxfam in Sri Lanka are illustrated but other models are available. These units provide about 500 to 700 liters/hour of treated water but can be used in parallel for larger volumes.

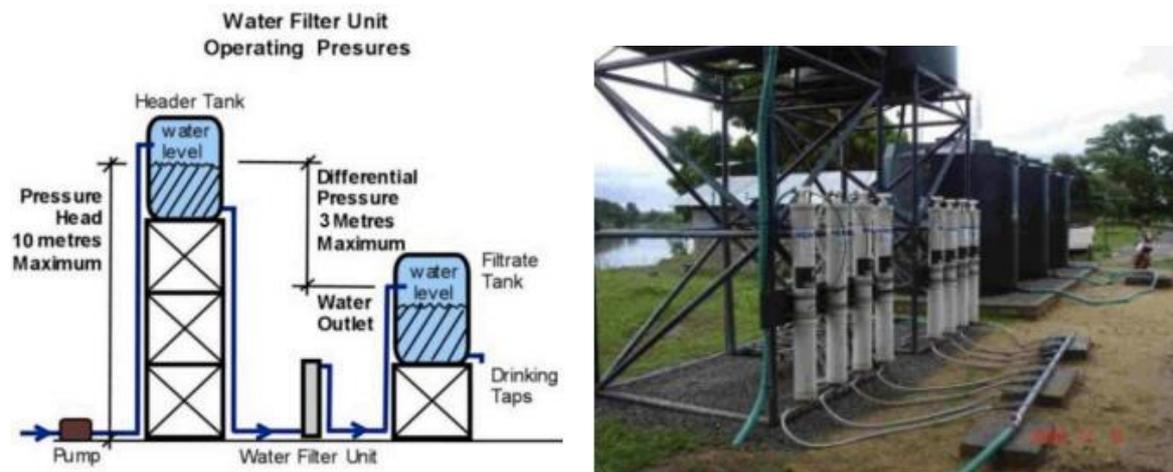


Diagram and photo courtesy of SkyHydrant

Emergency Mobile Water Treatment Units

These units are typically made up of several components discussed in previous sections:

- A) Pump with foot valve to take water from source and to pressurize system to allow flow of water through plant
- B) Coagulation/flocculation set up (using ferric chloride or alum)–
 - usually suction side doser so that coagulant is added before the pump and flash mixed in the pump
 - long length of flexible hose to allow flocculation to start
- C) Pressurized sand filters to remove the flocs and turbidity – two in parallel to allow one to be backwashed
- D) Possibly activated carbon to get rid of taste
- E) Chlorination – in line dosing of chlorine to disinfect the water and leave residual chlorine

The water then flows to tanks to allow for adequate contact time of the chlorine before distribution.



Skid mounted water treatment unit, in Ethiopia, showing pump in background with suction side coagulant dosing, flexible pipe for flocculation, pressurized sand filters in foreground and chlorine doser at front, (IFRC LMS Unit – capacity 4,000 liters/hour)



Trailer-mounted water treatment unit (IFRC SETA unit – capacity 3000litres/hour) this set up also has activated carbon filters to remove any odors

Photos courtesy of IFRC

These units are quickly set up but require skilled operators to operate and maintain them and high levels of consumables.

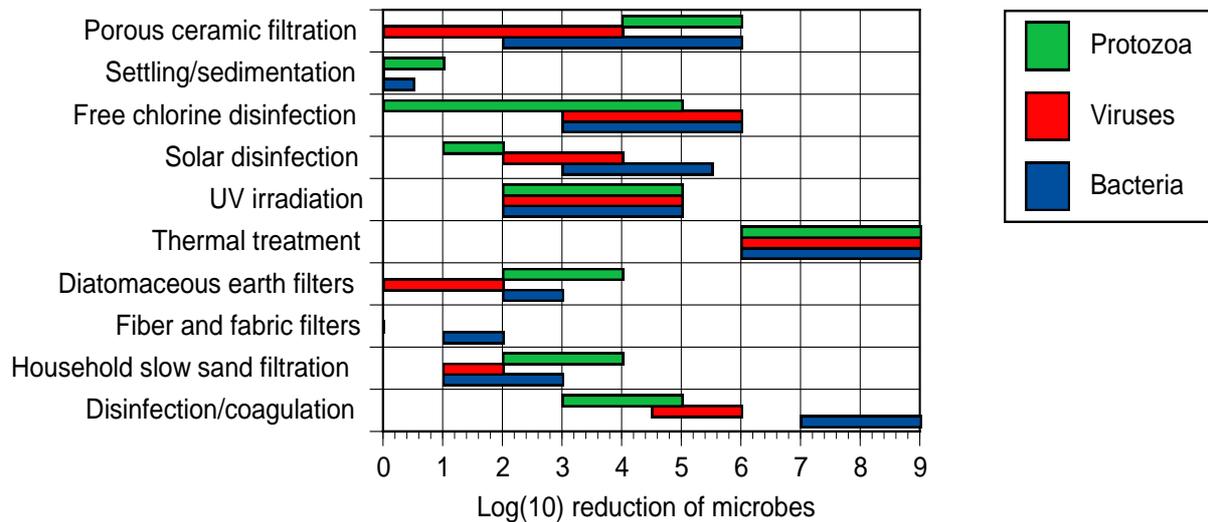
6.7.4 Household water treatment (HHWT)

Material is adapted from IFRC Household water treatment and safe storage in emergencies

Household water treatment (HHWT) uses a variety of methods to reduce the pathogens in the water when stored in the house. Some methods also reduce the turbidity of the water. HHWT will also treat pathogens that are introduced during collection and transport of the water (such as from dirty water containers or dirty taps or environment around the water source), which bulk water treatment should also do if enough chlorine is added to the water. If HHWT is combined with strong messages on water storage and use, it can be a major factor in reducing diarrheal disease.

For any HHWT, it is important that people are trained in both how to do it and why it is important so that they can reliably carry it out. It is also vital that hygiene staff carry out follow up visits and education to ensure the water treatment is carried out properly as it has been shown this can dramatically increase its effectiveness in the household.

The effectiveness of a variety of HHWT methods is shown below. Not all of these are relevant to typical households in Sudan:



Sources: Souter et al. 2003, Lantagne 2001, Sobsey 2002, Hijnen et al. 2004, Timms et al., Kaiser et al. 2002, Colwell et al. 2003, Huq et al. 1996, Logsdon 1990, Schuler et al. 1988, NAP 1997, Sobsey 1989, Batchley and Peel 2001, Walker et al. 2004, Meyer and Reed 2001, Reed 1996, Wegelin et al. 1994, Mendez-Hermida et al. 2005, CDC 2001, CDC.gov 2005, Brown and Sobsey 2005, Sobsey and Brown 2006

Note: a Log(10) reduction – log (10) reduction is a 10 times smaller number i.e. 10^{-1} so:

- 1 on the graph is 1/10 of the original amount, or a reduction in amount of 90%
- 2 on the graph is a reduction in amounts of 99%
- 3 on the graph is a reduction in amounts of 99.9%
- 4 on the graph is a reduction in amounts by of.99%
- etc.

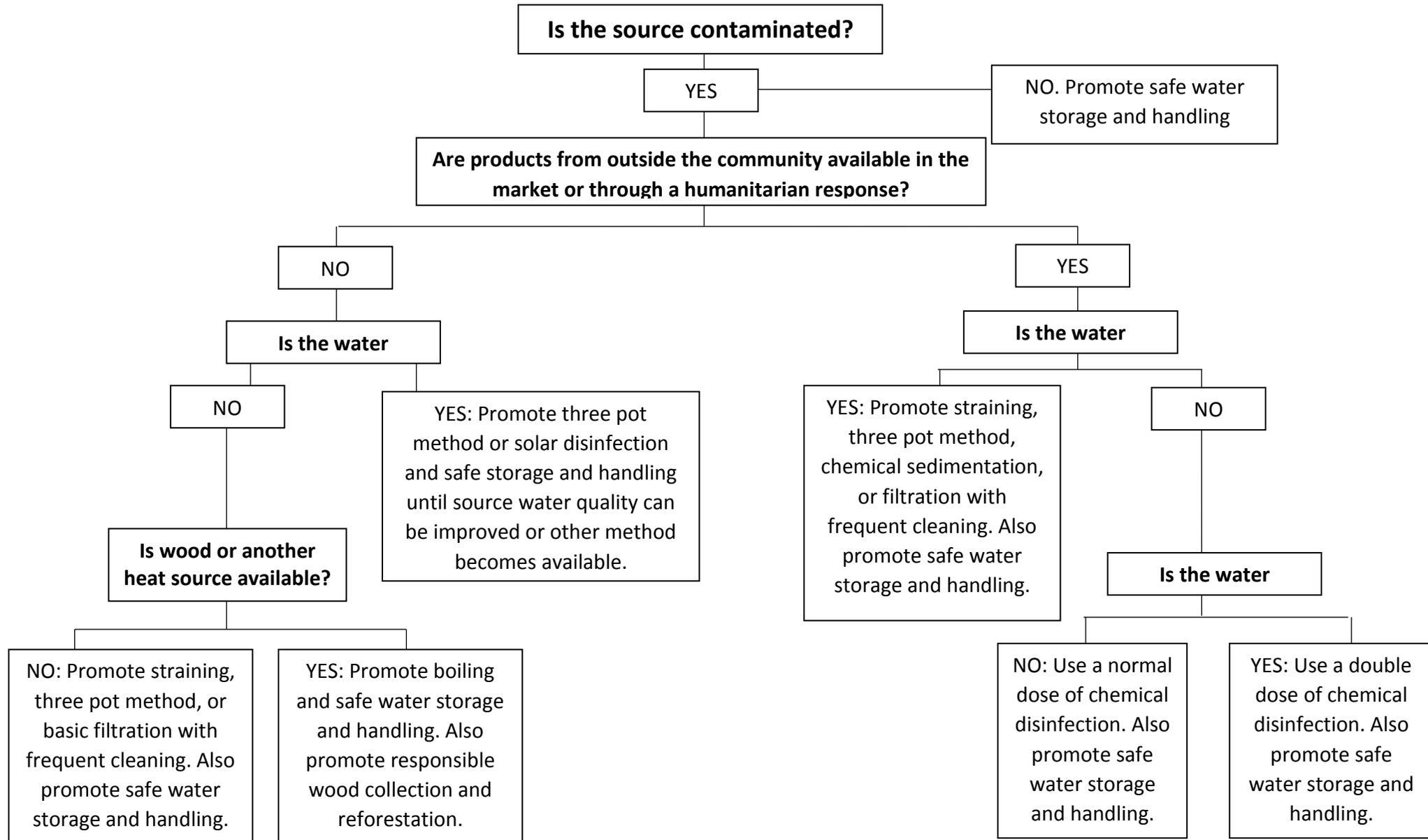
So for example, **Household slow sand filtration**,

- the reduction in protozoa is 99% to 99.99% (i.e. 0.01% to 1% protozoa remain),
- reduction in viruses is between 99% to 99.9% (i.e. 0.1% to 1% remain) and
- reduction in bacteria is between 99% to 99.99% (i.e. 0.01% to 1% remain)

The different methods outlined here are:

- **Disinfection** – making sure water is free from disease causing germs. This may be done by chemicals, heat, or even sunlight.
- **Sedimentation** – allowing dirt to fall to the bottom of a water container over time.
- **Filtration** – physically removing dirt by passing the water through a material such as ceramic or sand.

Household Water Treatment Decision Tree



Simple filtration - Straining

Straining water, if done correctly, will improve the effectiveness of all the other methods discussed in the rest of this section.

Pouring dirty water through a piece of fine, clean cotton cloth will often remove a certain amount of the suspended solids and insect larvae contained in the water. In Bangladesh, folding a cotton cloth in four and straining water through that, reduced the cholera bacilli by 90% and in the villages where this was promoted, cholera rates reduced by 50% (New York Times, 2011).

Washing the cloth between uses will make straining more effective.

Straining alone is unlikely to make water from a contaminated source completely safe to drink. But by reducing the turbidity, it makes further household water treatment more effective.

Boiling – thermal treatment

Boiling, if done properly can provide safe water for a household with no other alternatives. Boiling on a rolling, bubbling boil will kill all pathogens. At sea level 1 minute of a rolling boil is sufficient; at 2,500m, the rolling boil has to be kept going for 5 minutes.

Advantages:

- Boiling will kill all pathogens.
- Boiling water is something people can do themselves.

Disadvantages

- It takes 1kg of firewood to boil 1 liter of water for one minute. Boiling should not be promoted in areas where wood is scarce and no other heating options are available.
- Boiling will not reduce turbidity.
- Boiling has no residual effect, so improper storage can lead to re-contamination.
- Boiled water should be stored safely and used within a few days.

Boiling is only effective if the temperature is high enough. Water that is simply steaming has not been boiled.

Solar disinfection

Exposing water to sunlight will destroy most pathogens. This is even more effective at higher temperature (although the temperature of the water does not need to rise much above 50°C). An effective method is to put clear plastic or glass bottles of water to the sun. In tropical regions, a safe exposure period is about five hours, centered around midday. For greater effectiveness place the bottle on a corrugated-iron roof.

The amount of time the bottle is exposed to the sun will need to be doubled (two days instead of one) when the water is turbid. On cloudy days, the length of time will also need to be increased.

Advantages:

- Solar disinfection will kill most pathogens if exposed to the sun long enough.
- Solar disinfection easily done at household level with widely available materials (clear bottles or clear plastic bags).

Disadvantages

- Solar disinfection has no residual effect, so improper storage can lead to re-contamination. Water treated by this method should be stored safely and used within a few days.
- Solar disinfection takes more time than other methods and requires sunny weather.

Free Chlorine disinfection

As with bulk water treatment, chlorine will provide a residual disinfectant.

Make sure all people who receive chemicals are trained how to use them. Because of quality control concerns and the wide range of concentrations, common household chemicals such as laundry bleach should not be utilized as a chemical disinfectant unless no other options are available and careful training and monitoring is carried out.

Chemical disinfection, especially a double dose, can leave a taste that people do not like. This could cause them to stop treating water. The problem of chemical taste can be removed by using the correct amount of chemical and by shaking the water in a bottle to increase the air content.

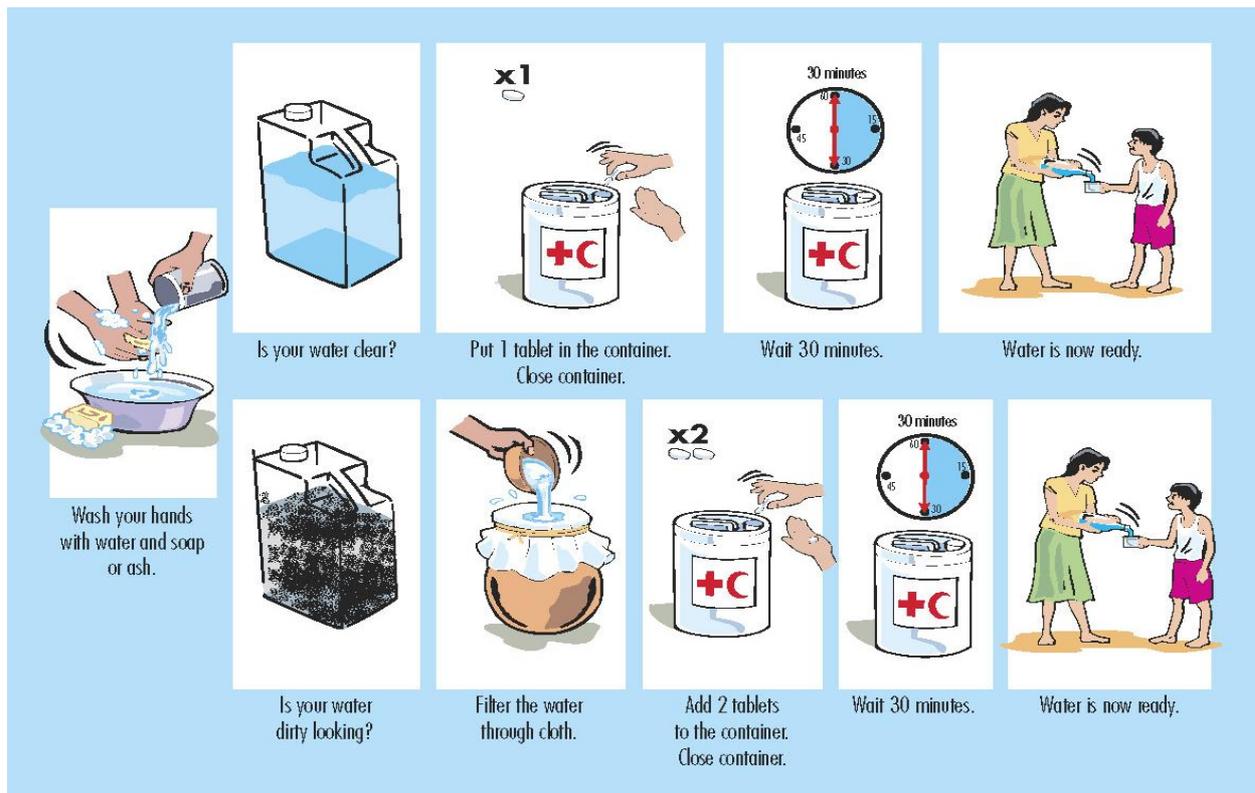
Advantages:

- These products are easy and safe to use.
- There is a residual effect of disinfection, which gives some protection against contamination after treatment.

Disadvantages:

- These products must be brought from outside the community; it is not something they can do with local resources.
- Chemical disinfection will not get rid of all germs that cause disease. Water should be strained prior to use of chemical disinfection in order to ensure all risks are eliminated.

How to treat water with chlorine tablets such as Aquatabs:



Coagulation/Disinfection

These are usually provided in sachets for treating a container of water (typically for 10 or 20 liters). They have a coagulant to produce flocs and a slow release chlorine product that will start disinfection after the flocs have settled. The actual ingredients and the processes of how they work in detail are often a commercial secret.

They are typically only used for turbid water as they are more expensive than chlorine tablets.

The water is stirred for 5 minutes once the product is added and then left for a further 5 minutes for the flocs to form. The water should be filtered through a cloth and then left for at least 20 minutes before drinking.

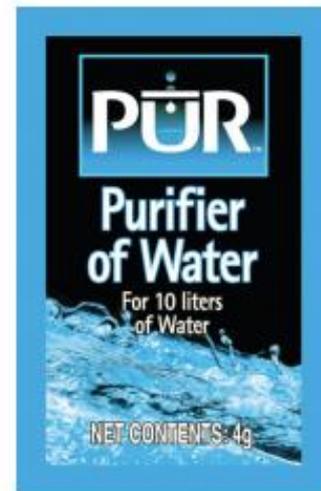




5g for 20 litres



2.5g for 10 litres

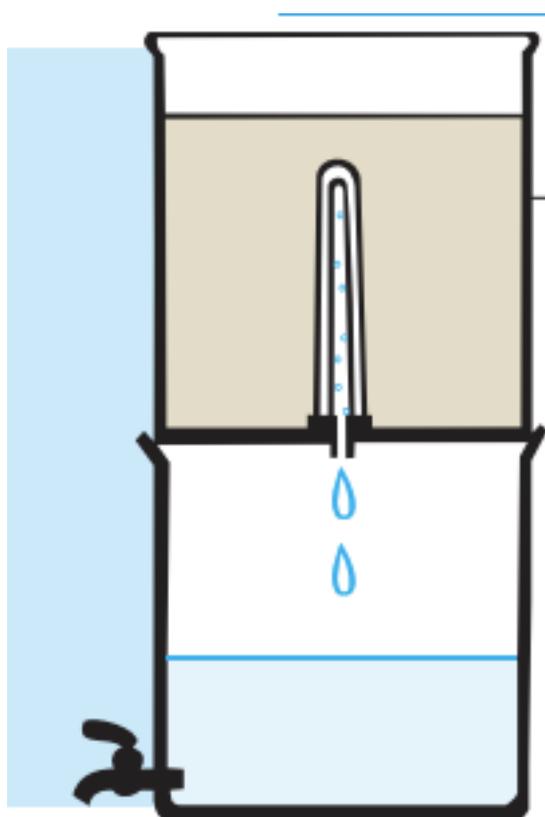


4g for 10 litres

Examples of commercial water treatment sachets used in emergencies.

Candle filters

Candle filters are made of ceramic.



Water is poured into one container and slowly passes through the ceramic candle into another container.

The filter is scrubbed clean with a brush whenever it begins to be clogged and the flow rate between the containers becomes slow. If possible, the filter should also be boiled to kill germs that cause disease that are caught in the filter.

The dirtier the water is the more frequently the filter will need to be cleaned. Eventually the candle will be worn away from scrubbing and must be replaced.

Advantages:

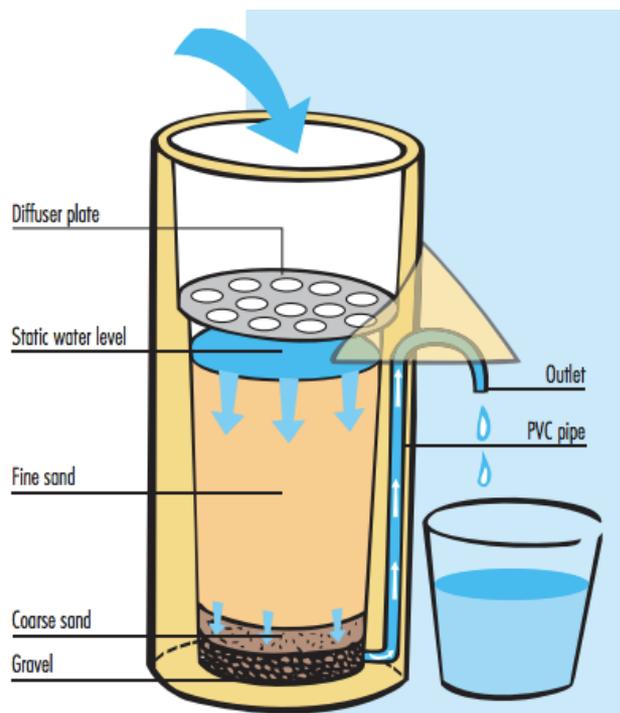
- These products are easy and safe to use.
- If properly maintained, this product can be used to produce clean water for a long time

Disadvantages:

- These products are expensive and often fragile.
- It can take a great deal of time to treat water, especially when the water is very dirty.

- There is no residual effect of disinfection, the clean water container must be covered to protect against contamination.
- These products need regular maintenance and require more training and follow up.
- If produced locally, the quality of the ceramic candle might not be good enough for effective filtration

Household Slow Sand Filter



Although not commonly used in emergencies, slow sand filters are an effective and long lasting method of household water treatment. They filter water through the sand and the biological material that grows on the top of the filter. The filter is cleaned when it becomes clogged.

Because the biological layer needs time to grow, the filter will not treat water properly when it is first put into use and after cleanings.

Although these filters are simple to use, they require hands on training when they are distributed.

Advantages:

- If properly maintained, this filter can treat water for a long time

Disadvantages

- It can take a great deal of time to treat water, especially when the water is very dirty.
- There is no residual effect of disinfection, the clean water container must be covered to protect against contamination.
- These filters need regular maintenance and require more training and follow up.

6.7.5 Household Water Storage and usage – hygiene promotion

Improvements in water quality due to household water treatment or bulk water treatment are lost if the water is not stored and used properly.

This means that the population must have access to sufficient suitable storage containers: either wide-necked containers that are easily cleaned and which should be kept covered or narrow necked containers that are less easily polluted but more difficult to clean.

It also means that people need to understand and try out new methods of treating water, especially if chemicals are involved – hygiene education is an important part of a successful household water treatment programme.

Four basic steps in hygiene promotion for household treatment and storage are:

- 1 **Conduct an assessment** of current hygiene practices and identify high risk practices. The table on the next page identifies key WASH practices that can be promoted in emergencies.
- 2 **Select target groups** for directing the specific messages and behavior changes. For example, children can be targeted about how best to collect and transport water as they are often the ones that collect the water.
- 3 **Develop hygiene messages** - These should focus on a few key practices: initially no more than 3 to 5 maximum. Present these in a positive light and make use of humor wherever possible, using simple locally understood words. If possible pre-test the messages with a group of similar age, educational level and culture to those the message is trying to reach.
- 4 **Select communication methods:** The choice of communication method depends on the nature of the audience and the resources available. In an emergency, mass media is the most commonly used method for the rapid spread of messages to the widest audience at the lowest cost.

Distribution points or water collection points are good places to disseminate messages: conduct different activities using popular media like drama, songs, puppets, and story-telling, etc. (they combine entertainment with practical advice) or mass media delivering through loudspeakers, posters, leaflets, notice boards, stickers, t-shirts, etc.

Messages delivered through mass media can be reinforced by face-to-face activities. These activities, like house to house visits might be conducted in parallel with the NFI distribution activities.

House to house visits offer an opportunity for the hygiene promoters to assess the domestic environment and tailor hygiene messages to the specific needs of the family.

Monitoring

For behavior change to sustain, follow up training and monitoring should be carried out after the initial training.

Hygiene promoters should be able to track changes in the community in relation to:

- People's satisfaction regarding the product selected
- Correct use of the products
- People's hygiene practices at household level in relation to water handling and storage.

Summary of Assessment of WASH practices for hygiene messaging

Water					Sanitation	Hygiene
Water source	Water collection and transport	Water storage	Water treatment	Water use	Latrine use	Hand washing
<p>1)Water sources should be used with care and maintained in good condition.</p> <p>2)There should be no risk of contamination from nearby latrines, wastewater drainage, animals, or objects falling into the well.</p>	<p>3)Drinking water should be collected in clean vessels, without coming into contact with hands.</p> <p>4)Water should be transported in covered containers.</p>	<p>5)Water should be stored in clean vessels which are covered and regularly cleaned.</p> <p>6)Drinking water should be stored in a separate container from other domestic water, wherever possible.</p>	<p>7)Water treatment procedures should be carried out at household level if the source is not clean and water is not stored properly.</p>	<p>8)Drinking water should be taken from the storage vessel with a dipper or ladle so that hands, cups or other objects can not contaminate water.</p>	<p>1)Latrines should be used instead of open defecation.</p> <p>2)Latrines should be located away from water sources and be kept clean.</p> <p>3)Pits need to be emptied or replaced regularly.</p>	<p>1)Homes should have soap and water for washing hands.</p> <p>2)People should be washing their hands at critical times.</p>

6.7.6 Water quality monitoring

If a Water Safety Plan (WSP) has been developed, then the monitoring process should come from that process (see Module 3 Water Safety Plans for more details).

Assessing the water quality when planning a water supply should be the starting point for long term water quality monitoring – see module 2 Water Source Selection for more details on the selection of water sources.

Water quality monitoring serves two purposes:

- to ensure that the quality of the water distributed to users or used by users, (depending on whether monitoring is carried out at the water point or at household level), is safe;
- to adjust water treatment processes for effective treatment as the water quality changes (due to increased turbidity during the rainy season for example) or as there is a change in the requirements for water quality (such as an increased chlorine residual during a diarrheal outbreak).

Tests for long term water supplies

Test the water comprehensively at a laboratory for the chemical and microbiological parameters listed below if the water is going to be used beyond 6 months to a year.

Refer to the Sudanese Drinking Water Quality Standards, 2016 for the maximum permissible levels.

More details on microbiological quality (testing for fecal coliforms) can be found in Annex 6.21.

Daily monitoring of treated supplies

If the water is being chlorinated then daily test for free residual chlorine in the taps, and monthly testing in representatively sampled households of stored water (see Annex 6.21 for testing details). Adjust the amount of chlorine used to treat the water according to the daily tests at taps. The amount of chlorine will need to be adjusted to allow for 0.2 mg/l at the household after 24 hours; and hence 0.5 – 1.0 mg/l at any point of distribution (tapstand, from a tanker or donkey cart) – both before and during an outbreak⁵.

⁵ During the process to develop the Sudan Drinking Water Safety Strategic Framework, 2017 it was agreed⁵ to: 1) Maintain a free chlorine residual of 0.2 mg/l at the household level after 24 hours; 2) Increase the chlorine residual to leave at least 0.5-1.0 mg/l residual at public standposts in any hot climate condition, irrespective of outbreak or normal conditions, and to monitor the effects along the water chain to check: a) residuals in households, as well as checking b) the community acceptance of the chlorine taste/rejection levels; and then to adjust accordingly. This update in level for FRC at distribution points is to take into account the hot climate and the high risk of contamination in Sudan from issues such as open defecation and old piped networks with intermittent supply. The changes have been based on recent learning from research in South Sudan and elsewhere. The recommendation has been discussed with WHO Geneva and it has been agreed that the increased levels are in alignment with the principles of the WHO Guidelines for DWQ 2017 with the main priority for chlorination to have a residual of 0.2 mg/l in the household.

If pre-treatment is required to reduce turbidity (and possibly change pH) of the water to ensure effective chlorination, then the raw water will have to be tested daily for these turbidity and pH to ensure the correct dosage. Jar tests will need to be carried out for determining the amount of chemical needed for pre-treatment and for chlorination (See Annex 6.19 for details).

It is important to also verify the piped water supply does not have fecal contamination and so microbiological testing is required according to the table from WHO below.

Monitoring of non-treated small scale water supplies

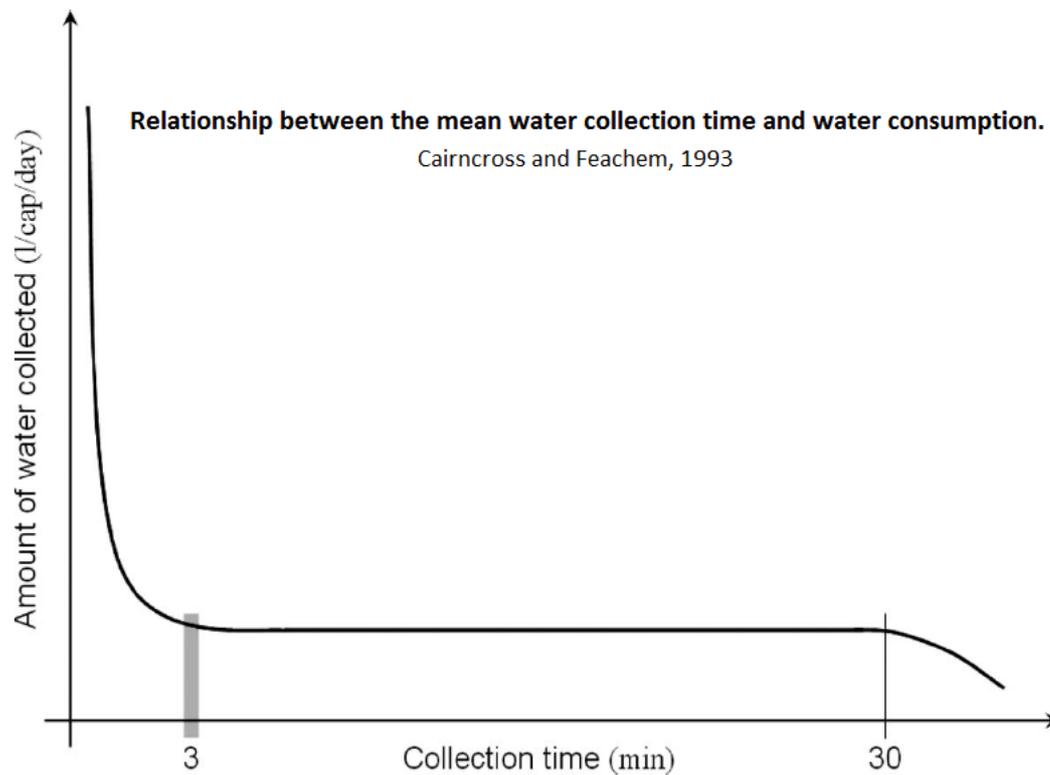
Initially, carry out a sanitary survey or sanitary investigation to identify pollution risks and carry out field-testing of the microbiological quality of the water.

Carry out regular field-testing of the microbiological water quality according to the table below for point sources, depending on risk analysis.

Refer to the recommended schedule for sanitary surveys and water quality testing sampling for both the drinking water supplier and the surveillance agency, that is included in the Annexes of the Sudan Drinking Water Safety Strategic Framework (SDWSSF) (final draft 2017).

6.8 Water Distribution

It is important to get water close to where people live and use the water. The graph below, from a 1993 study, suggests that people will not take more than 20 liters of water per person per day if they have to walk more than 30 minutes to collect it. More than 30 minutes will dramatically reduce the amount collected. 30 minutes' collection time translates to about 1km distance without waiting time for filling containers or 500m with a waiting/filling time of up to 20 minutes.



SPHERE standards indicate a maximum distance of 500m between supply and household, WASH Sector standards suggest 500m in the first 3 months of an emergency, increasing to 1km for longer term situations.

6.8.1 First Phase Emergency

In first phase emergencies, getting water supplies close to people is vital.

Assessing existing working water supplies is the first activity, and where these are not adequate, other solutions need to be identified and exploited as soon as possible. Negotiate with water owners/producers for short or long term use of the supply, ensuring existing users have continued access.

A short term option would be to use water tankers to transport water closer to the population (see Water Trucking module for details). Water points used for collecting water from water trucking operations will require storage capacity and a small distribution pipeline to taps. See Annex 6.23 for details of installing a bladder tank for storage and tapstands. It is vital though that an alternative supply that might take

longer to set up is found, otherwise water trucking will continue indefinitely and will be costly and susceptible to breakdown.

A - If initial water supply is by trucking carry out the following:

1. Map population locations and identify sites appropriate for distribution (and storage if using water trucking), ensuring households are within 500m of taps and that access is possible by truck if water trucking is the initial option for water supply. Sites should also allow easy access for the population and take into consideration issues that could impact vulnerable groups in the siting of water points (not just technical issues) i.e. protection concerns, ease of collection for elderly, disabled, children, women, equity, etc. It is important not just to consider where the water point is sited but also the route that people (especially women and adolescent girls) have to take to collect water and their views on its safety.
2. Consult population on collection times, quantities of water required and preferred siting of water points, ensuring space for drainage of wastewater.
3. Identify key public institutions that would require water storage and distribution – health facilities, schools, day care or early child care centers, etc.
4. Calculate number of taps required at each location (considering maximum flow rate at peak hours, and ratio of 250 people per tap)
5. Calculate storage required between refills, assuming peak demand of up to 60% of total daily demand in 4 morning hours.
6. Design water points and storage, using Annex 6.23 to define construction details.
7. Set up water quality monitoring and testing at distribution points. Train operators to measure the level of chlorination to ensure that the water supply meets the water quality standards of 0.2 mg/l at the household after 24 hours; and 0.5 – 1.0 mg/l at any point of distribution (tapstand, from a tanker or donkey cart) – both before and during an outbreak⁶ (using a pool tester or similar) and to record the amount of water supplied.
8. For each water point, there needs to be a Water Management Committee (WMC) to operate and maintain the water point, record deliveries and to help

⁶ During the process to develop the Sudan Drinking Water Safety Strategic Framework, 2017 it was agreed⁶ to: 1) Maintain a free chlorine residual of 0.2 mg/l at the household level after 24 hours; 2) Increase the chlorine residual to leave at least 0.5-1.0 mg/l residual at public standposts in any hot climate condition, irrespective of outbreak or normal conditions, and to monitor the effects along the water chain to check: a) residuals in households, as well as checking b) the community acceptance of the chlorine taste/rejection levels; and then to adjust accordingly. This update in level for FRC at distribution points is to take into account the hot climate and the high risk of contamination in Sudan from issues such as open defecation and old piped networks with intermittent supply. The changes have been based on recent learning from research in South Sudan and elsewhere. The recommendation has been discussed with WHO Geneva and it has been agreed that the increased levels are in alignment with the principles of the WHO Guidelines for DWQ 2017 with the main priority for chlorination to have a residual of 0.2 mg/l in the household.

in hygiene promotion. The Village Health Committee, if operational, would be a good option.

9. Carry out hygiene promotion including focus on safe water chains (collection, handling or transport, storage). Place signage that water is safe for drinking around water points. Hygiene promotion could also address issues of odour, taste and color of water if people are not used to changes in these.

B - If water supply for a camp is from another source and a piped network is required:

1. Where there is an ability to be part of the planning stage of a camp (i.e. site has not yet been selected) it is important that WASH considerations are some of the key parameters of selection.

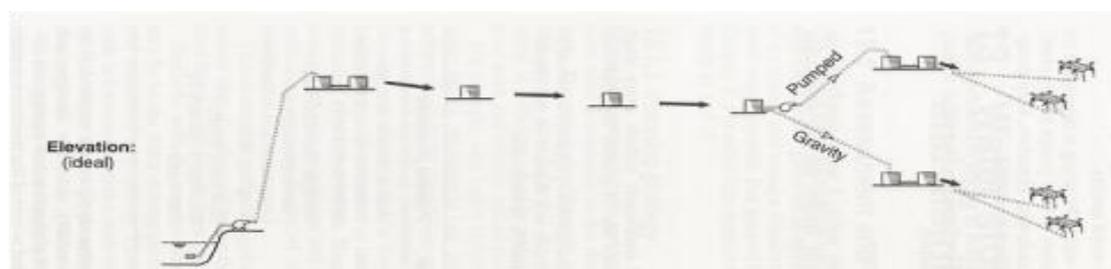
Of prime importance is the availability of water that is:

- reliable - throughout the year;
- adequate - enough water to meet the water supply needs of the planned population and possible camp extensions at 15l/c/d plus existing water users' needs;
- treatable – either direct chlorination or simple treatment to reduce turbidity to levels where chlorination is effective (<5NTU);
- and at a distance and elevation that can be effectively transmitted by pipeline through gravity or pumping.

Also important are:

- the slope of the site of between 1% and 6% to allow for drainage of surface water
 - soil conditions suitable for digging latrines – not hard rock, not collapsing soils, some level of permeability
 - no risk of major flooding, landslides or other natural disasters
 - if populations have moved from areas free of vector-borne diseases such as malaria or dengue, then they should not be moved to areas where these are endemic
2. Working with site planners, map camp and identify sites for water points, ensuring households are within 500m of taps and that access is possible by truck if water trucking is the initial option for water supply. Sites should also allow easy access for the population and take into consideration issues that could impact vulnerable groups in the siting of water points (not just technical issues) - see point A1 on the previous page.
 3. If population is present or can be contacted, consult population on collection times, quantities of water required and preferred siting of water points, ensuring space for drainage of wastewater.
 4. Identify key public institutions that would require water storage and distribution – health facilities, schools, day care or early child care centers, etc.

5. Depending on water quality, define water treatment process for the camp, using the module on Water Treatment and Ministry of Health Guidelines for Water Quality.
6. Using the design parameters and instructions of the Technical Guideline for Drinking Water Distribution Networks, sections 2 to 5, design a distribution network. Coordinate with the site planners to ensure that where people will be initially settled, the water points are available first, so that the water supply can be rolled out, matching the setting out of the camp.
7. For a long-term camp, the pipes will need to be trenched. All pipework will need to be protected, especially for road crossings. Ensure plans are drawn of the as-built water supply so that any further work to the camp (such as new buildings for schools, new roads etc.) do not cut pipelines.
8. Design the system as far as possible to be fed by gravity. This could mean all the supply is gravity fed from a supply above the camp (such as a spring) or, the water should be pumped from the water source to water tanks set at the highest point in the camp and gravity fed to the water points. The worst case would be where some parts of the camp have water pumped to them from storage tanks. See figure below:



Stages	Water abstraction and pumping	Raw water storage	Pre-treatment (such as roughing filtration)	Coagulation / Flocculation / Sedimentation or Sand filtration	Chlorination	Storage	Distribution

Adapted from Engineering in Emergencies, Davis and Lambert, Practical Action Publishing, 2002

9. It is important that the treatment process is defined at this stage so that the number of treatment tanks is designed for. Remember that the treatment is not instantaneous and will take time, both for the treatment process (up to 8 to 12 hours for flocculation and 30 minutes for chlorination) and for allowing the treated water to flow by gravity between treatment processes e.g. from flocculation to chlorination.
10. Calculate number of taps required at each location (considering maximum flow rate at peak hours, and ratio of 250 people per tap)

11. Ensure storage has a volume to store a minimum of 1 day's supply, if the supply is likely to be unreliable, a larger storage of up to 3 days might be more suited. Calculate volume available at final treated water storage to allow for peak demand of up to 60% of total daily demand in 4 morning hours.
12. For installation of bladder or onion tanks see Annex 6.23, for setting up Oxfam tanks and similar longer term storage see Annex 6.24.
13. Ensure all tapstands have drainage and soakaway pits designed for them, ensuring the pits are adequate for the permeability of the soil. Access to the tapstands for people with restricted mobility, children and women needs to be considered. Where there are steep slopes, steps would be important to put in, ensure they are not too narrow. Access for wheelchair users is also important to consider. Narrow access paths should be avoided, such as stepping stones over areas of poor drainage which can be an area where women and adolescent girls are harassed by men as they pass by each other. It is important to discuss with women, adolescent girls, children and disabled people their concerns about access.

Consider the height of the tapstands and the type of taps for children to use them. Taps should be positioned a little higher than the tallest water container used, but need also to be a height that children and people with reduced mobility can also use them easily. Using more robust taps (3/4" rather than 1/2" taps) also reduces the likelihood that they will get broken. Some taps, especially under high water pressure, are difficult for children to open and this must be checked and rectified.

A pedestal, about 45cm high, built close to the tapstand will allow children and others to lift their full water container half way and rest, before putting it on their head or wheelchair.

14. Set up water quality monitoring and testing at distribution points. Train operators to measure the level of chlorination to ensure that the water supply meets the water quality standards of 0.2 mg/l at the household after 24 hours; and hence 0.5 – 1.0 mg/l at any point of distribution (tapstand, from a tanker or donkey cart) – both before and during an outbreak (using a pool tester or similar) and to record the amount of water supplied.
15. For each water point, there needs to be a Water Management Committee (WMC) to operate and maintain the water point, record deliveries and to help in hygiene promotion. The Village Health Committee, if operational, would be a good option.
16. Carry out hygiene promotion including focus on safe water chains (collection, handling or transport, storage). Place signage that water is safe for drinking around water points. Hygiene promotion could also address issues of odor, taste and color of water if people are not used to changes in these.

Annexes

Annex 2.1 Basic Hygiene Kit and Full Hygiene Kit

Basic Hygiene Items

10–20 litre capacity water container for transportation	One per household
10–20 litre capacity water container for storage	One per household
250g bathing soap	One per person per month
200g laundry soap	One per person per month
Acceptable material for menstrual hygiene, e.g. washable cotton cloth	One per person

(taken from SPHERE Handbook 2011)

Full Hygiene Kit for family of 5 for 2 months

Description (core items)	Unit	Qty
Bucket with lid and tap, or solid jerry can, 20L	Pce	1
Collapsible Jerry Can, 10L	Pce	1
Soap, 125g bars	Pce	20
EITHER: Sanitary towels, packet of 10	Pkt	4
OR: Towel/cloth, 2m, washable absorbent cloth, dark coloured (as appropriate to culture)	Pkt	2
Aquatabs, 67mg	tabs	60
Bath towel, cotton, min 300 GSM, 50x80cm	Pce	2
Comb, plastic	Pce	2
Mirror, handheld, plastic cased for safety, 10cmx10cm	Pce	1
Razors, disposable, plastic, safety type	Pce	5
Safety pins	Pce	10
Shampoo, 500ml bottle	Pce	1
Soap box, plastic, boilable	Pce	1
Soap, laundry 250g powder	Pce	5
Toilet paper, pack of 6 rolls	Pkt	2
Jug, plastic water container, 2L (as appropriate to culture)	Pce	2
Toothbrush, adult size	Pce	2
Toothbrush, child size	Pce	3
Toothpaste, 150g	Pce	2
Washable baby diaper	Pce	12
Antiseptic cream 75ml	Tube	1
Disinfectant liquid 500ml	Bottle	1
Female underwear, pair, plain	Pce	2
Folded length of cloth, 1x2m (as appropriate to culture)	Pce	2

NOTES

Full description:

This is a full hygiene kit designed to provide materials to support basic levels of hygiene for a family of five, for 2 months. Note that consumable items are only designed for a two months supply and will then need to be replaced. Note also that this, or a simpler Basic Hygiene Kit, could also be assembled in country.

(taken from Save the Children – Standard Products Catalogue, December 2013)

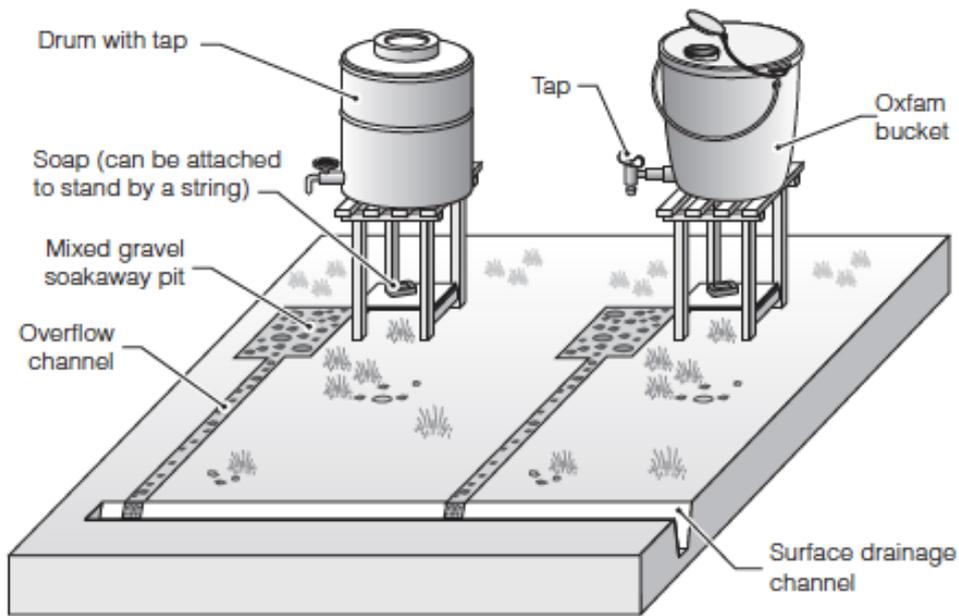
Annex 3.1 Bill of Quantities for Communal Pit latrine (4 block)

from *Excreta Disposal in Emergencies*, P Harvey, 2007 WEDC Publication

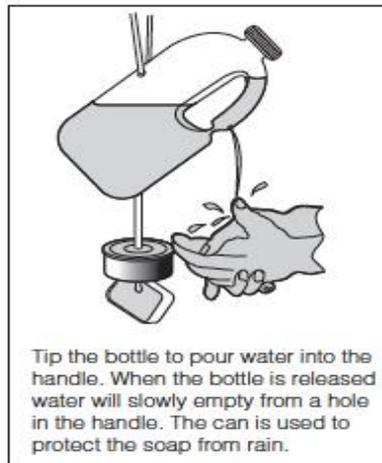
Dimensions	Length (m)	Width (m)	Depth (m)
Excavation of trench	4.00	0.80	2.00
Superstructure	Unit	Quantity	Linear metric length (m)
Timber 50 x 50 x 2300mm RT	front post	5	11.50
Timber 50 x 50 x 2100mm RT	back post	5	10.50

Dimensions	Length (m)	Width (m)	Depth (m)
Timber: 50 x 25 x 1200mm RT	cross tie	5	6.00
Timber: 50 x 25 x 1800mm RT	diagonal tie	5	9.00
Timber: 75 x 25 x 4000mm RT	long tie (bottom)	2	8.00
Timber: 75 x 25 x 4000mm RT	long tie (top)	2	8.00
Galvanized-wood nails 2"	No.	40	
Galvanized-wood nails 1"	No.	186	
Bottle tops or folded plastic pads	No.	226	
Plastic sheeting (2m wide x 1m long)	walls	10	10.00
Plastic sheeting (2m wide x 1m long)	door	4	4.00
Slab and supports			
Timber: 15 x 100 x 4000mm RT	support planks	2	8.00
Wooden Slab: 1m x 1.2m	slab	4	
Roof			
Timber: 38 x 50 x 1800mm RT	rafter	5	9.00
Timber: 25 x 25 x (4000+400) mm RT	purlin	3	13.20
Plastic sheeting (2m wide x 1m long)	roof	4.8	4.80
Bottle tops or folded plastic pads	No.	86	
Galvanized-wood nails 1"	No.	86	
Privacy screen (optional)			
Timber 50 x 50 x 2300mm RT	posts	5	11.50
Plastic sheeting (2m wide x 1m long)	screen	8	8.00
Bottle tops or folded plastic pads	No.	52	
Galvanized-wood nails 1"	No.	52	

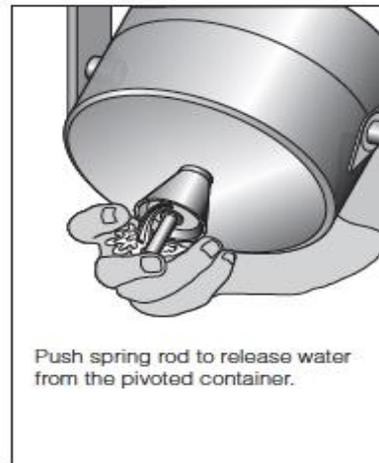
Annex 3.2 Handwashing Options



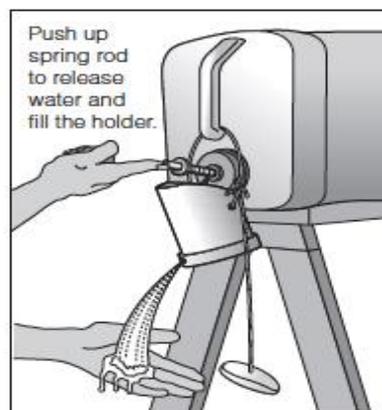
Handwashing drawings taken from *Excreta Disposal in Emergencies*, P Harvey, 2007 WEDC Publications



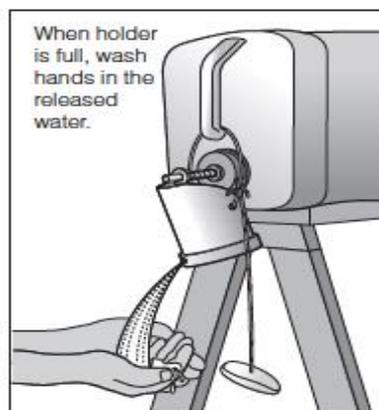
The Tippy Tap



The Handy Andy



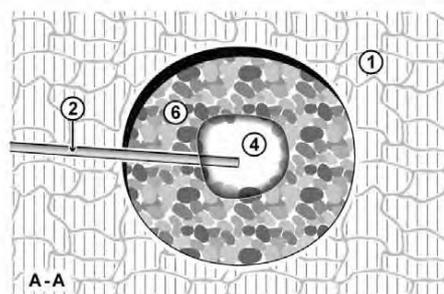
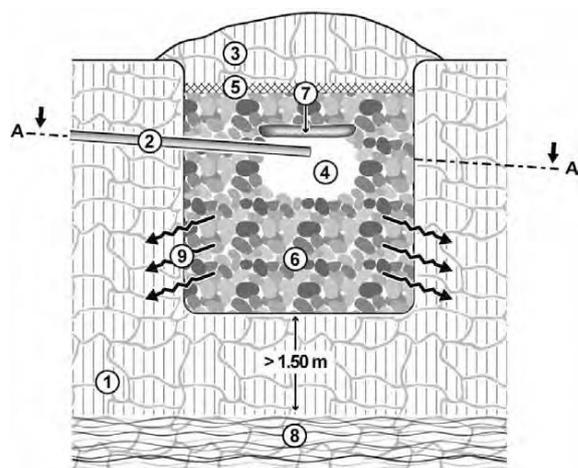
The Captap - Stage 1



The Captap - Stage 2

Annex 3.3 Soakaway

Large stone-filled pit, topped with plastic sheeting and earth to allow wastewater to percolate into the sides and base of the pit. Useful for water point wastewater or kitchen, clothes or shower washing wastewater after a grease trap.



Key	Input
1. Permeable soil	- Tape measure
2. Incoming pipe (min. diameter 100 mm)	- Shovels, hoes, picks and miner's bars
3. Compacted earth	- Wheelbarrow
4. Cleared space at the end of the pipe	- Pipe, minimum 100 mm diameter, in PVC or cement
5. Geo-textile or perforated plastic sheeting	- Geo-textile or plastic sheeting
6. Clean stones (boulders)	- Stones (0.05 – 0.15 m diameter)
7. Flat stone or concrete slab	- Temporary fence material
8. Water table	- Reinforcing bar or ½" galvanised pipe and hammer
9. Wastewater infiltrating in the soil	

From Public Health Engineering in Precarious Situations, MSF, 2010

Calculations for Soakaway Pit:

Calculate the volume of pit required for a soakaway pit using the following:

- 1 - Calculate the surface area of pit wall required to infiltrate the wastewater.

Pit wall area (m²) = daily wastewater flow (litres) / soil infiltration rate (see table 1)

2 - Choose a pit diameter

3 – Calculate the depth required to dispose of all liquids

Depth of pit required = pit wall area / (π x pit diameter)

4 – Add 0.5m to depth to allow for soil covering above active pit

Table 1: Soil Infiltration rates for clean wastewater – pretreated through grease trap or septic tank

Soil type	Description	Infiltration rate litres/m ² /day (mm/day)	
		Clean water	Wastewater
Gravel, coarse and medium sand	Moist soil will not stick together	1,500-2,400	50
Fine and loamy sand	Moist soil sticks together but will not form a ball	720-1,500	33
Sandy loam and loam	Moist soil forms a ball but still feels gritty when rubbed between fingers	480-720	24
Loam, porous silt loam	Moist soil forms a ball which easily deforms and feels smooth between fingers	240-480	18
Silty clay loam and clay loam	Moist soil forms a strong ball which smears when rubbed but does not go shiny	120-240	8
Clay	Moist soil mould like plasticine and feels very sticky when wetter	24-120	Unsuitable for soak pits

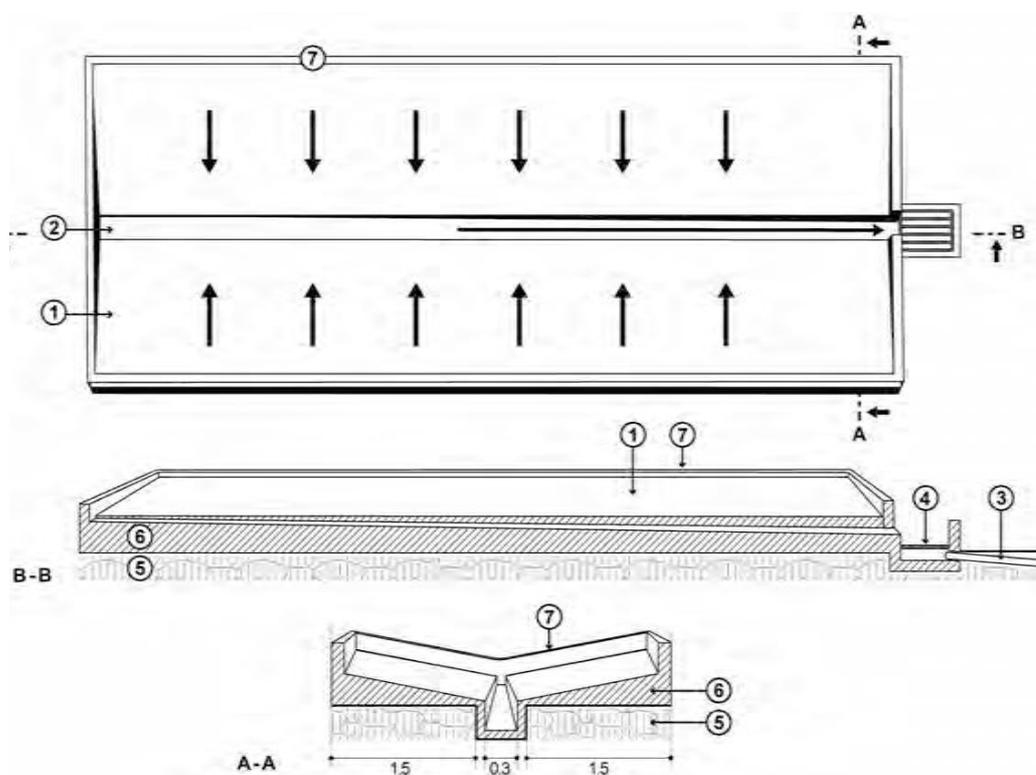
From Reed, R and Dean, P.T. (1994) Recommended methods for the disposal of sanitary wastes from temporary field medical facilities. Disasters, Vol 18, No.4

Annex 4.1 WASH Slabs and Showers

1 Wash slab

Key	Input
1. Washing slab (sloping towards drainage channel, maximum 4%)	- Shovels, hoes and picks
2. Drainage channel (1.5% slope)	- String line, sticks and tape measure
3. Drainpipe towards grease trap and final disposal	- Spirit level
4. Collection box with grid	- Plastic sheeting or jute sacking
5. Soil (possibly covered with sand / gravel or plastic)	- Sand, cement and gravel
6. Lean concrete slab	- Clean water
7. Protective kerb	- Fired bricks or cement blocks
	- Trowel, float, cement-mixing trough
	- Roof material and tools
	- Temporary and permanent fencing material

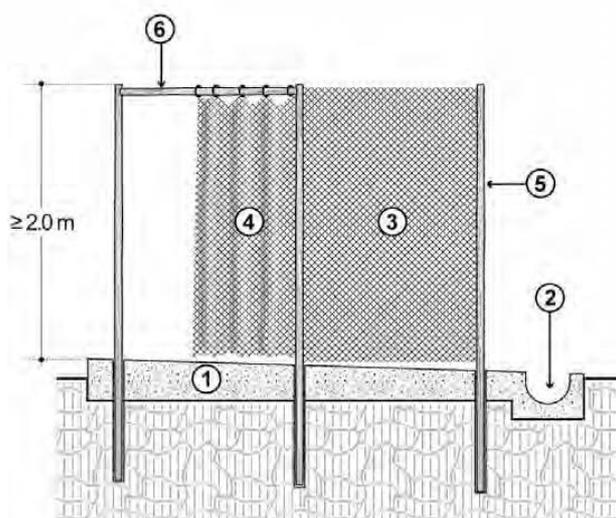
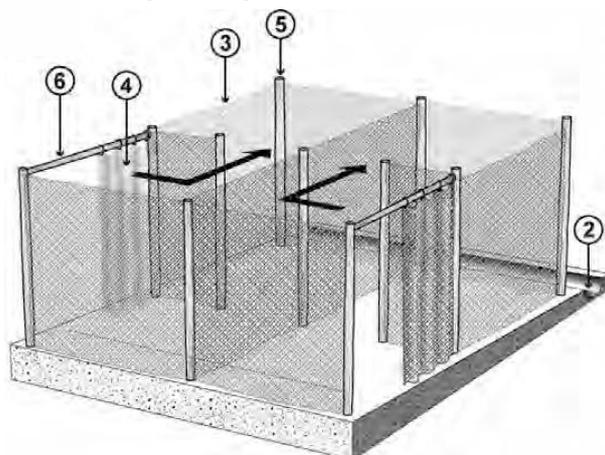
Measurements (in m) are indicative and have to be adapted according to the context.



from Public Health Engineering in Precarious Situations – MSF 2010

Annex 4.2 Shower Details

From *Public Health Engineering in Precarious Situations, MSF 2010*



Key

1. Shower slab (1 to max 4% slope)
2. Drainage channel (1.5% slope) leading via a grate and grease trap to an infiltration / disposal system
3. Superstructure (e.g. non-transparent plastic)
4. Entrance of the shower (curtain)
5. Strong poles (possibly connected diagonally)
6. Curtain support

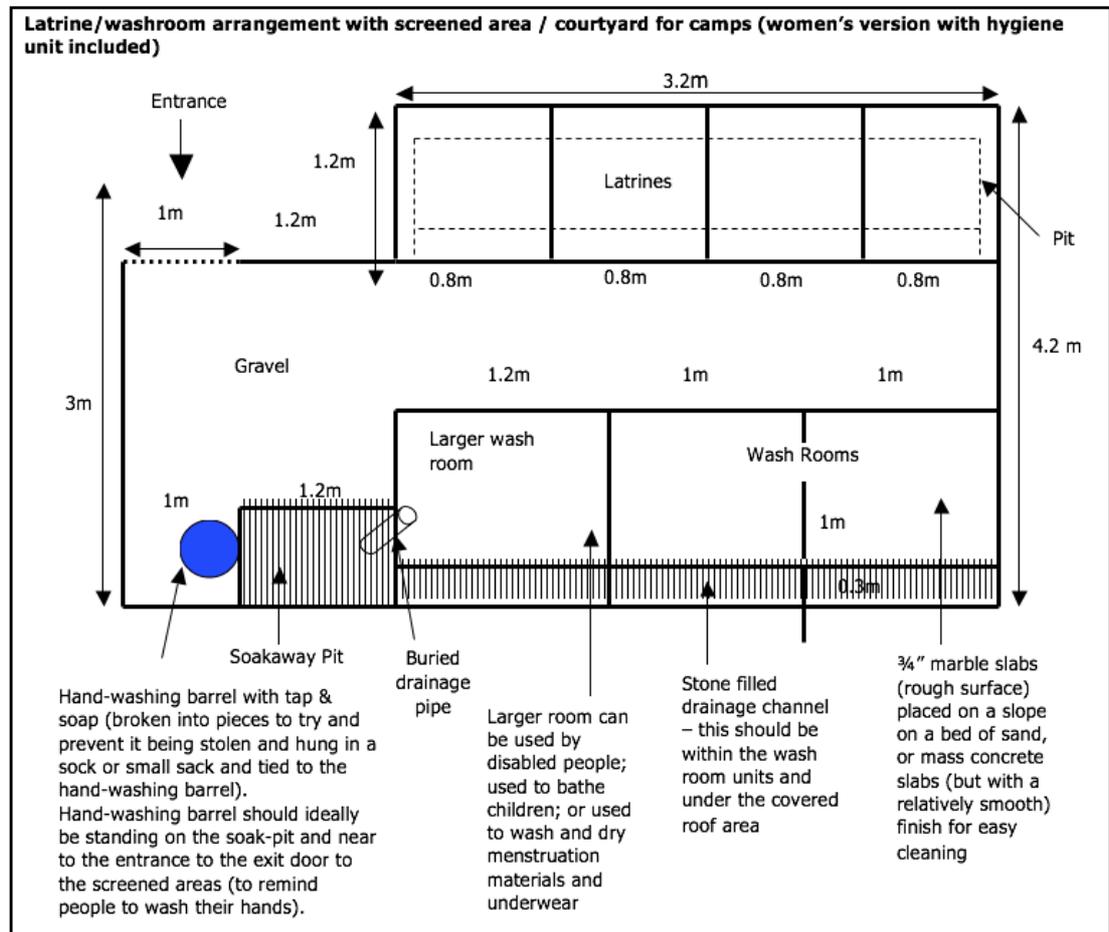
Dimension (in m) is indicative and has to be adapted according to the context

Input

- Shovels, hoes and pick
- String line, sticks and tape measure
- Spirit level
- Plastic sheeting or jute sacking
- Sand, cement and gravel
- Clean water
- Casing material (wooden planks)
- Trowel, float, long flat lath
- Plastic pipes (PVC)
- Poles, plastic sheeting or local waterproof material
- Big and small hammer
- Nails and rope
- Temporary and permanent fence material

Annex 4.3 Screened Hygiene Unit - Private Latrine and Shower Block

(adapted from *Excreta Disposal in Emergencies, A Field Manual*, P. Harvey et al, WEDC, 2007)



Notes:

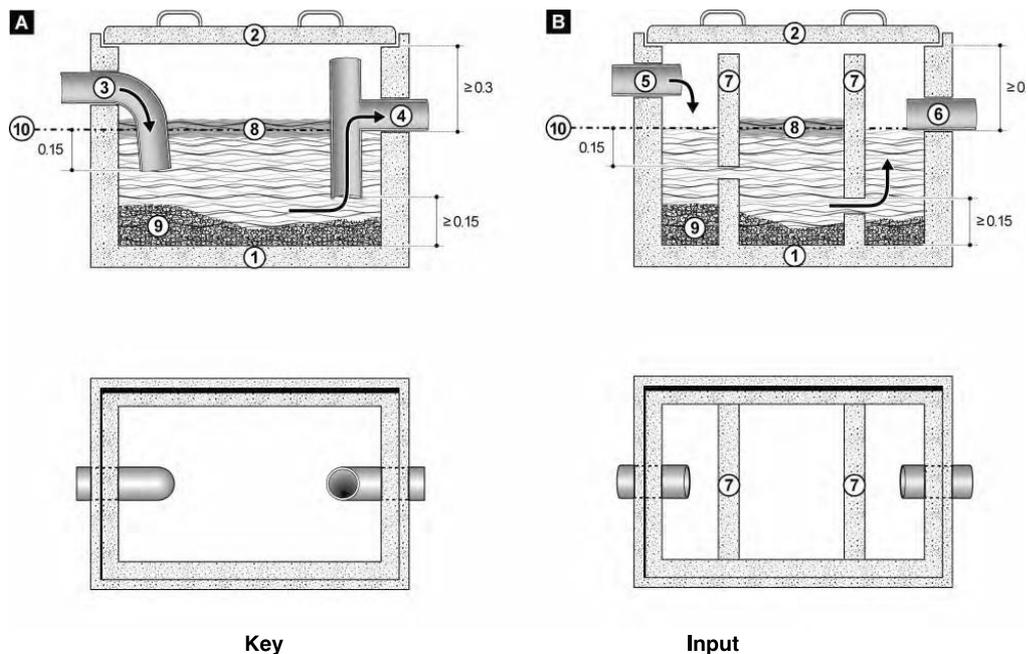
- It is very important to discuss with women and girls if they would like any modifications to help them wash private items such as underwear or menstrual hygiene materials, or to make the facility more usable or safer to use.
- A clothes washing area could be added inside each screened area for both male and female blocks, large enough to do clothes washing.
- Women and girls may appreciate a larger washing unit to be able to wash private items including menstrual materials. But also both men and women may appreciate a larger unit to be able to take in small children to bathe them. People with disabilities also often find larger units easier to use.

Annex 4.4 Bill of Quantities for Women's Hygiene Unit

Detail	Unit	Quantity
Wooden posts 50 x 50 x 2400mm	No.	14
Wooden posts 50 x 50 x 2100mm	No.	9
Wood 50 x 25 x 2400mm – used for cross bars and bracings for latrines, bath units and screens	No.	36
Wood 150 x 50 x 1600mm – wooden frame for supporting the latrine slabs at the top of the pit	No.	9
Small gravel chippings – no fines – for the ground surface, the stone drain for bath units and the top of the soakpits	m ³	0.6
Large stones / rocks for filling soakpit	m ³	1.2
Tarpaulin / plastic sheeting (thick, ideally coloured / not white, with fabric weave where possible)	m ²	100
'Washels' (washers to use with standard 2" nails – could be replaced with roofing nails, or rubber washers)	kg	3
Nails 3"	kg	1
Nails 2"	kg	5
Nails 1"	kg	1
Binding wire – for door locks and additional bracing for screen if required	kg	2
Sand – for bedding to form the slope for the marble bathing slabs and for constructing the edging for the hygiene unit	m ³	0.5
0.8m x 1.2m Oxfam slabs (produced in India)	No.	4
1.0m x 1.2m x 20mm (¾") marble sheets – with rough surface – for bath units and base of hygiene unit	No.	3
Cement – for plastering brick edges to hygiene unit and forming connection to uPVC pipe outlet	25kg bag	0.5
Burnt bricks – for constructing edging for the hygiene unit to direct water into the pipe	No.	30
90mm (3") UPVC pipe	metre	0.5

Annex 5.1 Wastewater Facilities

Grease traps remove floating grease, oil and fats and some solids from the wastewater which would otherwise clog the soil of the disposal unit. They are typically placed after the wastewater generating facility (shower etc.) and before any disposal method. Simple grease traps can be made from oil drums cut lengthwise.



- A. Model with elbow and tee
B. Model with baffles

1. Watertight casing
2. Removable lid with handles (each element < 50 kg)
3. Inlet elbow, 90°
4. Outlet tee
5. Inlet
6. Outlet
7. Separating partitions (baffles)
8. Middle zone (separation of fat, grease and oil)
9. Settled solids
10. Reference line indicating effective depth (max. water level)

- Detailed construction plans
- Fired bricks or cement blocks / concrete
- Cement, sand, (gravel), clean water
- Shuttering timber
- Reinforcing bars (6 – 8 mm)
- Shovel, hoe, pick and miner's bar
- Masonry tools
- Minimum 100 mm PVC pipe, or elbow and Tee
- Cover (e.g. concrete, metal, solid plastic)
- Temporary fence material

Measurements are indicated in m

From Public Health Engineering in Precarious Situations, MSF, 2010

Annex 6.1: Key Information Checklist Regarding the Water Source

(adapted from Emergency Water Sources, Guidelines for Selection and Treatment, S. House, R. Reed, WEDC, 2004)

Much of the following information requires a mixture of sources – key informants will include staff from the Drinking Water and Sanitation Unit (DWSU) and Ministry of Health, teachers, imams and Mahalia leaders, other development and humanitarian agencies working in the area as well as university staff.

It is vital to interview the local population, especially women, children, disabled and the elderly to both ensure their knowledge is included in assessments but also to ensure that communities are involved from the earliest stages in decision-making, planning, implementation and monitoring of any water source improvements.

The following figure provides an overview of the considerations that are needed when selecting a water source. Details of each are elaborated in the checklists which follow.

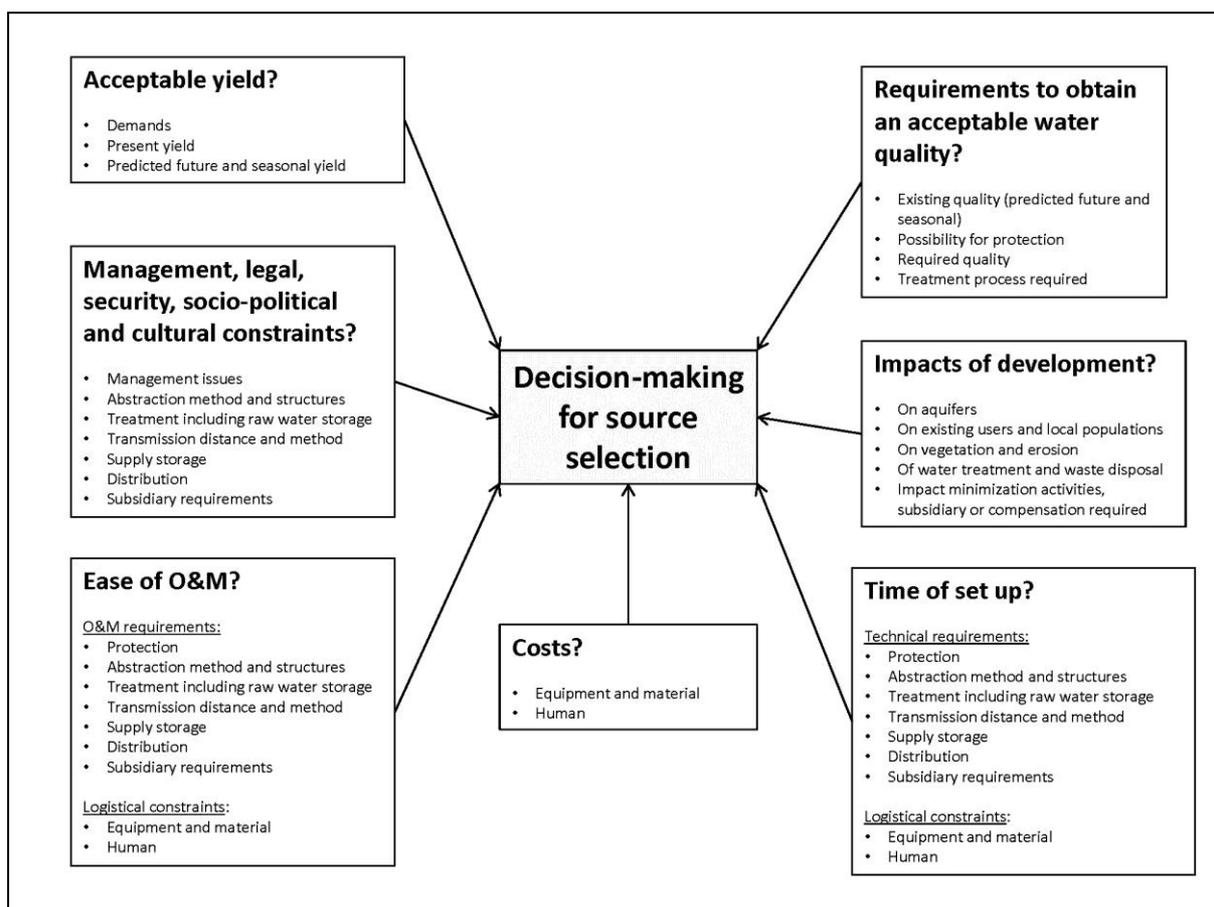


Figure from Emergency Water Sources: Guidelines for Selection and Treatment, S. House and R. Reed, WEDC 2004

A - Background information

- Maps (topographic, geological, road, hydrogeological, demographic, land-use, rainfall)
- Aerial photographs / Landsat images
- Regional details
 - Climate (including rainfall data)
 - Industrial and agricultural practices
 - Populations (culture, religion)
 - Economy
 - Political situation
 - Exchange rate
- Previous surveys / studies (organizations' database or library)
- Other agencies working in the field
- Structure of government and local government (including which store information and which make decisions)
- Contacts in key departments (water and sewerage, water resources, planning, surveying, meteorological)
- National policies and development projects
- Existing national emergency plans
- Capacity of the government to cope with the water demands of the affected population
- Background to the crisis and projected developments

B - Settlement orientation

- Boundaries, present sub-divisions (including ethnic or clan divisions), possible areas for expansion (include distances)
- Population density where settlements are dispersed or mobile
- Slope of ground (and existing drainage)
- Water sources (and areas susceptible to flooding and other physical threats)
- Areas with buildings / shelters, open spaces and communal areas
- Access roads
- Sanitation facilities including excreta disposal, refuse dumps / collection areas and graveyards
- Administration centers
- Chemical stores
- Lighting
- Security arrangements

C - Demographics, present water usage and water demands

- Water user numbers — affected population:
 - Individuals
 - Livestock large and small (and average number per family)
 - Other users / uses **if specific supply is within remit:** e.g. health centers (in-patient, out-patient and cholera centers); feeding centers
- Water user numbers — local population:
 - As affected population (above) up and downstream
 - Industries and agriculture
- Present water source (type, location, level of service, distance to collection point).
- Current water consumption (it is important to ask women (especially pregnant women and mothers of new-borne children), children, the elderly and disabled people what their water consumption needs are as these might be larger than other parts of the community)
- Does the affected population have adequate containers for water collection? Smaller containers of 10 to 13 liters might be more suitable for children collecting water.
- How long do people take to collect water?
- When are the peak periods for collecting water? Does there need to be extra storage to ensure the greater demands during peak periods can be met?
- Are the populations static or mobile?
- Diseases prevalent in the local and affected populations (e.g. cholera, dysentery, typhoid, malaria, fluorosis, diarrhea to those new to the area, skin diseases)

D - Features of the source (excluding water safety/quality)

Physical features including yield

- Source name / number, type and location
- Ground and water level (note instrument used for measurement)
- Layout / dimensions
- Yield estimation: (volumes / flows, variation with season, recharge capacity)
- Discharges (in and out; where are they from and where do they go)
- Environmental features of the area surrounding the source (river bed materials; plant and tree cover; activities such as farming or industries)
- Is the source affected by extreme weather conditions (e.g. below 0°C)?

Management, legal, security, socio-political and cultural issues

- Present demands (who, what for, how much, is there competition with animals)
- Are there intermittent users such as nomads
- Who owns the land and what is the procedure to obtain permission to abstract
- Responsible authority for control and maintenance
- Is a tariff being charged for using the source (paid to whom and how much)
- Accessibility at present for water collection (can elderly, children, or those with disabilities gain easy access to the source?)
- Security problems at the source (especially consider women and children and opposing groups in conflict situations)
- Do women, adolescent girls or children feel insecure when collecting water, are there

sources they would prefer to use?

- Are any areas mined?
- Socio-political constraints to using the source and cultural beliefs re: water provision

- Consider national development objectives
- What are the affected populations' and local populations' priorities for water provision?
- Natural threats within the vicinity of the source (cyclones, earthquakes, mudslides, etc.)
Is there water committee, if yes what is the legal status. Do they collect money, where they deposit, who audits the account? What is the gender make-up of the water committee, both in terms of percentage women (and older children) and also of roles they have?
- How does the committee link to SWC?
- Do SWC regulations allow community participation in water facilities management and related decision-making?

E - Water Safety/Quality

- The quality of the water at present
- Existing protection and potential for improved protection of the source
- Predicted variations in water quality in the future and pollution risks
- Refer to the SSMO standards 2016 for parameter levels and the Federal Ministry of Health in the Manual of Environmental Health in Emergencies
- Wherever possible water samples should be taken and sent to water testing laboratories at State or Federal level for analysis, although this will require appropriate transport mechanisms to check that the parameters do not change in transit.
- Turbidity, pH, Total Dissolved Solids (TDS) and fecal coliforms can be tested at field level (see section 7.5 and Annex 6.21 in Water Treatment module for details) but wherever possible should also be verified by a laboratory.

F - Requirements for development of the source

- **Technical requirements:**
 - Protection requirements -
 - Protection of source structure from natural hazards (landslides)
 - Protection of source from pollution hazards
 - Protection of storage and distribution networks from natural hazards
 - Protection of storage and distribution networks from
 - Abstraction method
 - Groundwater – well, spring, borehole
 - Surface water – infiltration gallery, dam intake, lake, river
 - Rainwater – roof catchment, rock or artificial catchment, below ground storage,
 - Treatment requirements including storage:
 - Infiltration
 - Sedimentation
 - Roughing filtration
 - Assisted sedimentation

- Slow sand filtration
 - Rapid filtration
 - Disinfection
 - Activated carbon
 - Transmission distance and means of transmission
 - Pumps (electrical; diesel; petrol; hand pumps)
 - Generators (diesel; petrol)
 - Tanks (galvanized steel / iron; Oxfam tanks)
 - Pipes (cast iron; galvanized steel / iron; asbestos cement; UPVC; MDPE), diameter, lengths
 - Pipe fittings (valves, bends, air valves, couplings, etc.)
 - Supply storage
 - Size and type of tanks
 - Distribution requirements
 - Service levels – tapstands, yard taps, in house taps
 - Subsidiary requirements (e.g. road construction; threat mitigation activities)
 - Consider standardization with existing systems in-country as support to national development objectives
- **O&M requirements (human and consumables):**
 - O&M human resources
 - O&M consumables
 - **Resources / logistics:**
 - Material and equipment requirements
 - Human resource requirements
 - Logistical requirements
 - **Costs:**
 - Costs for capital and O&M (materials, equipment, human resources, logistics)
 - **Time of set-up:**
 - Total time for system to be up and running (technical requirements versus resources / logistics and other constraints)
 - **Ease of O&M**
 - O&M requirements versus resources / logistics and other constraints

G - Impacts of development

- **Effects of source development on the aquifer and remote sources:**
 - Location and capacity of aquifers
 - Which sources are fed from the same aquifers
- **Effects of development on existing users of the source and local populations at the point of abstraction and downstream:**

- Determine: yield of source at present, existing demands, new abstraction demand, remaining yield (dry season) and the effects on existing users
- Possible compensation for local communities up and downstream for the loss of yield or inconvenience. Also compare local and affected populations' supplies and consider upgrading local supplies to prevent friction
- Consider migration of people and animals / livestock to improved water sources (may be pronounced with nomadic populations)
- Effects on community structures / management capacity of organizations and populations
- What subsidiary / ancillary activities are required (training, road construction, sanitation, agricultural extension, hygiene promotion, etc.)?

- **Effects on vegetation and erosion:**

- Change in yield
- Effects of abstraction on vegetation and erosion and potential actions to minimize effects
- Effects of migration to improved water sources on vegetation and erosion

- **Effects of water treatment and waste disposal:**

- Increase in waste water — how will it affect levels of standing water
- How will chemicals and fuel for water treatment be stored (location, security)?
- How will waste chemicals be disposed of?
- How will the sludge produced during treatment be disposed of?

H - Availability of resources / logistics

Logistics

- Condition of roads in the dry and rainy seasons (major access roads; minor access roads; internal settlement roads; road crossings)
- Flooding and other physical threats (settlement areas; access roads)
- Security (on access roads and within settlements). Which groups are causing the security problem? How common are guns in the area?
- Access to international freight (airstrips; ports; railways; road links)
- Customs clearance (import taxes, procedures, problems, delays)
- Availability and reliability of freight transporters
- Journey time for freight

Resources

- **Materials and equipment** (type; make; size; condition; capacity; power consumption; fuel requirement; cost; volume / number available; availability of drivers / operators):
 - Pumps (electrical; diesel; petrol; hand pumps)
 - Generators (diesel; petrol)
 - Tanks (galvanized steel / iron; Oxfam tanks)
 - Pipes (cast iron; galvanized steel / iron; asbestos cement; UPVC; MDPE)
 - Pipe fittings (valves, bends, air valves, couplings, etc.)

- Construction materials and tools (cement; reinforcement steel and tying wire; gabion mesh; aggregate; sand; construction hand tools; masonry hand tools; nails / screws; timber; cement mixer)
- Drilling rigs (rotary, percussion)
- Chemicals (chlorine; Polyaluminium Chloride (PAC); aluminum sulphate; ferric chloride; ferrous sulphate; lime)
- Fuel / power (diesel; petrol; electricity)
- General usage transport (pick-ups; small lorries or vans)
- **Human resources** (names; point of contact; employer; numbers):
 - Tradespeople: plumbers; mechanics; electricians; carpenters
 - General construction personnel and supervisors
 - Water technicians / engineers
 - Hygiene promoters/health educators / community development workers
 - Logisticians
- **Local construction techniques** (details):
 - Well construction (hand dug well, tube well)
 - Spring tapping
 - Borehole drilling (are the drilling teams available with rigs?)
 - Pipe laying and joining
- **Water treatment processes used locally:**
 - Infiltration
 - Sedimentation
 - Roughing filtration
 - Assisted sedimentation
 - Slow sand filtration
 - Rapid filtration
 - Disinfection
 - Activated carbon

Key Sources of Information will be as follows:

Information	Source of information	Method of Collection
Physical features, settlements	State level Government Ministries, Maps, internet Local and affected populations	Key informant interview (KII), secondary data collection, KII
Demographics, water use	Other humanitarian agencies, State level Ministries Local and affected populations, especially vulnerable groups (elderly, disabled, women and children) Observations	KII Formal and less formal focus group discussions (FGD), health staff, teachers
Logistics and Resources	Suppliers, Other humanitarian agencies, State level ministries	KII
Water Source physical features	Observations, calculations, risk assessment Local population State level ministry records	Measuring flow, testing, mapping catchment (see Annex 6.2 Catchment Mapping), sanitary survey KII KII
Management of water source	State level ministries Observation Local populations	KII KII

Annex 6.2: Catchment Mapping

(taken from Emergency Water Sources, Guidelines for Selection and Treatment, S. House, R. Reed, WEDC, 2004)

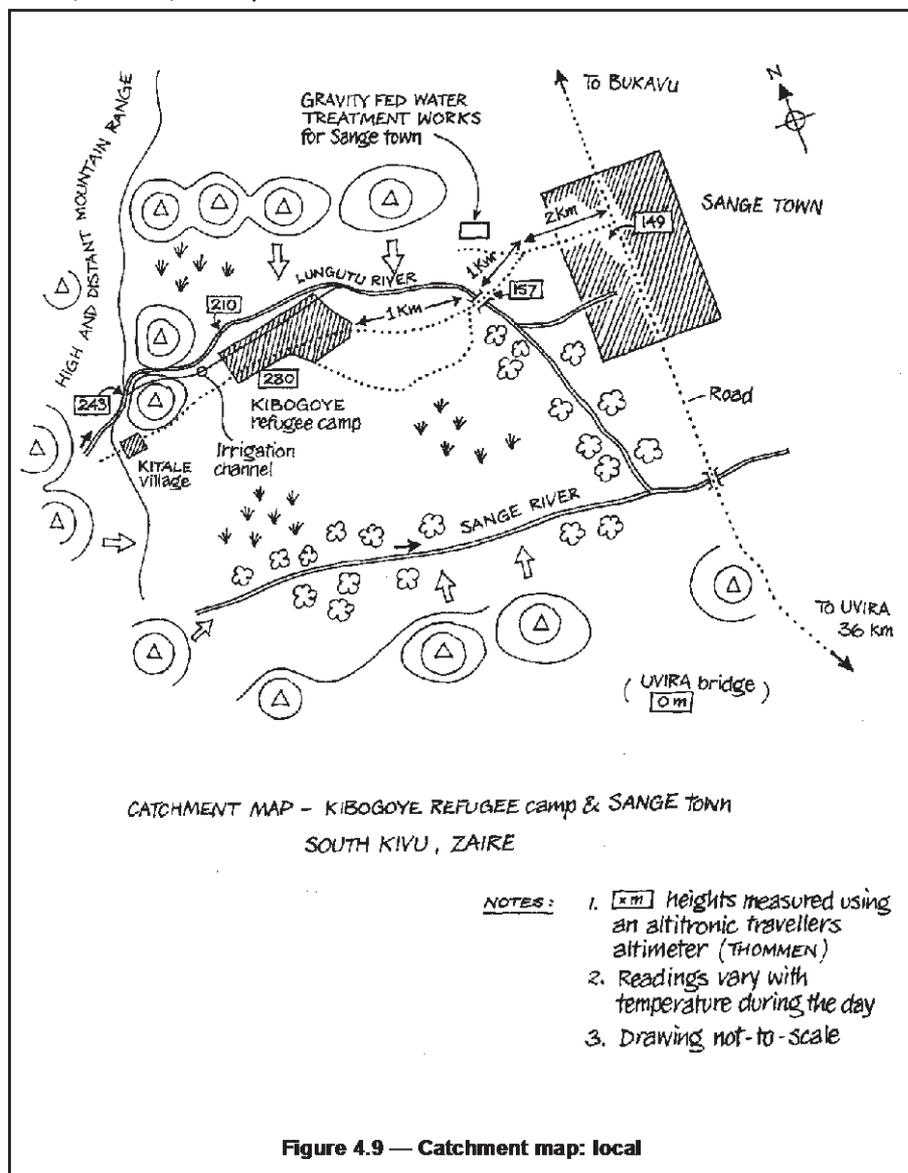


Figure 4.9 — Catchment map: local

Catchment mapping involves the mapping of all of the features in a catchment area or in a region which may include several catchment areas. Features to be highlighted by mapping include:

- Physical features (high and low areas, vegetation, water sources)
- Human features (settlements, industry, agriculture, roads)
- Distances between users and water sources
- Distances and approximate heights between features
- Rock and soil types (if known)

The maps are used for orientation in the area, the location of salient features, and the prediction of potential pollution pathways.

Type of Facility: OPEN DUG WELL

Name of Health Post -----

Village name and location of well -----

Date of Visit:.....

Water Sample taken? Sample No. Thermotolerant Faecal Coliform present?.....

Questions to be asked during survey:

- | | |
|--|-----|
| 1. Is there a latrine within 30 m of the well? | Y/N |
| 2. Is the nearest latrine on higher ground than the well? | Y/N |
| 3. Are there any animal excreta or rubbish within 15 m of the well? | Y/N |
| 4. Is the drainage poor, causing stagnant water within 2 m of the well? | Y/N |
| 5. Is the drainage channel broken allowing a pool of water to form? | Y/N |
| 6. Is the wall around the well inadequate, allowing surface water to enter the well? | Y/N |
| 7. Is the concrete floor less than 1.5 m wide all around the well? | Y/N |
| 8. Are there any pools of water on the concrete floor around the well? | Y/N |
| 9. Does the concrete floor around the well have any cracks that could let water in? | Y/N |
| 10. Are the rope and bucket left in such a position that they may become contaminated? | Y/N |
| 11. Are the walls of the well poorly sealed at any point for 3 m below ground level? | Y/N |

Total Score of Risks...../11

Contamination Risk Score: 9-11 Very high, 6-8 High; 3-5 Intermediate; 0-2 Low

Results & Recommendations

The following important points of risk were noted (list no.s 1 -11) and the authorities advised on remedial action.

Name -----

Signature -----

Type of Facility: DUG WELL WITH HANDPUMP

Name of Health Post -----

Village name and location of well/handpump -----

Date of Visit:.....

Water Sample taken? Sample No. Thermotolerant Faecal Coliform present?.....

Questions to be asked during survey:

- | | |
|--|-----|
| 1. Is there a latrine within 30 m of the well and handpump? | Y/N |
| 2. Is the nearest latrine on higher ground than the handpump? | Y/N |
| 3. Are there any animal excreta or rubbish within 15 m of the handpump? | Y/N |
| 4. Does the drainage channel contain stagnant water within 2 m of the handpump? | Y/N |
| 5. Is the drainage channel broken allowing a pool of water to form? | Y/N |
| 6. Does the wall or fencing around the handpump have any breaks that would allow animals in? | Y/N |
| 7. Is the concrete floor less than 1.5 m wide all around the handpump? | Y/N |
| 8. Are there any pools of water on the concrete floor around the handpump? | Y/N |
| 9. Does the concrete floor around the handpump have any cracks that could let water in? | Y/N |
| 10. Is the handpump loose at the point of attachment to the base which could let water enter the casing? | Y/N |
| 11. Is the cover of the well unhygienic (unclean)? | Y/N |
| 12. Are the walls of the well poorly sealed at any point for 3 m below ground level? | Y/N |

Total Score of Risks...../12

Contamination Risk Score: 9-12 Very high, 6-8 High; 3-5 Intermediate; 0-2 Low

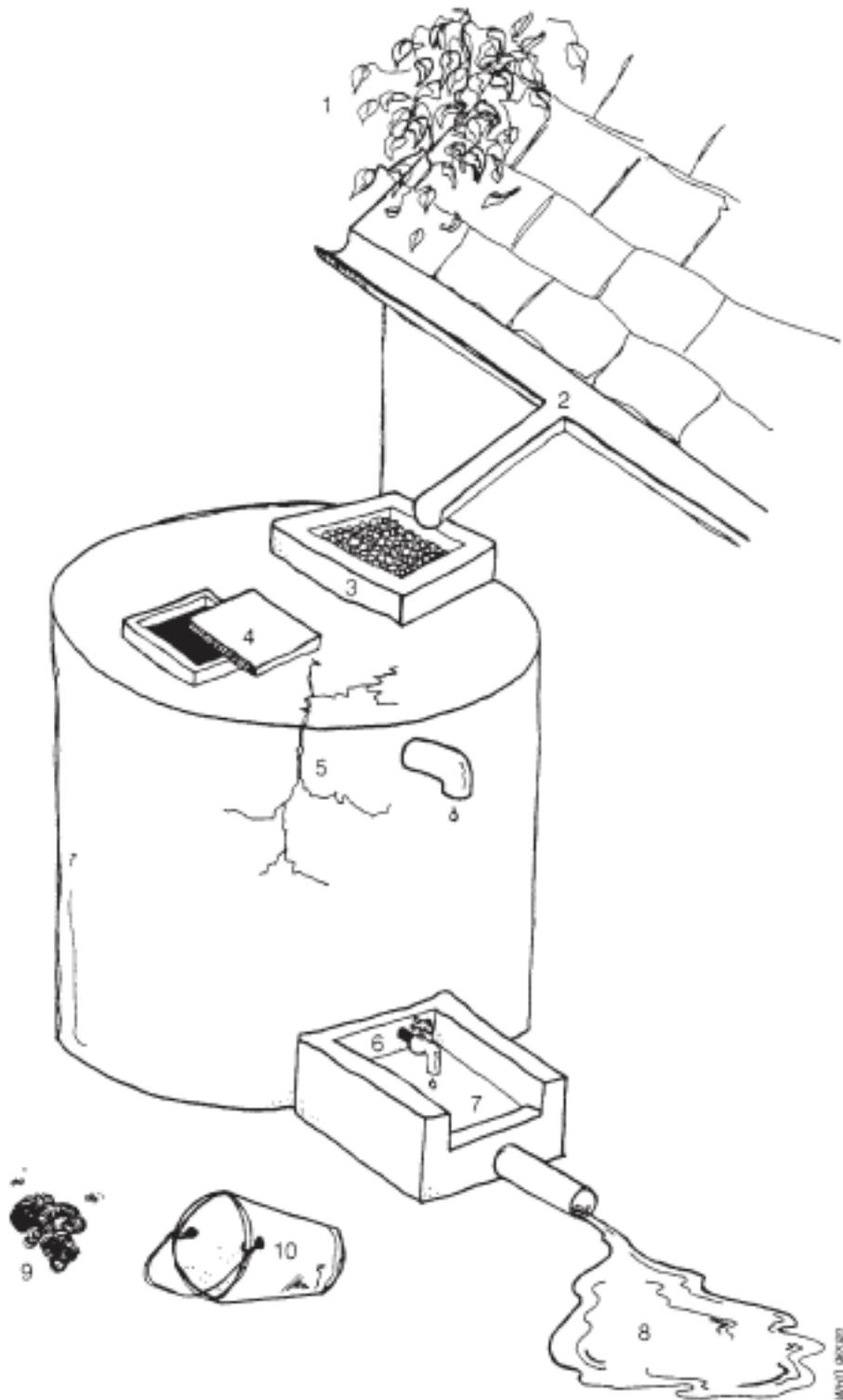
Results & Recommendations

The following important points of risk were noted (list no.s 1 -12) and the authorities advised on remedial action.

Name -----

Signature -----

3.3 - Sanitary Survey for Rainwater Collection and Storage



I Type of facility RAINWATER COLLECTION AND STORAGE

1. General information: Health centre
Village
2. Code no.—Address
3. Water authority/community representative signature
4. Date of visit
5. Water sample taken? Sample no. Thermotolerant coliform grade

II Specific diagnostic information for assessment Risk

- | | |
|---|-----|
| 1. Is there any visible contamination of the roof catchment area (plants, dirt, or excreta)? | Y/N |
| 2. Are the guttering channels that collect water dirty? | Y/N |
| 3. Is there any deficiency in the filter box at the tank inlet (e.g. lacks fine gravel)? | Y/N |
| 4. Is there any other point of entry to the tank that is not properly covered? | Y/N |
| 5. Is there any defect in the walls or top of the tank (e.g. cracks) that could let water in? | Y/N |
| 6. Is the tap leaking or otherwise defective? | Y/N |
| 7. Is the concrete floor under the tap defective or dirty? | Y/N |
| 8. Is the water collection area inadequately drained? | Y/N |
| 9. Is there any source of pollution around the tank or water collection area (e.g. excreta)? | Y/N |
| 10. Is a bucket in use and left in a place where it may become contaminated? | Y/N |
| Total score of risks /10 | |

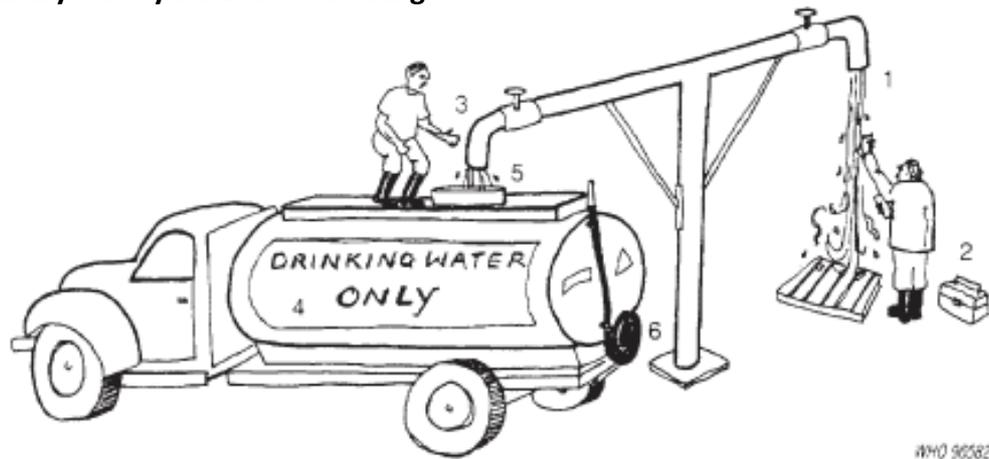
Contamination risk score: 9–10 = very high; 6–8 = high; 3–5 = intermediate;
0–2 = low

III Results and recommendations

The following important points of risk were noted: (list nos 1–10)
and the authority advised on remedial action.

Signature of sanitarian

3.4 - Sanitary Survey for Water Trucking



WHO 96582



WHO 96582a

I Type of facility FILLING STATIONS, TANKER TRUCKS, AND HOUSEHOLD TANKS

1. General information: Health centre
Village
2. Code no.—Address
3. Water authority/community representative signature
4. Date of visit
5. Water sample taken? Sample no. Thermotolerant coliform grade

II Specific diagnostic information for assessment Risk

Tanker filling stations

1. Is the chlorine level at the filling station less than 0.5 mg/litre? Y/N
2. Is the filling station excluded from the routine quality-control programme of the water authority? Y/N
3. Is the discharge pipe unsanitary? Y/N

Tanker trucks

4. Is the tanker ever used for transporting other liquids besides drinking-water? Y/N
5. Is the filler hole unsanitary, or is the lid missing? Y/N
6. Is the delivery hose nozzle dirty or stored unsafely? Y/N

Domestic storage tanks

7. Can contaminants (e.g. soil on the inside of the lid) enter the tank during filling? Y/N
8. Does the tank lack a cover? Y/N
9. Does the tank need a tap for withdrawal of water? Y/N
10. Is there stagnant water around the storage tank? Y/N

Total score of risks /10

Contamination risk score: 9–10 = very high; 6–8 = high; 3–5 = intermediate;
0–2 = low

III Results and recommendations

The following important points of risk were noted: (list nos 1–10)
and the authority advised on remedial action.

Signature of sanitarian

Type of Facility: DEEP BOREHOLE WITH MECHANICAL PUMP

Name of Health Post/Village ----- Code no./Address -----

Water Authority/Community representative signature.....

Date of Visit:.....

Water Sample taken? Sample No. Thermotolerant Faecal Coliform present?.....

Questions to be asked during survey:

- 1. Is there a latrine within 30 m of the pumphouse? Y/N
- 2. Is the nearest latrine a pit latrine that percolates to the soil (i.e. unsewered)? Y/N
- 3. Are there any animal excreta or rubbish within 15 m of the borehole? Y/N
- 4. Is there an uncapped well within 30 m of the borehole? Y/N
- 5. Is the drainage area around the pumphouse faulty, is it broken, permitting ponding and/or leakage to ground? Y/N
- 6. Does the wall or fencing around the pumphouse damaged or have any breaks that would allow unauthorised entry or animals to enter? Y/N
- 7. Is the floor of the pumphouse permeable to water? Y/N
- 8. Is the well seal unsanitary? Y/N
- 9. Is the chlorination functioning properly? Y/N
- 10. Is chlorine present at the sampling tap? Y/N

Total Score of Risks...../10

Contamination Risk Score: 9-10 Very high, 6-8 High; 3-5 Intermediate; 0-2 Low

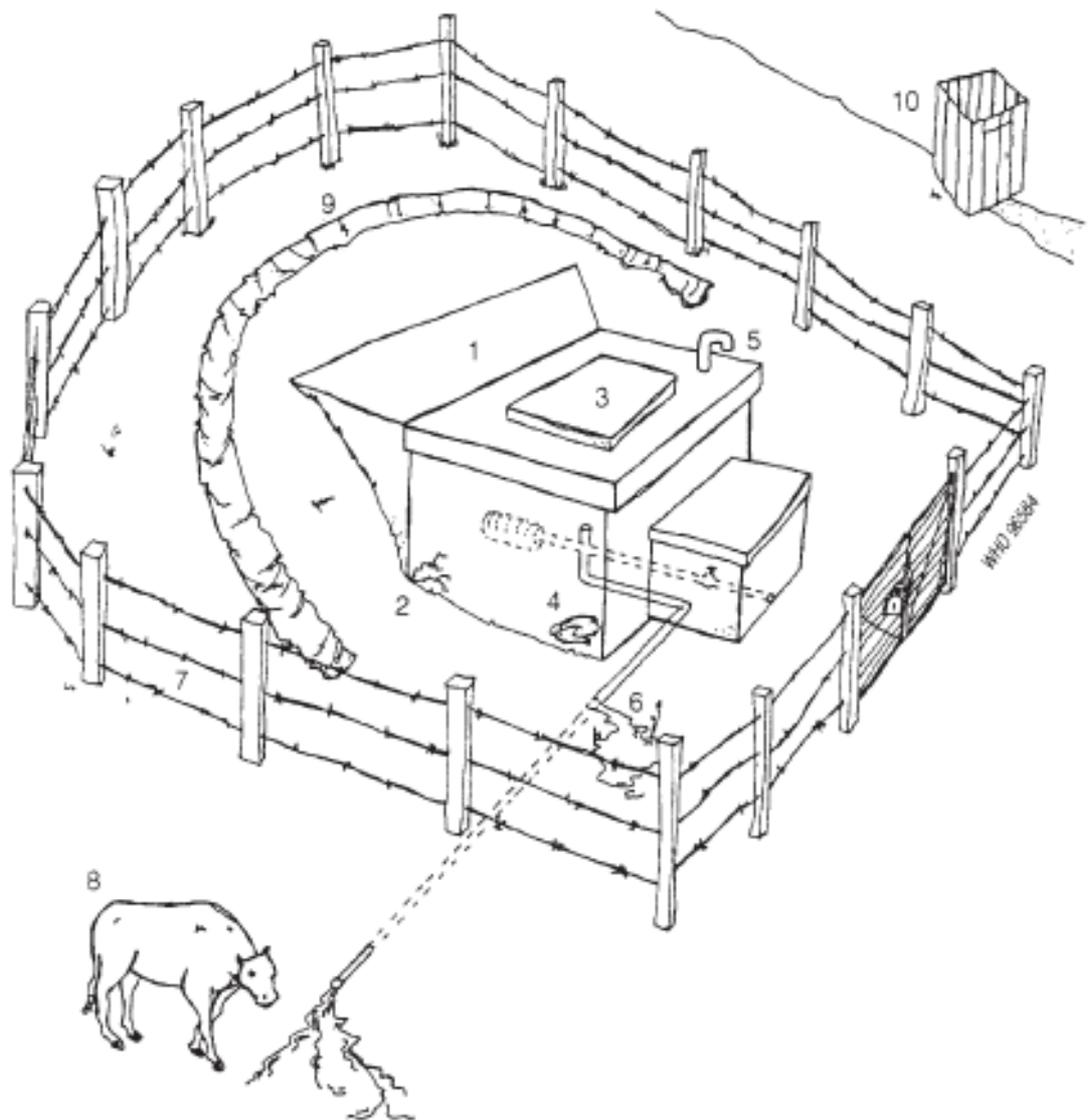
Results & Recommendations

The following important points of risk were noted (list no.s 1 -10) and the authorities advised on remedial action.

Name -----

Signature -----

3.6 - Sanitary Survey for Protected Spring (Source)



I Type of facility PROTECTED SPRING SOURCE

1. General information: Health centre
Village
2. Code no.—Address
3. Water authority/community representative signature
4. Date of visit
5. Water sample taken? Sample no. Thermotolerant coliform grade

II Specific diagnostic information for assessment Risk

- | | |
|--|-----|
| 1. Is the spring source unprotected by masonry or concrete wall or spring box and therefore open to surface contamination? | Y/N |
| 2. Is the masonry protecting the spring source faulty? | Y/N |
| 3. If there is a spring box, is there an unsanitary inspection cover in the masonry? | Y/N |
| 4. Does the spring box contain contaminating silt or animals? | Y/N |
| 5. If there is an air vent in the masonry, is it unsanitary? | Y/N |
| 6. If there is an overflow pipe, is it unsanitary? | Y/N |
| 7. Is the area around the spring unfenced? | Y/N |
| 8. Can animals have access to within 10 m of the spring source? | Y/N |
| 9. Does the spring lack a surface water diversion ditch above it, or (if present) is it nonfunctional? | Y/N |
| 10. Are there any latrines uphill of the spring? | Y/N |

Total score of risks /10

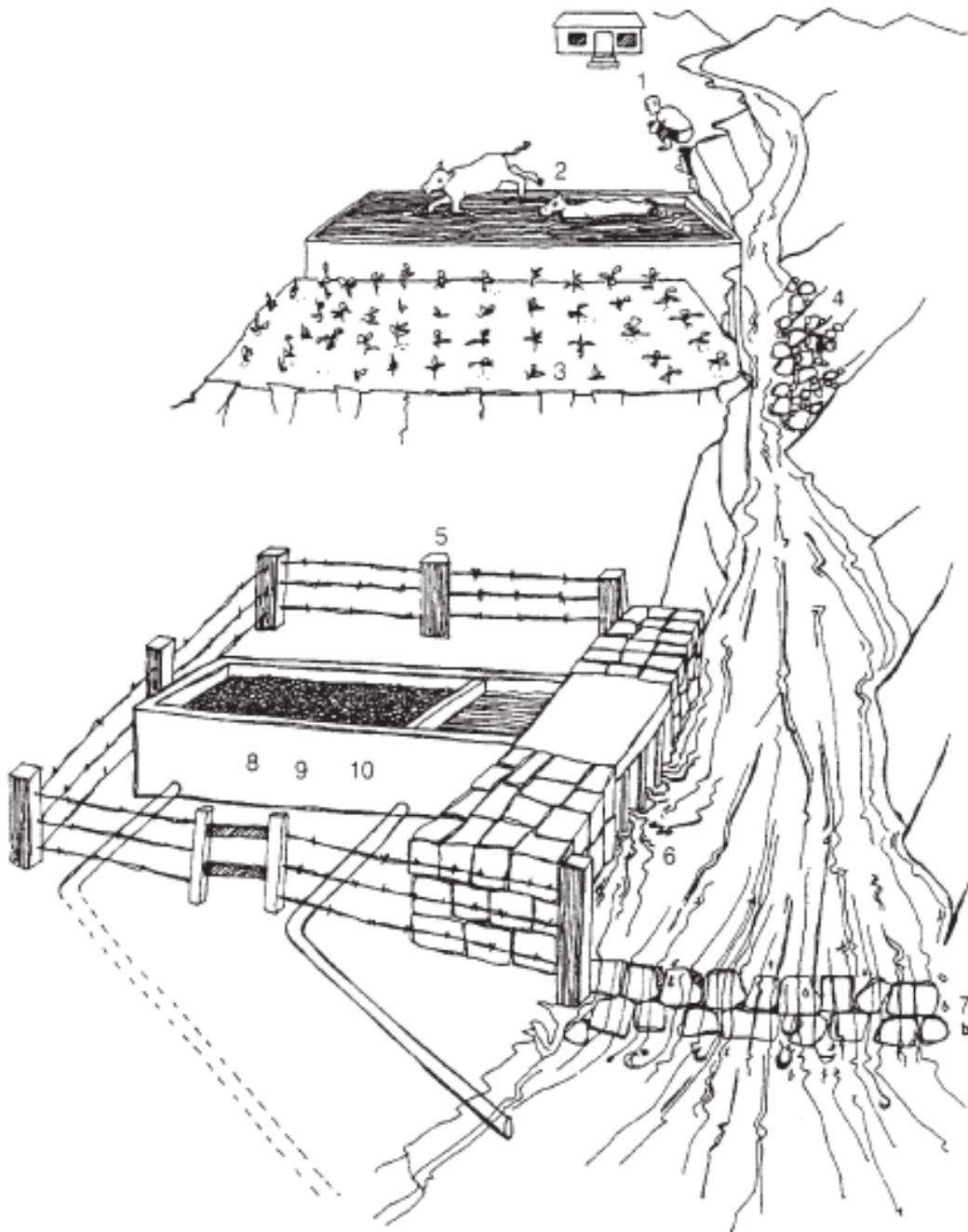
Contamination risk score: 9–10 = very high; 6–8 = high; 3–5 = intermediate;
0–2 = low

III Results and recommendations

The following important points of risk were noted: (list nos 1–10)
and the authority advised on remedial action.

Signature of sanitarian

3.7 Sanitary Survey for Surface Water Abstraction



WHO 96585

I Type of facility SURFACE SOURCE AND ABSTRACTION

1. General information: Health centre
Village
2. Code no.—Address
3. Water authority/community representative signature
4. Date of visit
5. Water sample taken? Sample no. Thermotolerant coliform grade

II Specific diagnostic information for assessment Risk

1. Is there any human habitation upstream, polluting the source? Y/N
2. Are there any farm animals upstream, polluting the source? Y/N
3. Is there any crop production or industrial pollution upstream? Y/N
4. Is there a risk of landslide or mudflow (causing deforestation) in the catchment area? Y/N
5. Is the intake installation unfenced? Y/N
6. Is the intake unscreened? Y/N
7. Does the abstraction point lack a minimum-head device (weir or dam to ensure minimum head of water)? Y/N
8. Does the system require a sand or gravel filter? Y/N
9. If there is a filter, is it functioning badly? Y/N
10. Is the flow uncontrolled? Y/N

Total score of risks /10

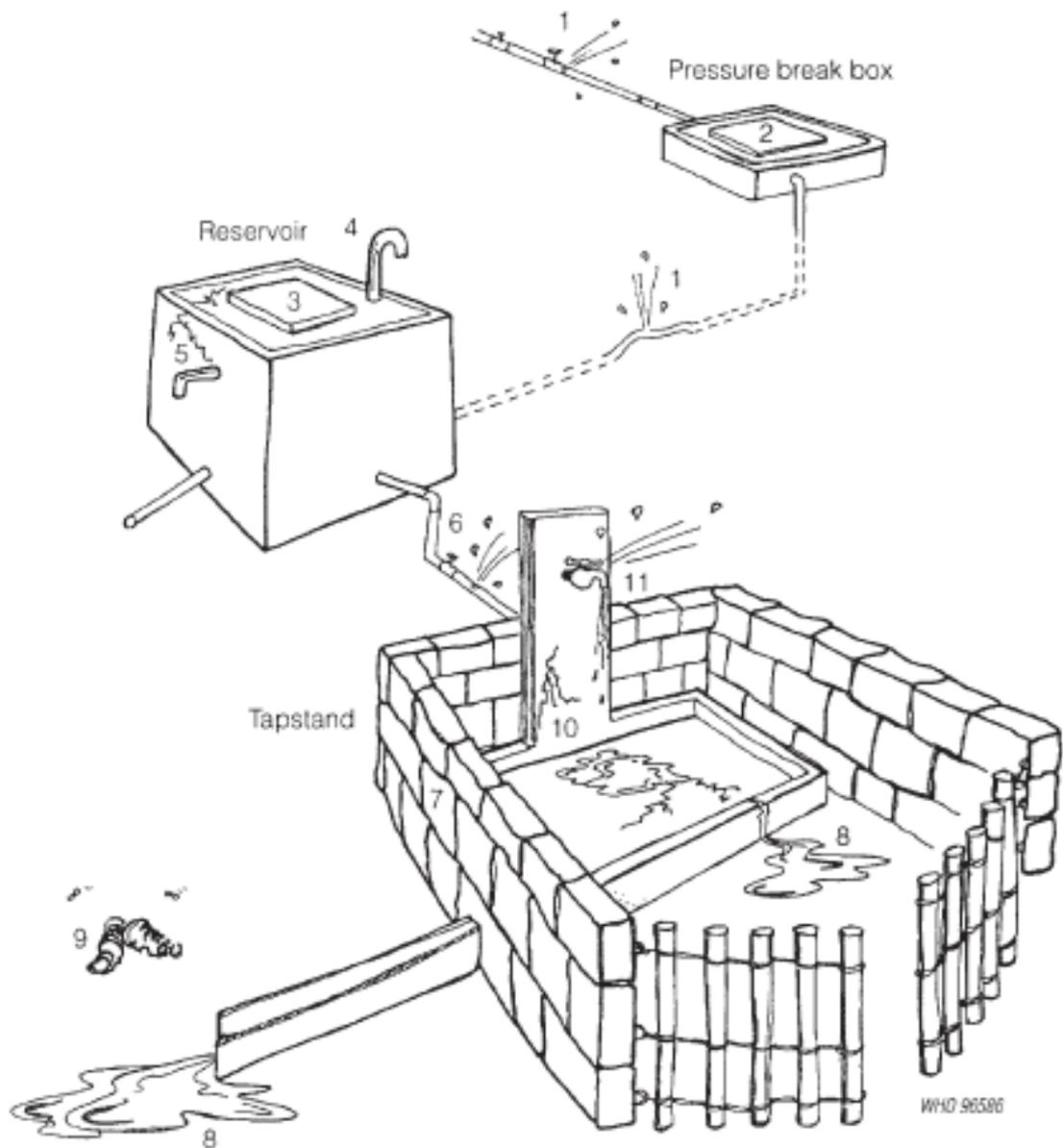
Contamination risk score: 9–10 = very high; 6–8 = high; 3–5 = intermediate;
0–2 = low

III Results and recommendations

The following important points of risk were noted: (list nos 1–10)
and the authority advised on remedial action.

Signature of sanitarian

3.8 - Sanitary Survey for Piped Water Distribution



I Type of facility PIPED DISTRIBUTION

1. General information: Health centre
: Village
2. Code no.—Address
3. Water authority/community representative signature
4. Date of visit
5. Water sample taken? Sample no. Thermotolerant coliform grade

II Specific diagnostic information for assessment Risk

1. Is there any point of leakage between source and reservoir? Y/N
2. If there are any pressure break boxes, are their covers unsanitary? Y/N

If there is a *reservoir*:

3. Is the inspection cover unsanitary? Y/N
4. Are any air vents unsanitary? Y/N
5. Is the reservoir cracked or leaking? Y/N
6. Are there any leaks in the distribution system? Y/N
7. Is the area around the tapstand unfenced (dry stone wall and/or fencing incomplete)? Y/N
8. Does water accumulate near the tapstand (requires improved drainage canal)? Y/N
9. Are there human excreta within 10 m of the tapstand? Y/N
10. Is the plinth cracked or eroded? Y/N
11. Does the tap leak? Y/N

Contamination risk score: 10–11 = very high; 6–9 = high; 3–5 = intermediate;
0–2 = low

III Results and recommendations

The following important points of risk were noted: (list nos 1–11)
and the authority advised on remedial action.

Signature of sanitarian

Annex 6.4: Sanitary Investigation

(adapted from Emergency Water Source Selection SJ House & RA Reed, WEDC)

The sanitary investigation highlights risks around the vicinity of the source and so gives an idea of faecal contamination.

- Use section A for unimproved water sources (e.g. spring cap, borehole) and use sections A & B for improved sources.
- Any 'yes' answers in the high risk section implies the source is high risk
- No 'yes' answers in the high risk but some in the medium risk implies the source is medium risk
- No 'yes' answers in the high or medium risk but some in the low risk implies the source is a low risk
- If there are no 'yes' answers in low, medium or high it is likely the risks are negligible

Almost all surface water sources will be high risk and disinfection is useful to reduce these.

Sanitary investigation	Yes	No	N/A
A. Use for a source with or without existing engineered facilities			
High risk of faecal or other pollution			
· animals drink near to or from the source			
· water is being collected directly from the source in individual containers			
· human defecation occurs in or near the source			
· the source is used for bathing or laundry			
· the source is used upstream by other communities			
· surface run-off from the camp is likely to enter the source upstream of the abstraction point			
Medium risk of faecal or other pollution			
· industries or agriculture operate near to the source			
· refuse can be found around or in the source			
· there is standing water within 2m of the source (i.e. drainage is inadequate)			
· there are latrines less than 30m away from the source (see also the note for the circumstances in which this is valid)			
· the source has a wide boundary (such as a lake, river or stream) and hence is difficult to protect			

Sanitary investigation	Yes	No	N/A
B Use for source with existing engineered facilities			
Medium risk of fecal or other pollution			
· protection structures are inadequate in design (borehole capping; drainage curtains or channels well lining; spring box)			
· if the source is a borehole it is <100m from uncapped wells or other sources of pollution such as sewers, septic tanks or refuse dumps			
· if the source is a borehole it is less than 800m from a graveyard			
· if the source is a spring the cut-off drain above the spring is inadequate			
When the source is from an existing piped supply:			
· the supply is intermittent			
· there is less than 0.5mg/l of residual chlorine at the tapstand / point of collection or 0.2mg/l of free residual chlorine at the household			
· the treatment systems are unreliable with possible interruptions			
· there are leaks from the pipework or valves			
· the pipes are closer than 10m to latrines, sewers or drains			
Low (but still possible) risk of faecal or other pollution			
· there is inadequate fencing around the source (if it is not enclosed in a building)			
· there is damage or cracks to the abstraction or protection structures (borehole capping; drainage curtains or channels; well lining; spring box)			
· if the source is a spring then the spring box contains silt or animals			
· if the source is a spring box the overflow pipe or air vents are damaged or blocked			
· the pump sumps are dirty			
· the pumps are not in good working order			
· the lifting or pumping devices are not secure and well fixed			
· storage tanks are uncovered or cracked.			

Annex 6.5 Water Safety Plan Team Responsibilities and Authorities

Teams for large scale water supplies should include the following skills:

- Appropriate authority to action any changes proposed in the WSP.
- Knowledge of the whole supply chain.
- Expertise in hazard identification and risk assessment.
- A team leader.
- Technical expertise and operational system-specific experience – and identify any gaps in knowledge/skills available.
- Organizational authority to report through to the relevant controlling authorities such as the executive of an organization or community leader.
- Understanding of water quality standards to be met.
- Appreciation of the water quality needs of the users.
- Understanding of the practical aspects of implementing WSPs in the appropriate operational context.
- Understanding of the impact of proposed water quality controls on the environment.
- Familiarity with training and awareness programmes.

Teams for smaller scale water supplies would have similar skills, but the large part would be understanding the community’s water quality needs of the users.

WSP Team details form:

Name	Affiliation	Title	Role within team	Contact information
<i>Name of employee</i>	<i>Organization</i>	<i>Job title</i>	<i>What is the employee responsible for?</i>	<i>telephone number and email address</i>

Annex 6.6 Worked Example of a Tankering Schedule

A new camp will serve 10 000 people. There are no immediate sources of water in the camp. Water will have to be trucked along a rough 10 km track from a single borehole source until sources can be developed nearby.

Estimate the quantity of water to be tankered.

Population	10 000
Minimum emergency water requirement	7.5 l/person/day
Daily water requirement	75, 000 l
Allow 20% extra for wastage and for new arrivals	15 000 l
Water to be tankered	90 000 l/day

Survey the 10 km route and identify a suitable means of transporting the water. Rigid (5,000-litre) tankers are found suitable and can be hired. Estimate the journey time from filling point to distribution point. Do not overestimate speed.

One-way journey time @ 20 km/h is 30 minutes.

The borehole pump discharges at 5 l/s.

Therefore time to fill a 5000 l tanker: $5000/5 \text{ seconds} = 1000\text{seconds} = 17 \text{ minutes}$.

Off-loading is by gravity through a 75 mm (3 in) diameter hose. (Offloading could be increased by using a small pump mounted on each lorry)

Each distribution site has been chosen to give a 1.5 m head difference between tanker outlet and receiving tank. This allows a tanker to discharge by gravity in about six minutes.

Calculate the turnaround time (total delivery time plus the return journey) for each site.

Time to fill tanker	17 minutes
Journey time from filling point to distribution point	30 minutes
Time for off-loading tanker	6 minutes
Return journey time to filling point	30 minutes
Net turnaround time	83 minutes
Add 30% for contingencies	25 minutes
Gross turnaround time	108 minutes = 1.8 hours

The number of journeys and tankers required can now be determined. Include a generous contingency time for rest breaks (for drivers, pump operators and supervisors) and for refueling, maintenance, breakdowns and punctures. Contingency time is very variable, particularly if the refueling point is some distance away. In this example, a contingency time of 30% is taken. The following estimate assumes all the distribution points are approximately the same distance from the borehole source. This is clearly not always going to be the case.

Number of deliveries/ tanker/ day = working hours in a day / gross turnaround time

$$= 12/1.8 = 6.7, \quad \text{say } 6 = (a)$$

Total number of deliveries in a day = daily tankered water / volume per tanker

$$= 90,000/5,000 = 18 = (b)$$

Number of tankers $(b/a) = 18/6 = 3$

Summary: A total of three tankers of 5000 l capacity will be required to make six deliveries each per day to supply enough water at 7.5 l/person/day for 10 000 people.

Annex 6.7 Water Truck Checklist

1) Number of Water trucks available:

Condition of the water trucks:

- i. Is the tanker safe for potable water storage (not formerly used for petrol; is clean and not corroded; etc.).
- ii. Is the tanker well maintained and able to reliably make deliveries on the roads they will be expected to drive on?
- iii. Is the water trucking operator equipped and able to operate a pump for emptying the transported water?

2) Number of flat-bed trucks available and their capacity:

Condition of the trucks (same as above);

- i. How will they transport water? Plastic tank, bladder, etc.

3) Does the truck possess pumps and hoses to enable pumping? Will these need to be procured?

4) Legality of the vehicle:

- i. Is the vehicle registration complete and up to date?
- ii. Does the driver have a legal driving license for this type of vehicle?
- iii. Is the vehicle road worthy according to local transportation law (working lights, sufficient tires, etc.)?

5) Previous experience – has this vehicle worked previously in a water trucking operation?

Annex 6.8 Accessibility and safety audit: water point

Taken from *Violence, Gender & WASH: A Practitioner's Toolkit – Making water, sanitation and hygiene safer through improved programming and services*. House S. et al (2014) London, UK: WaterAid/SHARE.

The purpose of the audit is to examine a water facility, and

- a) Find out if a physically vulnerable person⁷ is able to use the facility independently.
- b) Identify which features make it easy to use, and which features make it difficult to use by a physically vulnerable person.
- c) Find out if there are any safety concerns around using the facility, particularly for adolescent girls, women and children of different ages.
- d) Make suggestions for changes/improvements to the facility or its surrounds to improve accessibility and to reduce any safety risks identified.
- e) Involve the users in the design of facilities.

A. Allocation of tasks

Appoint a co-ordinator (if you haven't already). Assign or ask for volunteers for relevant recording tasks: note-taker, measuring dimensions, drawing diagrams, taking photographs, etc. (Team members may do more than one task).

<i>Names of team members</i>	<i>Equipment needed</i>
Co-ordinator	Note-book & pen
Interviewer	Note-book & pen
Note-taker	Note-book & pen
Measurer	Tape measure
Drawer of diagrams	Note-book & pencil, eraser
Photographer	Camera

B. Water point - general details

1. Type of water point
2. Location /Address
-
3. Name of implementing organisation/individual.....
4. Accommodation: owned rented other (specify).....

⁷ This might be a frail elderly woman or man, a small child, a heavily pregnant woman, a wheelchair user or person with difficulty walking, someone who is visually impaired, with weak grip, a broken leg, a limb amputation, the list is endless.

5. Geographic location: rural urban peri-urban village farm flat hilly

(Please describe)

6. General description of water point, including materials, technology used.

.....
.....
.....

7. Draw a diagram (on a separate sheet) a) from above and b) from the side, to show dimensions of the facility and surround.

C. Accessibility and safety

Different users now attempt to use the water point. Make a note of who can use it and who cannot, and what features make it difficult to use. Use the attached checklist to remind you of the kind of features to look for, ignore any that are not relevant, and add things that are missing.

8. Getting there:

.....
.....
.....

Suggested changes:

.....
.....
.....

Checklist

Distance: How far is it from home(s)/classroom to water point?

Access route:

- Is the route outside or inside?
- If used at night, is the path lit?
- What is the path/ access route made of?
- Is the path wide enough for all users? (recommended minimum width 90cm)
- Is the path level and firm, with nothing to trip up? Is the surface of the path slippery when either dry or wet? Are there obstacles that make it difficult to get past, or easy to trip up, especially for visually impaired people? (e.g. vegetation, rubbish, up to 2m above floor level).
- Are there any parts of the path which make women or children feel unsafe when using it? If so why?
- Are there landmarks that a blind/visually impaired person can follow, e.g. clear surface texture, landmarks or guide rail?
- If there is a slope or ramp, how steep is it? (Recommended maximum 1 in 10)⁸. Is the surface of the slope slippery or non-slip?

⁸ See Jones & Reed (2005, p.48-49) for ramp gradients and lengths.

9. Getting in/on/out:

.....
.....
.....
.....

Suggested changes:

.....
.....
.....

Checklist

- If there are steps, are they a height that disabled/ elderly people can manage? (recommended max 15 – 17 cm each step).
- Are the steps even or uneven, firm or broken, non-slip or slippery?
- Is there a hand-rail for support?
- What is the difference in height between surrounding area and platform/ apron? Can a wheelchair or crutch user easily enter/ get on?
- If there is a door or gate, does it open inwards or outwards?
- How easy is it to unlock and open the door/ gate? e.g. by someone with weak grip?
- If there is an entrance, is it wide enough for a wheelchair user to enter? (recommended minimum width 80cm)
- If someone faced harassment or other safety risks when using the facility would they be able to get away safely from the area?

10. Usability:

.....
.....
.....

Suggested changes:

.....
.....
.....

Checklist

- What is the floor made of? Is the floor even, or uneven, firm or unstable, slippery or non-slip?
- If there is a concrete surround/ apron, measure the dimensions (width – side to side, length front to back).
- Can the user get close enough to use the water point?
- Is there a flat platform for the user to sit or stand whilst drawing water?
- Is there something for the user to lean on while drawing water?
- Can the user easily reach the operating mechanism (handle/ tap/ rope/ water surface)? If not why not?

- Is there a place to stand the water container? Can the user easily lift the filled water container and carry it?

D Interviews

11. Who uses the facility?

.....
.....
.....

12. Can they use it easily?

.....
.....
.....

Are there people who would like to use it but cannot, or have difficulty?

.....
.....
.....

13. Have there ever been incidents where women, adolescent girls, children or others have faced harassment or other safety threats when using the facility? If so describe the problems that have occurred. Also ask if there are any ideas as to how this could be prevented in the future?

.....
.....
.....

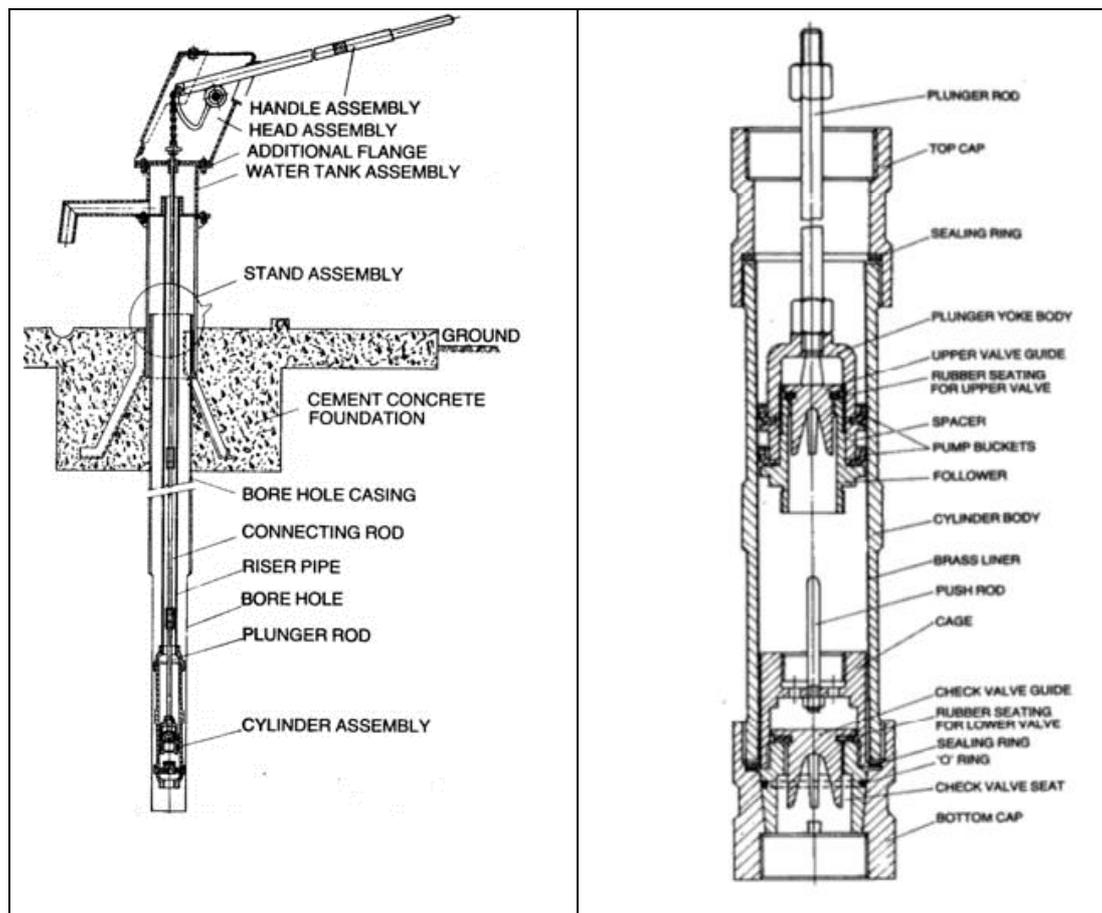
13. Please add any additional information or comments.

This tool is part of the toolkit:

House, Sarah, Suzanne Ferron, Marni Sommer and Sue Cavill (2014) *Violence, Gender & WASH: A Practitioner's Toolkit – Making water, sanitation and hygiene safer through improved programming and services*. London, UK: WaterAid/SHARE.

It has been adapted from: Jones, H (2012) *Accessibility Audit: Water Point*. WEDC, Loughborough University, UK. <https://wedc-knowledge.lboro.ac.uk/collections/equity-inclusion>

Annex 6.9 Maintenance schedule for India MkII in a hand dug well



India Mark II and Cylinder Assembly

i) Daily activities

Well

- Check for any debris in the well by regular visual inspection
- Clean the concrete apron
- Clear the drains
- Check that the gate is closed

ii) Weekly

Handpump

- Check the fittings such as nuts, bolts and handle assembly and tighten them.
- Check the axle bolt and tighten as needed.
- Make sure the lock nut is tight.
- Make sure the hand pump is firm on its base.
- Check the flange bolts fastening the water chamber to the pedestal are tight.
- Testing water quality using a Field Test Kit if available.

iii) Monthly activities

Handpump

- Tighten the handle axle nut and lock nut.

- Check for loose or missing flange bolts and nuts and tighten as needed.
- Open the cover and clean inside the pump.
- Check the chain anchor bolt for proper position and tighten if needed.
- Look for rusty patches, clean with a wire brush and apply anticorrosive paint.
- Find out whether the hand pump base is loose and arrange for repair of the foundation as needed.
- Greasing of all components.

Well

- Check the concrete apron and well seal for cracks and repair them with cement mortar
- Record the water level with a rope-scale Village Health Committee
- De-silting of dug wells periodically as required

iv) Annual activities

Handpump

- Check discharge is satisfactory.
- Check if handle is shaky.
- Check if guide bush is excessively worn out.
- Check if chain is worn out.
- Check if roller chain guide is excessively worn out.
- Check all parts of the hand pump for wear and tear / damages, replace damaged parts and reassemble the hand pump.
- Measure the well depth.
- All the components of the hand pump to be checked for wear and tear/damages and damaged parts replaced and hand pump re-assembled.
- Washing and cleaning of the components of the hand pumps should be done with water and bleaching powder, if required instead of mixture of water and kerosene.
- The repairs to the hand pump platforms to be done as and when needed and need not be on daily basis.

Well

- Dewater the well and clean the bottom
- Inspect the well walls and lining and repair as needed
- Check the water level and deepen the well as needed
- Record the depth of water level & depth of well with a rope scale

Annex 6.10 Maintenance schedule for India MkII in a borehole

i) Daily activities

Borehole

- Confirm water is being delivered.
- Check for leaks in the rising main
- Clean the concrete surround
- Clear the drains

ii) Weekly

Handpump

- Check the fittings such as nuts, bolts and handle assembly and tighten them.
- Check the axle bolt and tighten as needed.
- Make sure the lock nut is tight.
- Make sure the hand pump is firm on its base.
- Check the flange bolts fastening the water chamber to the pedestal are tight.
- Testing water quality using a Field Test Kit if available.

iii) Monthly activities

Handpump

- Tighten the handle axle nut and lock nut.
- Check for loose or missing flange bolts and nuts and tighten as needed.
- Open the cover and clean inside the pump.
- Check the chain anchor bolt for proper position and tighten if needed.
- Look for rusty patches, clean with a wire brush and apply anticorrosive paint.
- Find out whether the hand pump base is loose and arrange for repair of the foundation as needed.
- Greasing of all components.

Borehole

- Check the concrete surround and borehole seal for cracks and repair them with cement mortar
- Record the water level with a dip meter

iv) Annual activities

Handpump

- Check discharge is satisfactory.
- Check if handle is shaky.
- Check if guide bush is excessively worn out.
- Check if chain is worn out.
- Check if roller chain guide is excessively worn out.
- Check all parts of the hand pump for wear and tear / damages, replace damaged parts and reassemble the hand pump.
- Measure the well depth.
- All the components of the hand pump to be checked for wear and tear/damages and damaged parts replaced and hand pump re-assembled.
- Washing and cleaning of the components of the hand pumps should be done

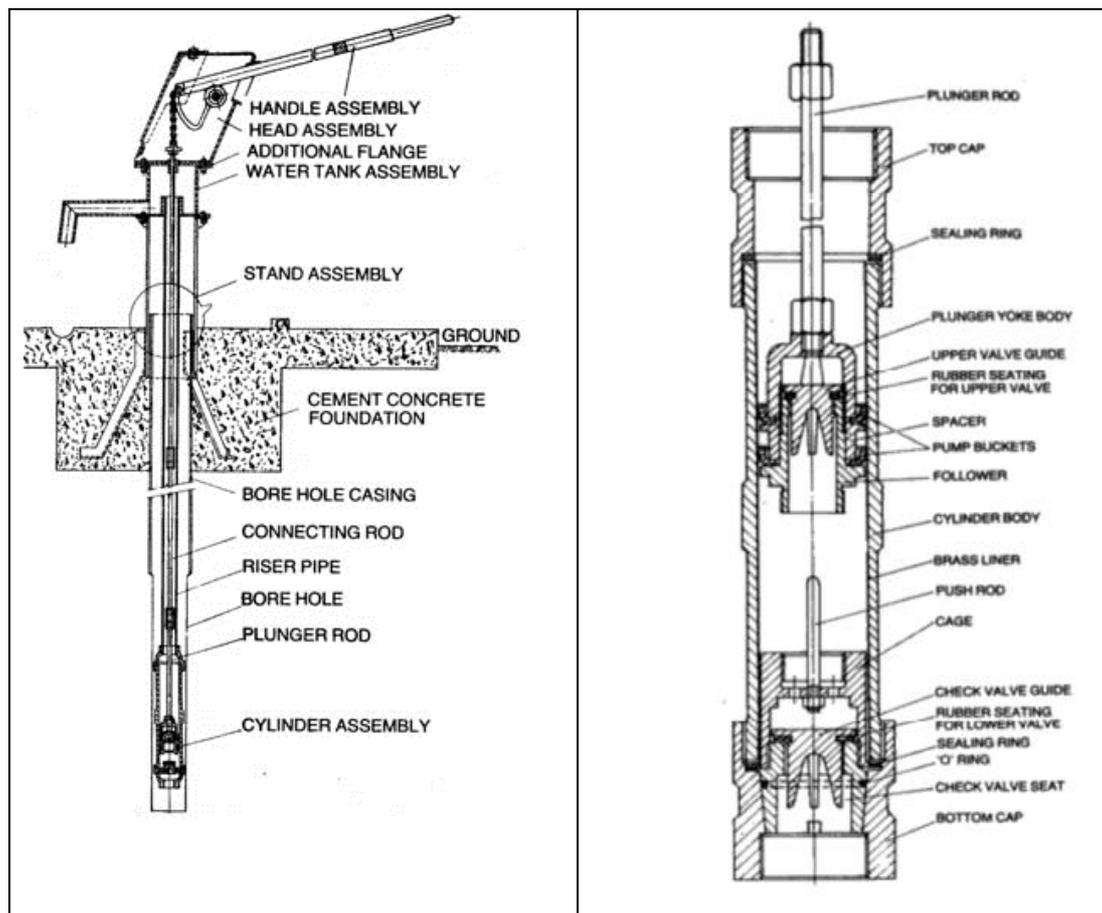
with water and bleaching powder, if required instead of mixture of water and kerosene.

- The repairs to the hand pump platforms to be done as and when needed and need not be on daily basis.

Borehole

- Record the depth of water level with a dipmeter & depth of borehole with a rope scale

Annex 6.11 Disassembly, inspection and reassembly of hand pump



(i) Disassembly of the hand pump may be required from time to time if major problems are faced:

1. Loose pump head cover bolt.
2. Remove inspection cover from head assembly.
3. Insert chain coupling supporting tool.
4. Lift the handle to the top position and disconnect chain from handle by removing the “nylon” nut and bolt (i.e., nylon insert lock nut).
5. Take out handle axle; while removing use the handle axle punch to protect the axle thread and remove the handle from the head assembly.
6. Remove flange bolts from the head assembly.
7. Remove head assembly from the water tank.
8. Place the connecting rod vice on to the water chamber top flange and tighten vice against connecting rod and allow the head assembly to sit on the connecting rod vice.
9. Disconnect the chain assembly from connecting rod.
10. Support connecting rod with connecting rod lifter, loosen connecting rod vice and remove; gently lower connecting rod to sit on check valve; remove connecting rod lifter.
11. Loose water tank nuts and bolts and remove water tank bottom flange bolts.
12. Lift water tank by using tank pipe lifter and lifting spanners.

13. Fit self-locking clamp and remove water tank.
14. Join plunger assembly to check valve by turning the rod lifter in clock wise direction
15. To take out water from the pipe, remove the rod lifter; join the rod lifting adaptor to the connecting rod; place head assembly over water tank and fix handle to the lifter
16. Remove water from riser pipe by pushing down handle suddenly.
17. Lift handle upwards slowly and disconnect connecting rod lifting adapter and take out head assembly.
18. Tighten the connecting rod lifter to the connecting rod and lift the connecting rod and fix the connecting rod vice.
19. Hold the connecting rod, slowly loosen the rod vice and lift the connecting rod; tighten the vice and repeat the process until it is possible to remove the connecting rod; repeat the process until the last connecting rod with plunger and check valve is pulled out.
20. Separate the check valve from the plunger.
21. Unscrew the plunger from the check valve.
22. Remove all the parts of the check valve and clean them.

(ii) Inspection for reassembly covers the following:

1. Check the water tank for leakage or damage.
2. Wash and clean all parts with a mixture of water and bleaching powder.
3. The stand assembly should be on a perfect level – check with a spirit level
4. Check the coupler for broken threads.
5. Check flanges and spout pipe for cracks and leakage.
6. Check the handle axle, bearings and chain; apply grease to the bearings and chain.

(iii) Reassembly is as follows:

1. Ensure parts are clean and dry, and moving parts are lubricated with oil and grease
2. Check 'O' ring and cup seal and replace as needed.
3. Remove cover of casing pipe for fixing stand assembly.
4. Place stand assembly over casing pipe and make sure that it is vertical and check level of flange by spirit level.
5. Fix water tank assembly on the stand flange by tightening the nuts and bolts.
6. Join the check valve and plunger.
7. Connect the plunger to the connecting rod.
8. Insert the plunger assembly connected with the check valve in the riser pipe and connect the riser coupler to the water tank.
9. Insert the lower end of the connecting rod in the riser pipe, and place the connecting rod over the water tank and fix it to the vice.
10. Join the connecting rod pieces as per the requirement and insert in the riser pipe.
11. Remove the connecting rod vice from the water tank by holding the top end of the connecting rod.
12. Fix the connecting rod lifter to the top end of the connecting rod and rotate in

the direction of the arrow so as to separate the check valve from the plunger and ensure that it reaches the bottom plate.

13. Make a mark by hack saw on the connecting rod at the level of the water tank.
14. Lift the connecting rod assembly, fix the connecting rod vice and tighten the connecting rod.
15. Cut the connecting rod as per the marking after removing the connecting rod lifter.
16. Smoothen with the help of a file the cut surface of the connecting rod.
17. Make necessary threads on the top most end of the connecting rod.
18. Fix the middle flange on the top of the water tank and ensure that all four corners coincide.
19. Tighten the check nut at the top of the connecting rod.
20. Screw the chain on to the connecting rod.
21. Place the chain coupling supporting tool on the middle flange and remove the rod vice.
22. Place the middle flange and set flanges with water tank.
23. Place head assembly over the middle flange and tighten by spanner.
24. Place handle assembly and insert the handle axle by handle axle punch.
25. Lift the handle for fixing chain and tighten chain anchor bolt and nylon nut fully (i.e., nylon insert lock nut); remove chain coupler supporting tool by lowering the handle
26. Lift handle up and apply grease on the chain.
27. Lower down the handle and fix inspection cover and tighten the cover bolt fully by the crank spanner.

Annex 6.12 Maintenance schedule for boreholes with motor pumps

Submersible or electric centrifugal pump

(i) Daily O&M activities:

- Clean the pump house.
- Check available Voltage in every phase.
- Check reading on ammeter is normal – stop pump if electric motor is drawing too much current and report problems, open isolation valve.
- Check power factor.
- Confirm water is being delivered.
- Check for leaks in the rising main.
- Continue to check voltmeter and ammeter readings during the day.
- Check external wiring for frayed insulation or loose connections
- Maintain pumping log book and history sheets of tools, plants & equipment's.
- Observe the abnormal sound of pumping machinery by listening the changes in noise level.
- Clean the concrete surround
- Clear the drains

(ii) Weekly activities at the tank:

- Testing water quality using a Field Test Kit (for small schemes only).

(iii) Monthly activities:

- Check the concrete surround and borehole seal for cracks and repair them with cement mortar
- Record the water level with a dip meter

(iv) Annual activities may include:

- Remove the pump and rising main from the well and inspect.
- Check pipe threads and re-cut corroded or damaged threads.
- Replace badly corroded pipes.
- Inspect electric cables and check insulation between cables.
- Check as per Recommendations of manufacturer's operational manual.

Maintenance of a diesel engine

(i) Every Third Day:

Operate the diesel engine at about 1,000 rpm for at least 5 minutes or until warm. This would allow the lubricant and coolant to circulate around the engine.

(ii) Every 8 hours Operation:

Check coolant level, sump oil level, oil reservoirs, for oil, water or fuel leaks and clean oil bath cleaner.

(iii) Every 200 hours of Operation:

1. Drain and renew engine lubricating oil.
2. Renew lubricating oil canisters.
3. Check tension of drive belt
4. Clean fuel water trap.
5. Lubricate dynamo rear brush.
6. Clean air filter element.

(iv) Every 400 hours of Operation:

1. Renew fuel and air filter elements.
2. Check hoses and clips.
3. Clean lift pumps sediment chamber.

(v) Every 2,400 Hours of Operation:

1. Check and adjust valve clearances.
2. Service injector units.

Annex 6.13 Sample O&M activity checklist format – example for India MkII in Hand-dug well

Daily activities (1 month O&M activity checklist) Month: _____ Year: _____

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Well																															
Check for any debris in the well by regular visual inspection																															
Clean the concrete apron																															
Clear the drains																															
Check that the gate is closed																															

Weekly activities (1 month O&M activity checklist) Month: _____ Year: _____

	Week 1	Week 2	Week 3	Week 4	Week 5
Handpump					
Check the fittings such as nuts, bolts and handle assembly and tighten them.					
Check the axle bolt and tighten as needed.					
Make sure the lock nut is tight.					
Make sure the hand pump is firm on its base.					
Check the flange bolts fastening the water chamber to the pedestal are tight.					

Monthly checks (1 year O&M activity checklist)

Year: _____

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Handpump												
Tighten the handle axle nut and lock nut.												
Check for loose or missing flange bolts and nuts and tighten as needed.												
Open the cover and clean inside the pump.												
Check the chain anchor bolt for proper position and tighten if needed.												
Look for rusty patches, clean with a wire brush and apply anticorrosive paint												
Find out whether the hand pump base is loose and arrange for repair of the foundation as needed.												
Greasing of all components.												
Well												
Check the concrete apron and well seal for cracks and repair them with cement mortar												
Record the water level with a rope-scale Village Health Committee												
De-silting of dug wells periodically as required												

Annual checks (10 year O&M activity checklist) 10 year period starting year:

Year	1	2	3	4	5	6	7	8	9	10
Date of check here										
Handpump										
Check discharge is satisfactory.										
Check if handle is shaky.										
Check if guide bush is excessively worn out.										
Check if chain is worn out.										
Check if roller chain guide is excessively worn out.										
Check all parts of the hand pump for wear and tear / damages, replace damaged parts and reassemble the hand pump.										
Measure the well depth.										
All the components of the hand pump to be checked for wear and tear/damages and damaged parts replaced and hand pump re-assembled.										
Washing and cleaning of the components of the hand pumps should be done with water and bleaching powder, if required instead of mixture of water and kerosene.										
The repairs to the hand pump platforms to be done as and when needed and need not be on daily basis										
Well										
Dewater the well and clean the bottom										
Inspect the well walls and lining and repair as										

needed										
Check the water level and deepen the well as needed										
Record the depth of water level & depth of well with a rope scale										

Annex 6.14 Checklist for Community Participation and Responsibility to be used before deciding on Solar Powered Water Supply Systems

(Adapted from Solar Pumping Systems (SPS), Ratterman et al, 2007, Green Empowerment)

The checklist below can help you to think about the issues that are important in making sure that the community can accomplish what will be needed to use a Solar Powered System.

- ✓ Complete a survey of all community members regarding water uses. The purpose of this is to get a better idea of the requirements of a solar pumping system and the expectations of the community.
- ✓ The community already has organizations or groups that meet regularly to solve problems or make decisions. Do you already have a group to handle water usage issues? Will you create one?
- ✓ What is the proposed legal ownership structure of the project? If this is not done right at the start, there can be serious problems later on.
- ✓ The community leaders have worked with NGOs or other outside organizations. If not, how can you support them to do so?
- ✓ Individuals in the community can step forward to take the roles of: water steward, security, technical lead, maintenance supervisor, and perhaps more.
- ✓ The community can agree to the equitable division of labor necessary for installing the system. All able members of the community should be willing to chip in with the required work.
- ✓ The community is agreeable to sharing the costs of operating and maintaining the system. It will be important to go through a process to determine how much money needs to be charged to each individual or family for use of the water to pay for the long term maintenance, repair, and equipment replacement.
- ✓ You have considered the possible population increase and other social changes that may occur from installing a Solar Powered Water Supply System. Make a plan of action for several scenarios.
- ✓ You have considered how to fairly distribute the water resources both physically and socially.
- ✓ You have considered a long-term plan including procedure for emergencies and component repair and replacement (pumps last 10 years).
- ✓ You have considered how your SPS might interact with regional water authorities. Will they help?

Annex 6.15 Example calculations for Solar Pumping

The hydraulic energy required (kWh/day)

$$\begin{aligned} &= \text{volume required (m}^3\text{/day)} \times \text{head (m)} \times \text{water density} \times \text{gravity} / (3.6 \times 10^6) \\ &= 0.002725 \times \text{volume (m}^3\text{/day)} \times \text{head (m)} \end{aligned}$$

The solar array power required (kWp)

$$= \text{Hydraulic energy req.d (kWh/day)} / \text{Av. daily solar irradiation (kWh/m}^2\text{/day)} \times F \times E$$

where F = array mismatch factor = 0.85 on average
and E = daily subsystem efficiency = 0.25 - 0.40 typically

(from Peter Fraenkel: Water Pumping Devices. A handbook for users and choosers. ITDG Publishing, 1997)

Example Calculation

Assuming 800 people with a total daily demand of 40l/p/d

Assuming a total dynamic head (distance from water level whilst pumping to top of tank + friction losses in pipe) = 27m

$$\text{Then } Q = 800 \times (40/1000) = 32\text{m}^3\text{/day}$$

$$\text{Hydraulic Energy required } E_{\text{hyd}} = 0.002725 \times 32 \times 27 = 2.35\text{kWh/day}$$

Assuming the efficiency of the pump subsystem (conversion of electricity to hydraulic output)

$$\eta = 50\%$$

This will vary depending on the pump and pump controller and details need to come from the pump manufacturer. Newer technologies will have a better efficiency, therefore this needs to be checked with the manufacturer.

$$\text{Daily energy demand } E_{\text{hydeff}} = E_{\text{hyd}} / \eta = 2.35/0.5 = 4.71 \text{ kWh/day}$$

Using Annex 6.15, daily solar irradiation/m² = 5.89 (for worst month August)

Using a safety factor of 0.8 (assuming panels not fully clean, not in optimal position to the sun, etc.)

$$E_{\text{dailysolar}} = 5.89 \times 0.8 = 4.7\text{kWh/m}^2$$

$$\begin{aligned} \text{Approximate peak watt rating } P_{\text{peak}} &= E_{\text{hydeff}} / E_{\text{dailysolar}} \times 1000 \text{ W/m}^2 \\ &= 4.71/4.7 \times 1000 \\ &= 1002 \text{ Wp} \end{aligned}$$

Calculate number of modules

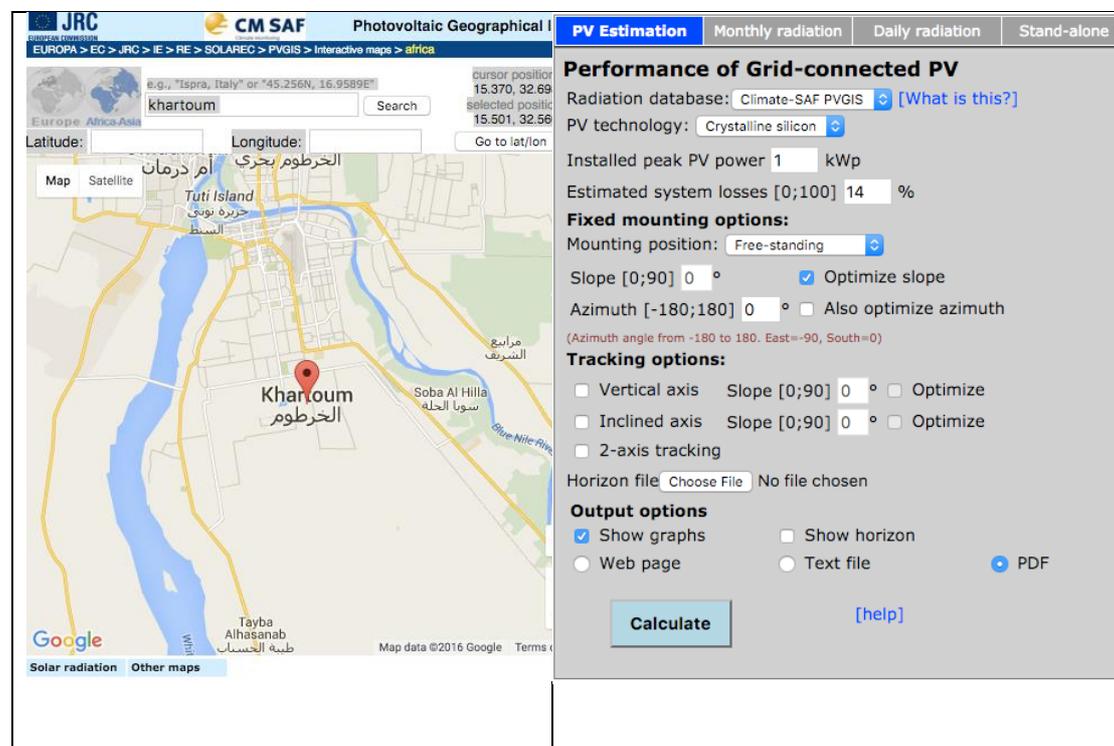
Choose a module – gives a Wp/unit – assume the module chosen has a Wp value of 55Wp/panel

$$\begin{aligned}\text{Number of modules} &= P_{\text{peak}}/Wp \\ &= 1002/55 \\ &= 18.2, \text{ say } 19 \text{ or even } \mathbf{20} \text{ to get a useful array.}\end{aligned}$$

Storage Tank required, assuming 3 days' contingency storage (for cloudy days, pump breakdowns etc.)

$$\mathbf{\text{Storage Required}} = 3 \times 32 = 96\text{m}^3, \text{ say } \mathbf{100\text{m}^3}$$

Annex 6.16 Using the JRC Photovoltaic GIS Website to get Average Daily Solar Irradiation (also known as Daily Solar Peak)
 Website <http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?map=africa&lang=en>



Website page from : <http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?map=africa&lang=en>

Filling in the webpage:

You need to make sure the Africa-Asia part of the globe in the top left corner is clicked (otherwise you can only do this for Europe). Put in the town name (or latitude and longitude) for the place you want results for, check that the map is correct for the place you want. Click on PV estimation tab on the right side of the webpage.

Radiation database: Keep as climate-SAF PVGIS, this does not affect the outcome much.

PV technology would be crystalline silicon typically, unless a new technology is used For this calculation, keep installed peak PV power as 1 kWp as you are trying to get an idea of the peak solar hours.

Keep estimated system losses around 14 to 18% for monocrystalline cells.

Unless the solar array is going to be mounted on a building, keep this the mounting position free-standing

Click optimize slope and keep the Azimuth 0° as this is due South (best position for north of the equator).

It is unlikely that you would have a tracking option (this means that a motor would be fixed to the solar array to move its position so that it always directly faces the sun (this is expensive and will break down))

Output the results as PDF - easy to save, you can show a graph if you want, but it is the figures you really want.

For solar pumping, you need H_d – average daily global irradiation per m^2 (same as peak solar hours).

Results

Fixed system: inclination=17 deg., orientation=0 deg. (Optimum at given orientation)				
Month	Ed	Em	Hd	Hm
Jan	4.76	148	6.59	204
Feb	4.94	138	6.98	196
Mar	5.44	169	7.83	243
Apr	5.00	150	7.32	220
May	4.60	143	6.75	209
Jun	4.38	131	6.39	192
Jul	4.12	128	5.94	184
Aug	4.10	127	5.89	183
Sep	4.56	137	6.61	198
Oct	4.68	145	6.82	212
Nov	4.70	141	6.70	201
Dec	4.64	144	6.45	200
Year	4.66	142	6.69	203
Total for year		1700		2440

Ed: Average daily electricity production from the given system (kWh)

Em: Average monthly electricity production from the given system (kWh)

Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m²)

Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m²)

Typically, it is best to use the worst figure, if the pump is to be used year round as this will allow you to run the pump the whole year through. It would also be possible to take the average result (it might be worth trying both to see if this would change the number of panels in the array).

Annex 6.17 Maintenance for Solar Powered System

For pump maintenance, see Module 5: Water Source Operation and Maintenance

1. Shade

Do:

- Make sure that all objects that may shade your module are removed.
- Make sure that only direct sunlight falls on your panel.

Do not:

- Concentrate artificial light on your solar module.

2. Cleaning

Your solar module must remain clean at all times.

Do:

- Inspect your solar module regularly for dirt such as dust or bird droppings.
- Clean your solar module once every three months (or when dirty) using clean water and a soft cloth.

Do not:

- Use soap or detergent.

3. Security

Ensure that a fence with padlocked gate is put around the array, and make sure the fence is high enough to prevent vandals or thieves but not too high to cast a shadow on the solar array.

If the solar array is set up on a building, ensure it is well anchored to the building and access is limited. Do not fix a wire mesh around it as it is already secure. This is because shadows cast by the wire mesh will make it produce less energy.

4. Safety

Your solar module consists of glass which can easily break.

Do not:

- Throw objects at the solar module.
- Stand or step on the module.
- Try to repair your solar module if it breaks because once the module is broken, it cannot be repaired.
- Carry out modifications on your system without technical guidance from your system supplier or a qualified technician.

5. The Charge Regulator

Do:

- Ensure connections are firm. In case of a problem, consult your solar installer or supplier.

Do not tamper with it.

6. Cable Network

- Inspect the cable network every three to five years to ensure there are no exposed wires.

- Protect your solar wiring from damage as this can result in the failure of your system.
- Avoid short circuiting your cables as this can lead to system damage.

7. If a solar battery is installed:

Do:

- Keep the solar battery in a clean environment.
- Place the solar battery on a stable surface to prevent it from falling or tilting.
- Keep the solar battery safely inside a well-ventilated wooden box.
- Always check the level of electrolyte in every cell of your battery. If the level has gone down, add some distilled (or de-ionized) water.
- Top the solar battery with distilled water from a good source, never use tap or rain water since they have impurities, which may damage your battery.
- Apply Vaseline, not grease or oil, on both battery terminals to prevent acid mist (a white substance) forming on them.
- Clean the terminals and battery's top surface regularly with hot water to prevent accumulation of acid mist which causes batteries to self discharge.

Do not:

- Short -circuit the terminals of your solar battery. Your solar battery stores huge amounts of energy. If you connect the terminals directly, the stored energy will be released at one go causing the wires to melt or fire to occur. All power must be consumed through the installed regulator. This will protect your solar battery for a long time.
- Pour out the acid and fill with fresh acid as it damages the battery.
- Add acid to your solar battery at any time.
- Accept advice on battery repairs from unauthorized persons. Rather, contact battery suppliers directly.
- Keep the solar battery near open flames as there is danger of explosion.
- Take your old batteries for repair.

Annex 6.18 Infiltration Galleries

They can be constructed on river banks or a stream bed (see diagram below). A slotted pipe is buried in a trench of gravel in the river bed or bank. This leads to a collection well where the water is pumped out. Several grades of gravel can be used, the larger sizes closer to the infiltration pipe

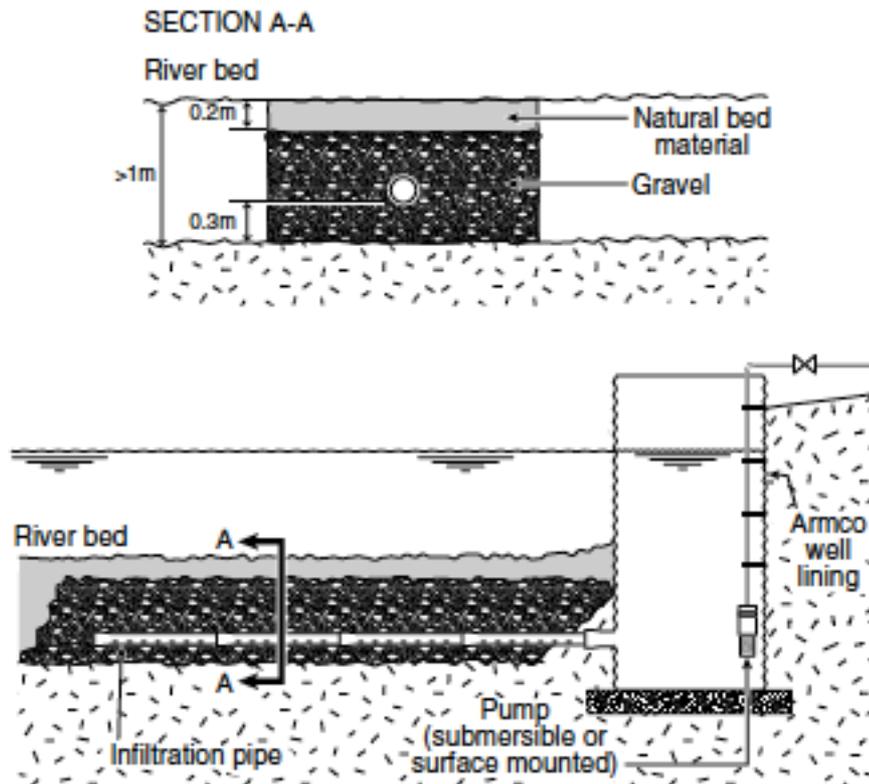


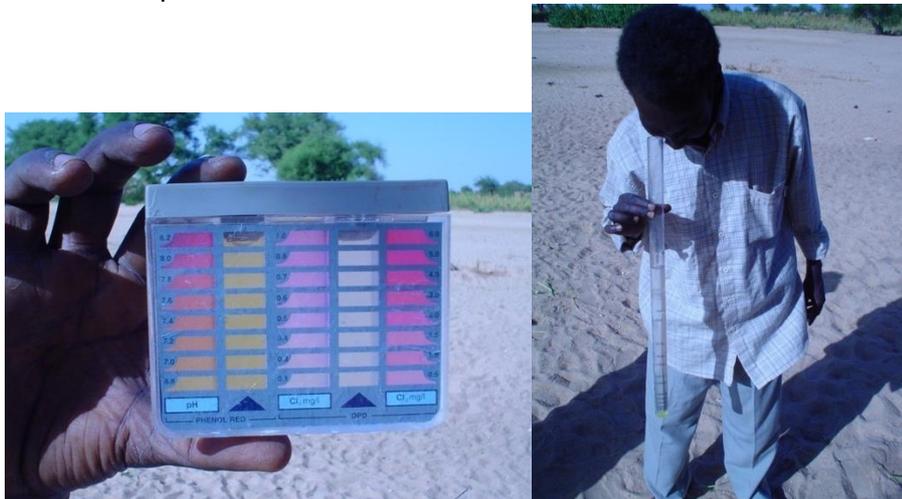
Figure: A river bed infiltration gallery (taken from Engineering in Emergencies, J Davis and R Lambert, Practical Action Publishing, 2002)

Annex 6.19 Jar Tests for Alum Coagulation and Chlorination Dosing

Water analysis and jar tests for aluminum sulphate:

For pre-tests of raw water

Measure the pH with a pool tester and turbidity with a turbidity tube to ensure a pH of 6.5 – 7.5



Pool tester and turbidity tube photos courtesy of E. Fewster

Jar tests

1. Prepare a 1% mother solution of aluminum sulphate by dissolving 10 grams of granular alum into 1 liter of clean water.
2. Use 6 one liter transparent measuring beakers and rinse each one three times with the raw water to be treated.
3. Fill the rinsed beakers to the one liter mark with the raw water to be treated.
4. With a syringe, inject a dose of the 1% mother solution in the following quantities, 5 ml, 6 ml, 7 ml, 8 ml, 9 ml and 10 ml and mark each jar with the dosage injected.
5. Stir the coagulant thoroughly in a circular moment for approximately one minute
6. Wait approximately 30 minutes, observing forming of flocs and measure the turbidity of each beaker.
7. Identify which beaker has the clearest water on top, with the greatest number of settled flocs on the bottom.
8. If there are no beakers with any flocs, repeat the exercise with new dosing concentrations (10ml, 12ml, 15ml, 20ml, 25ml, 30ml) following the instructions above.
9. **If it is difficult to determine the best result between several jars, use the one where the least amount of coagulant was injected.**
10. Extrapolate how much coagulant is required for the production of a large volume of water based on the 'ideal' dose that has been determined by the jar test.



Field Jar Test – photo courtesy of S House

Example calculation below:

Calculate the dosage required for a 30,000litre tank if the jar test indicates 3ml of aluminum sulphate per liter of raw water:

- Jar test indicates 3 ml of aluminum sulphate per liter of raw water,
- Aluminum sulphate required for 30,000 liter tank = 3 ml / l x 30,000 l = 90,000 ml/tank

or 90 l of 1% mother solution per batch of 30,000 liters

- Based on the active ingredient of $\text{Al}_2(\text{SO}_4)_3$,
- 5kg would be required for 90 l (55.6 g / l x 90l)

Water analysis and jar tests for calcium hypochlorite (HTH):

For Pre-tests of raw water, measure:

- pH with a pool tester for pH of 6.5 – 7.5,
- turbidity with a Turbidity tube for turbidity of < 5 NTU
- water temperature with a thermometer to ensure a water temperature of 20°C

Jar tests

1. Prepare a 1% mother solution of chlorine by dissolving 14 g, approximately one soup spoon full) of calcium hypochlorite (HTH) with 65 – 70% active chlorine
2. With 4 x 20 liter buckets rinse each one three times with the water to be treated
3. Fill the rinsed buckets to the 20 liter mark with the water to be treated
4. With a syringe, inject a dose of the 1% mother solution in the following quantities, 1 ml, 1.5 ml, 2 ml and 2.5 ml and mark each jar with the dosage injected
5. Wait approximately 30 minutes. NB. This is the minimum contact time required for chlorine to react for water that has a pH < 8. If the pH > 8, contact time is increased to 60 minutes
6. Measure the free residual chlorine of each bucket, choosing the sample that has a range of 0.5 mg/l
7. If needed, fine tune the dosing following the instructions above and
8. Extrapolate how much HTH is required for the production of a large volume of water (e.g. 2 m³) based on the 'ideal' dose that has been determined by the jar test

Example calculation: how much HTH is required for a 2000 liter bladder if jar tests indicate 2ml of 1% solution is required for 20l bucket.

- Jar test indicates 2 ml of 1% mother solution per 20 liter of water,
- means that it needs 100 times as much to chlorinate 2000 liters,
- or $100 \times 2 \text{ ml} = 200 \text{ ml}$ of 1% mother solution

Water Testing Log / Record

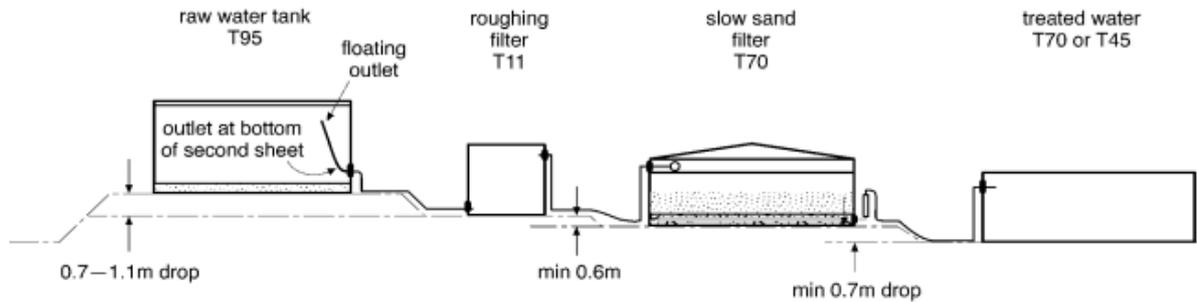
Name of Technician: _____

Location: _____

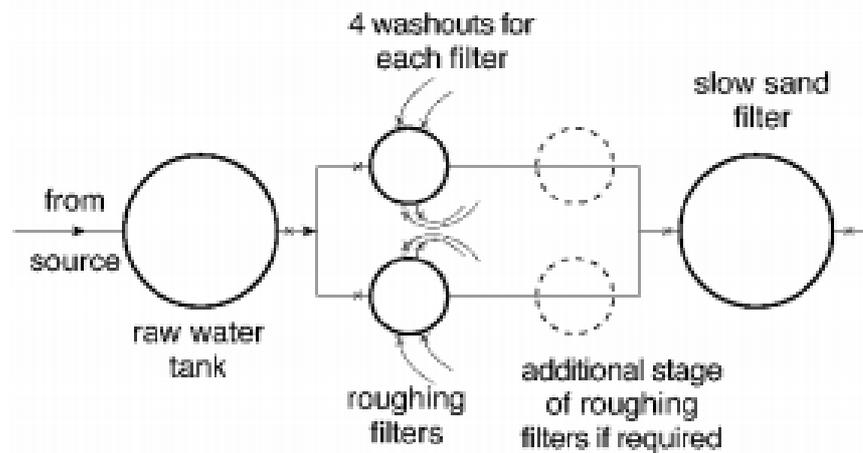
Date and Time	pH	Turbidity (NTU)	PAC or other coagulant (mg/l)	Free Residual Chlorine (mg/l)	Fecal Coliforms (# per ml sampled)	Notes / Problems

Annex 6.20 Oxfam Slow Sand Filter Kit

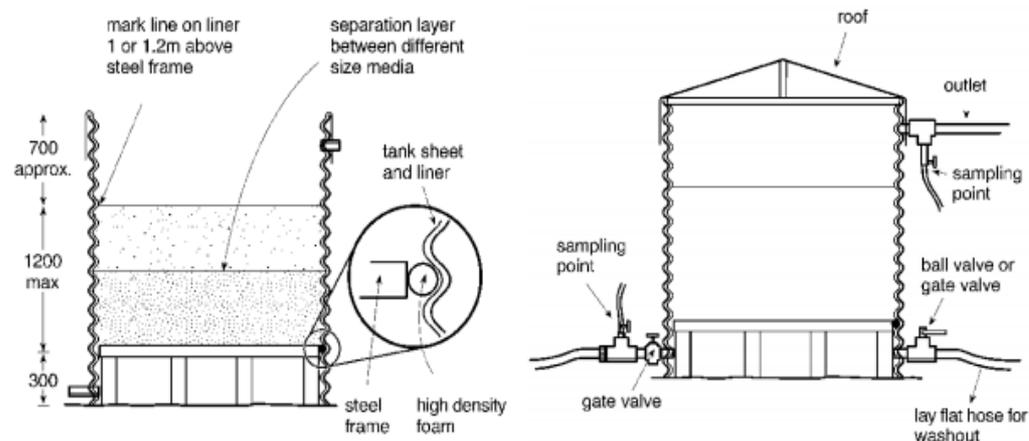
For complete details of setting up an Oxfam Slow Sand Filter Kit see <http://www.bvsde.paho.org/texcom/desastres/oxfamwfm.pdf>



Set up of components of kit: Raw water tank, roughing filter, slow sand filter and chlorination tank

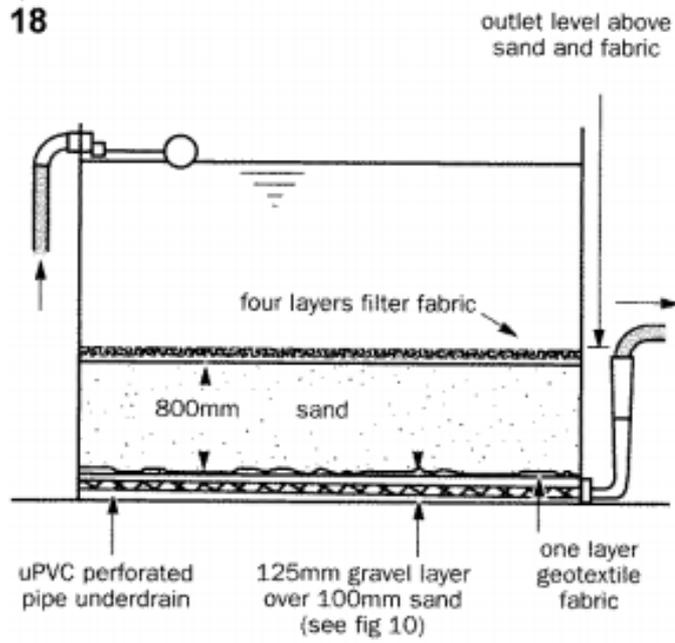


Plan of set up



Roughing Filter construction details

18



Slow Sand Filter Details

Annex 6.21 Microbiological Testing of Water Quality

There are too many pathogenic organisms in water to test each type, almost all are related to faecal pollution, except Guinea worm. An overall indicator of likely faecal pollution is the easiest way to assess the microbiological water quality. *Escherichia coliform* (*E.Coli*) is the best indicator organism, more generally thermotolerant coliform are easily tested in the field (and 80% of thermotolerant coliform are *E.Coli*). Sphere refers to thermotolerant coliform as 'Faecal coliform'.

Microbiological analysis of water quality tests are usually undertaken using either membrane filtration tests (such as included in the Wagtech/Palintest field kits) or using the Most Probable Number (MPN) method (which tends to be undertaken in a laboratory) or testing for hydrogen sulphide (H₂S). The H₂S tests do not however only indicate faecal contamination, but can also indicate other environmental based H₂S producers or H₂S naturally occurring such as in groundwater. The membrane filtration and MPN tests are not instant tests and take time to collect samples, process and incubate. The membrane filtration test requires an experienced operator to take samples and to filter and incubate the water, all of which can lead to errors. The results are more precise (when error free) than MPN testing. MPN testing is easier to perform and less likely to have operator error but is generally undertaken in a laboratory.

The SPHERE key indicator for microbiological water quality is 0 faecal coliforms/100ml of water at point of delivery and use.

If using Wagtech/Palintest or Delagua kits or MPN kits, refer to operator's manuals for details.

A range of Wagtech/Palintest kits can be found on this link with further links for brochures on the specific kits pages.

<https://www.palintest.com/en/products/categories/drinking-water-wastewater-and-process-water?category=wagtech-water-safety-kits>

For the Delagua kit:

<http://www.delagua.org/assets/library/329/DelAgua-Kit-Manual-Version-50-English.pdf>

For most probable number (MPN) methodologies, the following provides a link to Chapter 10 of "Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes". Bartram J and Balance, R, 1996 UNEP/WHO.

http://www.who.int/water_sanitation_health/resourcesquality/wqmchap10.pdf

The whole book can be found here:

http://apps.who.int/iris/bitstream/10665/41851/1/0419217304_eng.pdf

Annex 6.22 Types of water tank for emergencies

Source: Public Health Engineering in Precarious Situations, MSF, 2010

Most commonly used tanks in emergencies

Type	Capacity m ³	Set up	Use	Remarks
Bladder (pillow tank) Closed tank	0.85 2 5	-Very easy and fast to set up - Mountable on a flatbed truck	- Storage - Chlorination - Transport	- Static or mobile - Difficult to clean
Bladder (pillow tank) Closed tank	15	- Very easy and fast to set up	- Storage - Chlorination	- Static - Difficult to clean
Onion tank Self sustaining open tank with roof	30	-Very easy and fast to set up	- Storage - Chlorination - (Assisted) sedimentation	- Static - Relatively difficult to clean
Liner tank supported by metal frame Open with roof	10 30 60	- Easy and relatively fast to set up	- Storage - Chlorination - (Assisted) sedimentation	- Static - Easy to clean when mounted
Corrugated iron sheet tank with a separate lining Open with roof	11 45 70 95	- Least easy to set up - Bulky transport because of corrugated sheeting	- Storage - Chlorination - (Assisted) sedimentation	- Static - Easy to clean when mounted - Less suited for acute emergency - Longer life expectancy

Source: Public Health Engineering in Precarious Situations, MSF, 2010

Annex 6.23 Bladder/Onion tank and Tapstand Construction

- Find a position for the water point that allows a flat space for the bladder, onion or PVC tank at least 1.5 m above the site for the tapstand to allow gravity flow of water. If the bladder is to be put on a roof, assess the ability of the roof to safely support that weight of water.
- If necessary, construct a platform for the bladder tank using earth and sandbags or similar to ensure a stable platform when the bladder is fully loaded. If the platform is made of compacted earth, it is advisable to allow an extra 0.5m platform border around each side of the bladder. Lay out the groundsheets before the bladder is put down, checking the ground for any sharp objects that could pierce the bladder first.



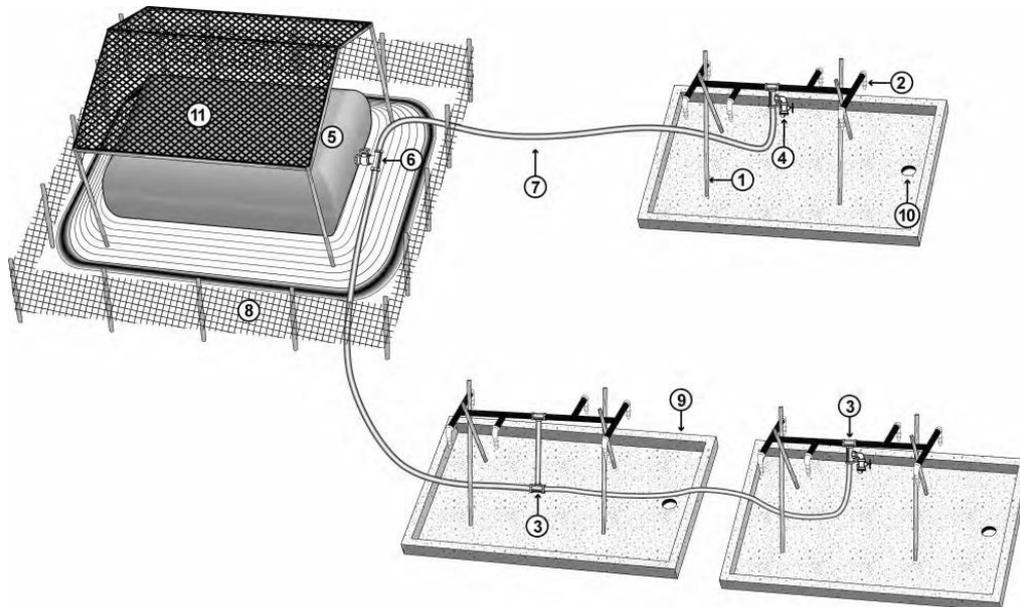
Bladder on raised earth embankment above tapstand, Afghanistan (photo credit: Eric Fewster)

- Where water distribution points will be used in the medium to long term, they will need to be protected, pipes should be laid underground, storage tanks require

protection from the elements, either through their materials of construction (metal with rubber liner or concrete) or with a roof for shade or to prevent covering with snow, tapstands will require protection from freezing if this is likely. Where a tank is to be placed on a flat roof, ensure the roof has the strength to carry it safely.

- Decide on the number of tapstands, for a 10,000 liter bladder tank, 1 or 2 tapstands (6 or 12 taps) is recommended. The SPHERE handbook has an indicator for adequate water access of 250 people per tap and a distance to collect water of 500m.
- Site the tapstand(s) about 5 to 10m from the tank, close enough to allow a good flow through the pipes but not too close that people collecting water are likely to damage the tank. Ensure issues that could impact vulnerable groups in the siting of the tap stands (not just technical issues) i.e. protection concerns, ease of collection, equity, elderly, disabled, children etc. are addressed through discussions with the groups themselves. Child-friendly tapstands would include ensuring that taps are not too high; that they are robust but easy to operate; that if there are steps to the tapstand they are not too high; that there is a step or stand to allow children to lift containers halfway and rest before they lift them up onto their head.
- The taps on the tapstand should be positioned slightly higher than the height of the tallest container so that they minimize splashing and wastage. The legs of the tapstand are longer than the maximum height, to allow them to be dug into the ground or set in a concrete drainage apron.
- Ensure there is good drainage of wastewater, the best way is to construct a concrete apron to collect spilt water around the tapstand which is then channeled off to a dug soakaway pit filled with large stones.
- Fence off the tank to prevent unauthorized access and dig a drainage trench around the base of the platform or tank site to reduce erosion.
- If the tank is to stay for any length of time, construct a roof from available materials to prevent UV deterioration of the tank.

Source: Public Health Engineering in Precarious Situations, MSF, 2010



Key	Input
1. Tapstand	- Reservoir for water supply
2. Self closing taps	- Tapstand kit(s)
3. Double connection (different models)	- Delivery pipes
4. Stopper and chain	- Material to make apron (T.B. 2.04)
5. Reservoir	- Material to make roof (leaves, shadow net, plastic sheeting, poles, timber, rope, tools)
6. Reservoir outlet and tee	- Spanner to fix the tapstands' legs
7. Delivery pipe towards the tapstand	- Hook spanners
8. Fence	
9. Apron with a protective kerb	
10. Drain towards the infiltration system / garden	
11. Roof	

Annex 6.24 Construction stages of Oxfam type tanks

From Engineering in Emergencies, J. Davis, R. Lambert, 2002 Practical Action

<i>Oxfam ordering code</i>	<i>Nominal storage capacity (litres)</i>	<i>Height (m)</i>	<i>Diameter (m)</i>
T11 S,L,R	10 500	2.3	2.5
T45 S,L,R	45 000	1.5	6.4
T70 S,L,R	70 000	2.3	6.4
T95 S,L,R	95 000	3.0	6.4

Preparation of ground for placement of tank:

A circle with a diameter of at least 1m larger than the tank diameter needs to be leveled and cleared of sharp objects such as stones, roots etc. Where soil is likely to compress under weight of water (such as black cotton soil), a concrete ring of width 0.3m can be constructed at least 0.25m deep (with reinforcement for very soft soils) with a smooth top surface for the steel sheets to sit on.

The tanks can be built on raised earth platforms to provide extra head. These need to be very well compacted to ensure no further settlement when the tank is full, leading to tank collapse.

Make sure that the ground the butyl rubber liner sits on does not have any oil-based spillages as these can destroy it.

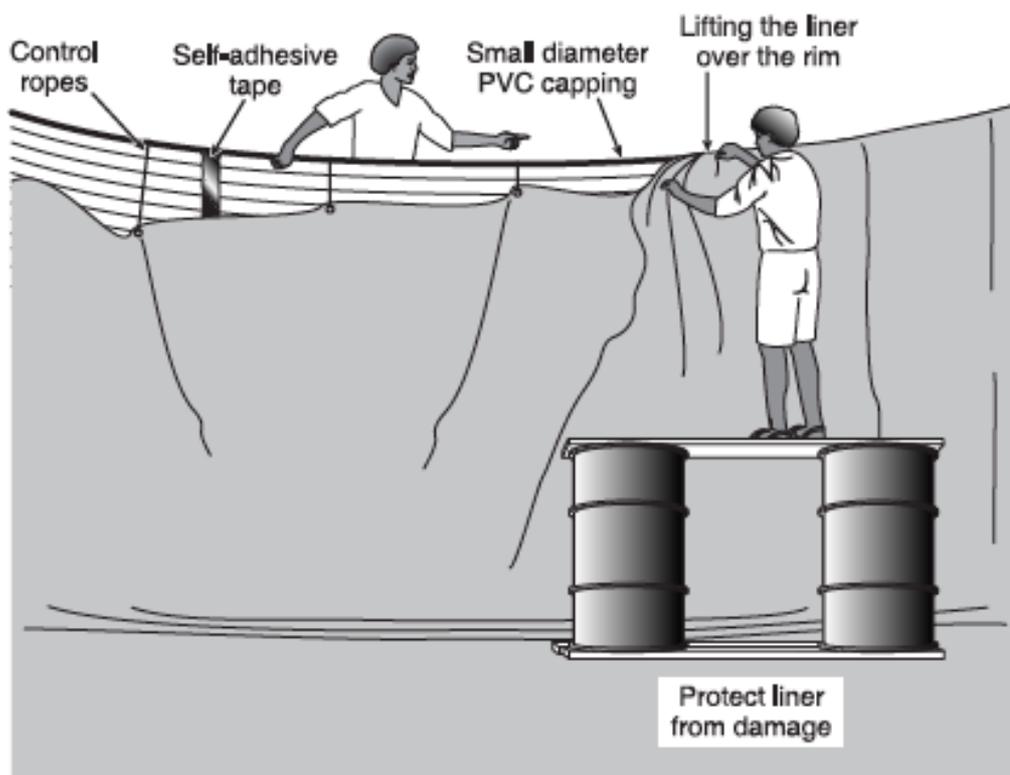
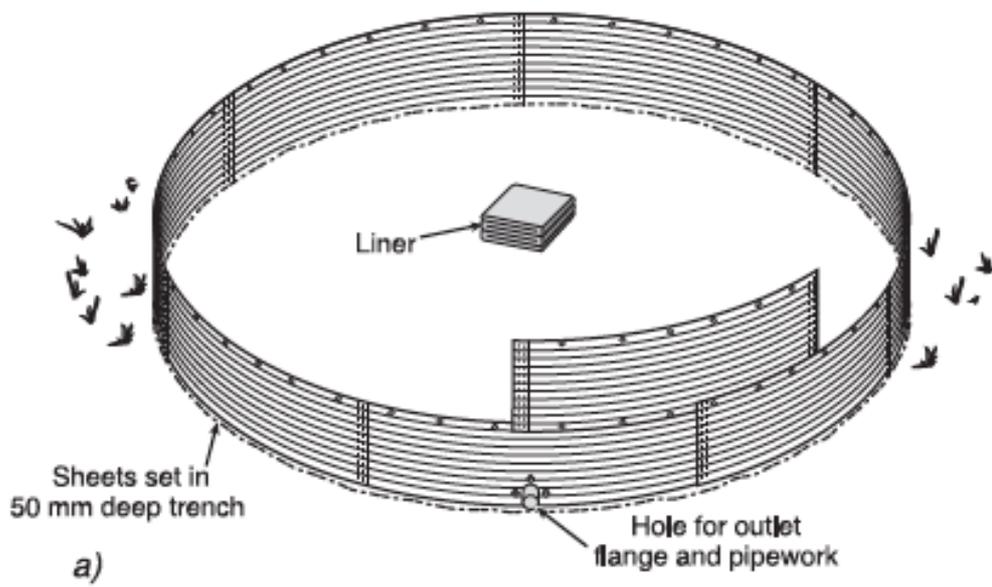
Dig a 50mm deep trench the diameter of the steel tank sheets so that they sit in the ground, preventing the butyl rubber liner from bulging out from underneath and bursting.

Similarly constructing an earth bank around the tank will protect the ground at the edge of the tank from rain erosion. This would lead to the rubber liner bulging out from under the base of the steel sheets and bursting.

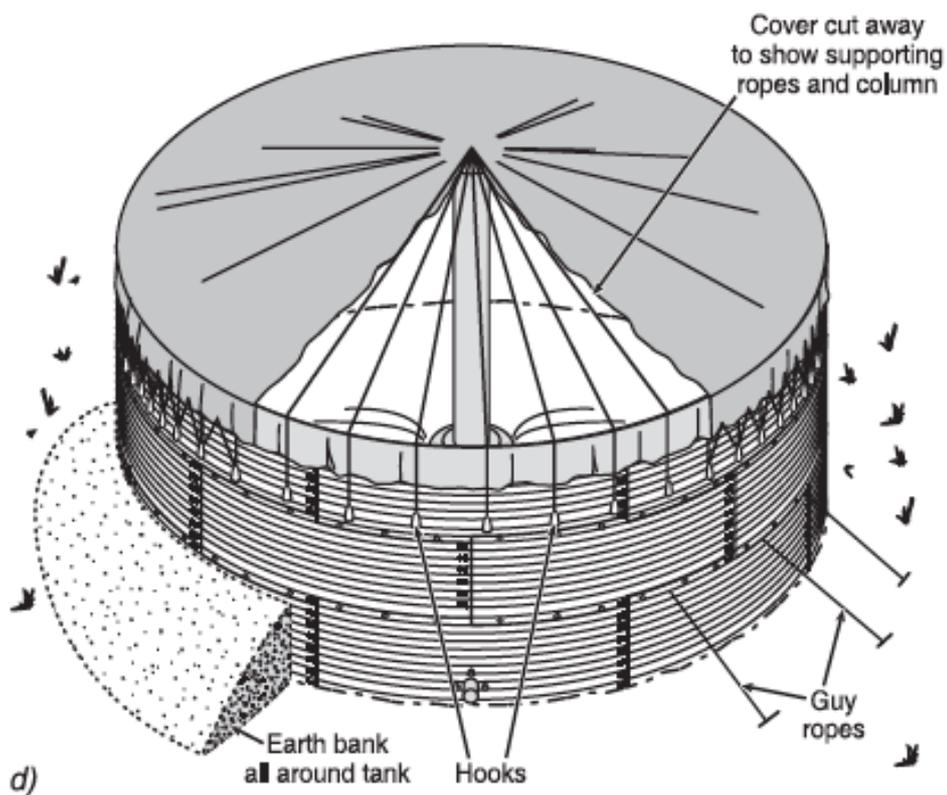
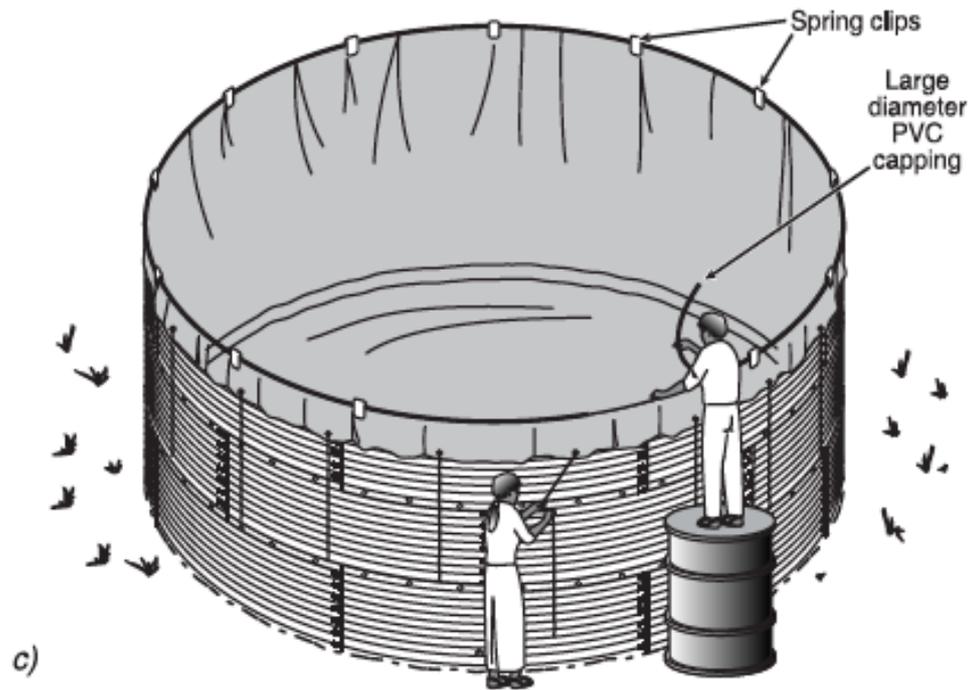
For the taller tanks, it is vital that the tanks are built vertically as any deviation from the vertical will over time encourage the tank to lean further, and cause a collapse.

It is vital to regularly monitor the tank for:

- signs of soil erosion around its base or erosion from leaking valves;
- any signs of the tank no longer being vertical,
- rust from any treatment chemicals
- tears in the liner



b)



Diagrams are from Engineering in Emergencies J. Davis and R Lambert, IT Publications (2002)
 For specific details of setting up Oxfam tanks see:
https://www.oxfam.org.uk/equipment/catalogue/resources-included-available/water-and-sanitation/water-storage/Water_Storage_Manual.pdf/at_download/file