3. Water Supply

Safe water is essential for life, health and human dignity, and is a critical determinant for survival of a displaced population. In refugee emergencies consumption of contaminated water and insufficient water for personal and domestic hygiene can put the population at extreme risk. Water is among the primary criteria in the selection of a site for refugees.

Introduction

The importance of safe water supplies in refugee settings

1. Safe water is essential for life, health and human dignity. People cannot survive longer than a few days without water and therefore the provision of adequate quantities of safe water demands immediate attention from the start of any refugee emergency. Consumption of water contaminated with faecal pathogens can quickly put the population at extreme risk of water-borne diseases such as diarrhoeal diseases and enteric fevers. Consumption of water contaminated with harmful chemicals present in the aquifer geology, or from domestic, agricultural, or commercial activity can put the population at risk from lethal, acute, or chronic toxic effects.

All water supplies in the refugee setting must be fit for human consumption, free from faecal pathogens and harmful chemicals that may be present as a result of the aquifer geology, or contamination from industrial, agricultural and human activity.

2. Water is an essential element to ensure the refugee population is able to carry out basic personal and domestic hygiene including: washing hands with soap; bathing; laundering clothes, bedding and menstrual management materials; cleaning the domestic environment; cleaning eating and cooking utensils; cooking; and practising safe food hygiene. Insufficient quantities of water for personal and domestic hygiene can put the population at risk from both water-borne and water-washed diseases including scabies, ringworm, trachoma, conjunctivitis, louse-borne typhus and relapsing fever. After the emergency phase, water will be essential for watering animals, and basic agricultural and livelihood activities. In some places, water-based sanitation may be the preferred method of conveying and treating excreta, or may be the culturally preferred method of anal cleansing. A safe and sustainable supply of water is among the primary prerequisites in the selection of a temporary or permanent site for refugees.

3. Providing sufficient access to water is an important factor in reducing the risks of violence and conflict between hosts / refugees, neighbours, and adults and children. Queues at water points around collection times can often lead to frustration and violence. Women and children may be subject to domestic violence if they are perceived to be taking too long to collect water.

Safe water supply as part of a comprehensive public health approach

4. The provision of adequate quantities of safe water must be seen as an essential element of the larger preventative health strategy with the overall aim of improving the health status of the population. The link between contaminated water, insufficient quantities of water and disease must be clearly understood by all.

Messages concerning the importance of safe water abstraction, handling, storage and consumption must be fully incorporated into the community health and hygiene education programmes. Water availability and water quality parameters should be investigated as part of the Health section's case management and follow up activities.

The importance of seeking expert professional advice

5. The implementation of water supply programmes in refugee settings can be complicated by additional constraints that include:

   i). Sites that are arid with water supplies that are difficult to locate and extract; at extreme depths, or of small quantities.
   ii). Sites that are marshy, have high water tables, or where water supplies are heavily contaminated.
   iii). Sites where surface water sources are contested or need to be shared with local host populations without over-exploitation or conflict.
   iv). Sites where water is of poor quality due to high mineral content, saline intrusion, or contamination from industrial, agricultural, or human activity.
   v). Sites that are geographically remote and challenging to access with water prospecting, water trucking, or water development equipment.
   vi). Sites with high density urban populations with water infrastructure that requires retrofitting or upgrading.
   vii). Sites where the population is unfamiliar or unwilling to use improved water supplies, resorting to traditional unprotected sources.
   viii). Contexts with lack of qualified and experienced personnel.

6. Due to these challenges it is essential to seek expert advice from professional water engineers who are familiar with the context. Assistance can be sought from sources such as government departments, NGOs, Universities, consultants or contractors. UNHCR Headquarters and Regional assistance should be requested if required.

The importance of respecting UNHCR's WASH philosophy and principles

7. In addition to the guidance in this chapter, all water supply programmes must be designed and carried out in full accordance with UNHCR's general WASH principles including (refer to **Chapter 1** for more information).

   - Safety and protection
   - A timely and adequate response
   - Participation of stakeholders
   - Universal access
   - Child friendly facilities
   - Designs and construction that meet minimum standards
   - Value for money and cost effectiveness
   - Appropriate technology
   - Sustainable solutions
   - Reinforcing the capacity of stakeholders
   - Monitoring the effectiveness of WASH interventions
   - Protecting the environment
   - Planning for contingencies


UNHCR

Priority actions

An immediate response

8. The human body's basic survival drinking water requirement lies in the range of 3-7 litres / person / day, depending upon the climate, workload and other environmental factors. Taking into account the need for additional water for cooking and basic personal hygiene, it is essential that UNHCR and WASH actors ensure that the refugee population has access to a minimum of at least 15 litres / person / day on immediate arrival at the refugee setting. Basic water interventions (for example distributing water directly off the back of a water tanker) are better than delayed provision of improved systems. As the emergency response progresses, it is typical to employ a staged approach whereby water accessibility (in terms of distances and numbers of water points) and water quantity are both steadily increased as more water infrastructure is installed and brought online.

People cannot survive more than a few days without water and the speed at which water supply systems are established must be given absolute priority. Since water is a basic survival need, the priority in any response must be to provide water of sufficient quantity as quickly as possible whilst respecting quality.

9. Due to the health risks associated with drinking contaminated water, it is essential that UNHCR and WASH actors either select water supplies that are fit for human consumption, or can be easily treated so that they are fit for human consumption. Basic water treatment interventions, for example disinfecting with chlorine in a water tanker en-route to the setting, allowing suspended matter to settle overnight in storage tanks, or distributing water treatment tablets, are better than delayed provision of improved treatment systems. Some NGOs that are specialized in emergency response have developed compact water treatment units that are able to rapidly treat large volumes of water and are very useful in certain contexts during the initial emergency response phase.

Provision of water of sufficient quantity

10. Optimum standards in most refugee settings call for a minimum per capita allocation of 20 litres/person/day for human consumption, cooking, laundry and personal hygiene. In reality the total daily water production needs to provide more water than this to not only meet the per capita water demand, but also take into account spare capacity for communal needs (allow 10%), and an allowance for wastage and leaks (allow 15%). Some general basic water consumption planning figures can be found in the box on the following page.

11. In urban settings the influx of the refugee population may place a huge burden on existing municipal water services. UNHCR and WASH actors should plan water interventions to restore levels of service to meet conditions prior to the influx. This typically requires rehabilitation of existing

infrastructure and construction of new water supplies in areas with high numbers of refugee families.

Box: UNHCR water consumption planning figures

Water need	Water quantity
Basic needs	20 litres/pers/day
Transit centres	20 litres/pers/day
Anal cleansing	1-2 litres/pers/day
Conventional toilet	30 litres/flush
Pour flush toilets	5 litres/flush
Handwashing	1-2 litres/pers/day
Cubicle cleaning	5 litres/cubicle/day
Schools	5 litres/pupil/day
Mosques	5 litres/pers/day
Health centres and hospitals	5 litres/visitor/day 60 litres/bed/day
Cholera centres	60 litres/bed/day 15 litres/carer/day
Therapeutic feeding centres	30 litres/bed/day 15 litres/carer/day
Cattle / donkey / horse / mule	40 litres/beast/day
Sheep / goat / pig	5 litres/beast/day
Crop irrigation	5 litres/m^2/day

Note: Quantities are minimum values and figures should be adapted to context.

Adapted from UNHCR Handbook for Emergencies 3rd Ed (2007).

12. Water production and consumption rates (from rapid household surveys) should be closely monitored during all phases. Up to date daily water availability figures from tanker or pumping logs should be closely tracked and fully documented in the site WASH plan/strategy along with an analysis of any trends and discrepancies in service levels.

13. Once the basic human needs have been met, UNHCR and WASH actors may consider increasing the availability of water for livestock, agricultural and livelihood activities. Provision of additional water should be carefully planned with the refugee and host populations in a transparent manner so that all sections of the population are able to benefit equitably and responsibly. Water for livestock, agricultural and livelihood activities should be closely monitored and documented in the medium and long term strategies for equitable and responsible water resource management in the site WASH plan/strategy. Any historical records of community meetings related to water for livestock, agricultural and livelihood activities should be included as an annex to the site WASH plan/strategy.

The 20 litres/person/day target figure is a minimum planning value. In every context efforts should be made to match water availability to ensure the refugee population is able to experience a similar standard of access to their place of origin or the same level of access as the host community before the crisis.

Provision of water of sufficient quality

14. UNHCR and WASH actors must ensure that all water supplies in the refugee setting, regardless of their intended use, are fit for human consumption. All water supplies must be free from faecal coliforms at the point of storage, delivery and consumption. All water supplies must be tested for common chemical contaminants based on an analysis of hydrogeological conditions, and

local industrial, agricultural and human activity (see **section 3.91**).

15. The greatest threat to refugees during an emergency is from diarrhoeal disease outbreaks. Therefore at a minimum, UNHCR and WASH actors must ensure that all water supplies, regardless of use, are properly treated with chlorine so that a free residual of at least 0.5 mg/l is present at the point of water distribution. A surveillance system must be in place to ensure that all water supplies are free from faecal coliforms at the point of storage, delivery and consumption. Even if water supplies have been chlorinated they must also be checked for faecal contamination resulting from insufficient contact times, inadequate chlorination procedures, water network leaks and post delivery contamination.

16. UNHCR and WASH actors must also ensure all water supplies are free from chemical contaminants that are harmful to health either in the short or long term. In all cases, UNHCR and WASH actors must ensure that the quality of water supplied complies with national water quality guidelines. In the absence of recognised national standards, UNHCR potable water supply programmes should refer to the recommendations and guideline values contained in the WHO Water Quality Guidelines (2011).

An immediate distribution of water containers

17. UNHCR and WASH actors must ensure that the refugee population has immediate access to sufficient quantities of water containers to facilitate collection, treatment and storage of water for drinking, cooking, cleaning, bathing and laundering purposes. The minimum quantity of water storage per person should be no less than 10 litres per person in all settings. Often, the refugee population will arrive in a camp or community with virtually no possessions. One of the first activities they will need to carry out is the collection of water; therefore, the rapid distribution of water containers is an essential activity.

18. Water containers should be durable, stackable, and easy to use by older persons, pregnant women, children, people living with HIV and AIDS, and disabled people. If flexible water containers are used, new water containers may need to be distributed every six months. If more durable rigid water containers are used, then the period of replacement may be longer. All water containers should be closed with a narrow neck and screw cap to prevent secondary contamination.

19. Water container condition should be closely monitored and cleaning or replacement activities should be initiated if needed. Small quantities of soap or bleach should be made available through the hygiene promotion programme for container cleaning purposes. Household surveys should be used to monitor that availability and condition of household water containers.

Immediate protection of water sources

20. In order to reduce the burden of treatment, UNHCR and WASH

actors must ensure that steps are taken to immediately protect all water supplies from sources of contamination including pollution from excreta management, solid wastes, and domestic, agricultural, or commercial activities. Water sources may need to be upgraded to ensure they have functional sanitary seals and surface water diversion channels. Fencing and the use of guards can be used to stop animals and people defecating near water sources.

Selection of sites based on water quality and ease of treatment

21. UNHCR and WASH actors must ensure that the selection of sites for refugees is based upon a thorough investigation of the quality of water available and the required treatment to make them potable. Sites with groundwater should be prioritized as they are generally less susceptible to contamination from domestic, agricultural, or commercial activity and they generally require less treatment.

22. When selecting a site for the refugee population, the assessment of each water source should include..

- Discussion with local public health and water authorities to identify known aquifer or water source water contaminants and treatment requirements; taboos and seasonal variations.
- A sanitary survey to identify contamination risks in the immediate vicinity of the water source along with any corrective and mitigative actions.
- Catchment risk mapping, identification of zones of domestic, agricultural and industrial activity within the vicinity of the water source along with an assessment of the types and risks of contamination to aquifers or surface water bodies.
- An analysis of water quality parameters (based on the risks identified in the stakeholder interviews, catchment mapping and sanitary surveying exercise).
- An analysis of any secondary data sources to determine spatial and temporal water quality characteristics.
- An analysis of the type and level of treatment required to make the water source fit for human consumption.

23. In addition to carrying out an assessment at the water source, sanitary surveys should also be undertaken in and around the refugee setting to identify risks from solid waste, medical waste, and faecal waste to water aquifers in particular the risk of leachates from collection, storage and final disposal activities.

Water accessibility and reducing the burden of water collection.

24. UNHCR and WASH actors must ensure that the refugee population is not unnecessarily burdened with the task of collecting water. The most effective way to achieve this is to ensure that sufficient numbers of water points are located close to dwellings. Long round trip times in excess of 30 minutes are likely to reduce the amount of water used in the home, negatively impacting


SEWING MACHINE
缝纫机机头
SEWING MACHINE HEAD
MADE IN THE PEOPLE'S REPUBLIC OF CHINA
UNHCR

on domestic and personal hygiene. In some situations long queues and / or distances may result in the refugee population resorting to unprotected sources. Queues can also contribute to frustration and violence, or domestic violence for having taken so long to collect water. Reducing distances and the numbers of users per water points may also increase a sense of ownership of the water collection point.

25. In all planned settlements, a functional water tap must be available for every 100 persons (or every 200 persons in the case of a handpump or well) and water points must be available within 200m of every household. Examples of maps showing water collection buffer zones can be found in **Chapter 10**. Water point coverage should be routinely reported in the site WASH plan/strategy (and mapped where possible).

26. Excessive queuing of more than 10 persons at water points is an indicator of either insufficient numbers of water points, inadequate flows, or insufficient hours of operation. In settings where the refugee population is integrated with the host population, it is essential to re-establish the same standards of water access as the host population prior to the emergency. In locations with high numbers of refugee families this may require the provision of additional water infrastructure, or repairs to existing infrastructure.

27. Water points must be located so as to ensure the physical safety users. The location of water points must take into account protection issues of all users. In many contexts the burden of collecting water for domestic use falls to women and children. Protection issues can include the potential of water source locations to expose populations to the risk of Gender Based Violence (GBV) during water collection.

Working in collaboration with local service providers and local authorities

28. It is highly critical that UNHCR and WASH actors do not undermine or replace the local authorities or service providers responsible for water supply services. In all scenarios, water supply programmes should be carried out in close collaboration with national actors and in full compliance with national legislation. In many cases, local authorities or service providers responsible for supply may be overwhelmed by the additional burden created by the refugee population. Programmes should aim to strengthen capacities and build resilience from the start. Where possible, WASH programmes should aim to handover service operation and maintenance to the local authorities.

Water sources

Surface water sources

29. Surface water includes water abstracted from ponds, streams, lakes, marshes, irrigation ditches and dams. The advantages of using surface water sources in an emergency response is that they can be rapidly exploited to provide

large quantities of water in a short period of time.

30. Surface waters are prone to contamination and must be immediately protected. Unless surface water is abstracted high in the mountains, or in areas with low population density, surface water quality is often poor in terms of high quantities of suspended particles and high levels of microbiological contamination. Surface water invariably requires significant levels of treatment before it can be used a potable supply.

Figure 3-1 Multiple use surface water

UNHCR and WASH actors must ensure that people are immediately prevented from defecating, bathing, washing clothes, or watering animals upstream of any settlements or surface water intakes.

31. Surface waters tend to exhibit high temporal variability in terms of water quality and availability. This variability can be diurnal or seasonal and may reflect long-term trends that are difficult to assess in an emergency. Surface water sources may even dry up completely for parts of the year. Surface waters are often subject to high sediment loads (turbidity spikes) following periods of heavy rainfall, which can affect the treatment processes.

32. Before a surface water source is chosen for a long term refugee settlement, hydrological data (in particular average monthly precipitation and flow rates) and catchment data (size, evaporation and run-off data) must be sought. The seasonal variation of the source should be determined from local sources of information. The catchment area for the surface water source should also be mapped and all potential sources of agricultural, domestic and commercial contamination should be identified. The water must be analysed for harmful contaminants based on an assessment of likely contaminants originating within the catchment.

33. In the long-term, reliance on pumping water from surface water sources, and the use of water treatment equipment and chemicals, can make the use of surface water unsustainable. In many scenarios, it is unlikely that the refugee population, host population, or local authorities will have the capacity to procure the necessary fuel, spare parts and water treatment chemicals when the emergency period is over.

Figure 3-2 Floating surface water intake

34. As a general rule surface water sources should not be considered suitable long term solutions for refugee settlements if feasible groundwater alternatives exist. The capital investment costs associated with detailed feasibility studies, environmental impact assessments, and civil engineering, are likely to be prohibitive. In addition, the need for treatment and maintenance is likely to entail continuous financial and technical support. These overhead costs are likely to be prohibitive and difficult to fund over the average lifespan of a camp. In addition, present demands on surface water source may cause conflicts, especially in areas where water is scarce. In all cases, the upstream and downstream effects should be investigated and mitigated.

Groundwater sources

35. Groundwater is water flowing through and residing in rock voids, pores and fissures in the ground. An aquifer is a geological formation or layer, made up of permeable material, which transmits or yields water in appreciable quantities. Aquifers are either recharged by rainwater percolating through the soil and through rock fractures or by infiltrating surface water bodies.

36. Significant recharge can even take place in arid climates, if the recharge zone has a large areal extent, or if wadis or occasional flooding takes place above the aquifer. In large aquifer systems, the recharge zones may be a long distance from the point of abstraction. Aquifers act as buffers to the effects of seasonal and climatic variations, e.g. low rainfall and droughts. The longer the residence times are in the aquifer, the better the natural filtration will be and the better the water quality is. Groundwater, if available in sufficient quantities is therefore normally preferred to surface water, due to smaller seasonal variations and generally better quality.

37. Groundwater is found in most places in the world and may be rapidly exploited in an emergency by increasing the demand on existing infrastructure (for example motorizing a hand dug well) or less rapidly by drilling new wells or boreholes. Groundwater sources include springs, hand dug wells, boreholes, qanats or karezes, and subsurface dams.

38. If groundwater sources are correctly protected from pollution and contamination, the cost and complexity of water supply, treatment and quality monitoring activities may be significantly reduced. Many groundwater sources exploit shallow aquifers which are prone to surface contamination. The quality of groundwater can often be significantly increased by ensuring the source is well sealed off from any surface contamination, fitting a self-priming pump, ensuring the water collection area is kept clean and free from stagnant water and animals, and carrying out a parallel programme explaining the fundamentals of household water management and hygiene.

39. Occasionally, groundwater in certain aquifers contains dissolved chemicals from the rocks and soils

that may give it a bad taste (in particularly iron and manganese), colour, or even be a health hazard (e.g. fluoride, arsenic). Aeration, followed by filtration is sometimes required to allow dissolved gases and minerals to come out of solution before consumption. Therefore, it is crucial to rapidly proceed with a complete water analyses for new water sources in order to understand what is required to make the water potable.

40. The main disadvantages of groundwater are the high complexity and exploitation costs. Specialist equipment and personnel are required in locating and constructing groundwater sources. The costs of abstracting groundwater can easily be far more than necessary unless well siting, construction and development is optimised and measures are in place to ensure the highest possible quality.

Figure 3-3 Drilling rig

Rainwater sources

41. Rainwater collected from the roofs of houses, local institutions, collection structures, or from specially prepared areas of ground, can make an important contribution to drinking water supplies. In some locations where groundwater is not potable, or difficult to extract, rainwater may be the only viable method of water supply. Options for collection of rainwater include:

- ☐ Plastic sheeting
- ☐ Corrugated roofing panels
- ☐ Clay / concrete tiles
- ☐ Wooden panels or planks
- ☐ Any hard, clean, surfaces including areas of ground.

Options for storage of rainwater include:

- ☐ Plastic, clay or metallic drums
- ☐ Cement jars
- ☐ Masonry, concrete or ferro-cement reservoirs
- ☐ Lined ponds

42. Rainwater is reasonably pure and can be considered safe for human consumption provided it has been collected from surfaces that have been kept clean and off the ground away from contamination, and rainwater is not collected in high density urban settings. The first major rainfall event after the dry season is typically diverted from the storage system and is used to flush the collection surfaces from dust, bird droppings and other contamination. Storage tanks should be kept covered to prevent mosquito breeding and to reduce evaporation losses, contamination and algal growth. In no circumstances whatsoever should

rainwater harvesting take place where asbestos roofing panels are present. Rainwater harvesting systems require regular maintenance and cleaning to keep the system hygienic and in good working order. A great deal of responsibility lies with the user and it is important to carry out a parallel programme of operation and maintenance training.

Figure 3-4 School rainwater harvesting

43. Rainwater systems are simple to construct from inexpensive local materials, and can be used in almost all locations around the world. The size of the rainwater storage structure must be sufficient to hold enough drinking water to meet the daily water demand throughout the year up until the following rainy season. The size of the water catchment area must be large enough to capture sufficient water to completely fill the rainwater storage structure before the start of the dry season. The quantity of water that can be collected is dependent on the plan area of the system, its collection efficiency, and the quantity of rainfall (in mm) that falls during the rainy season. Roof gutters should have sufficient incline to avoid standing water. They must be strong enough and large enough to carry peak flows.

44. Rainwater collection can provide a useful supplement to other sources of water, especially at health centres, schools and at structures that have large roofs for collecting rainwater and where storage can be provided and maintained. Rainwater from surface run-off can be collected in ground catchments and used for non-domestic uses and livelihoods activities such as animal watering and brick making.

Rainwater harvesting is generally not suited to the emergency phase as it takes a complete rainfall cycle for sufficient water to be stored for the coming dry season. Rainfalls can also be unpredictable and it is essential to ensure that backup arrangements are available if this approach is to be used.

45. Ground catchments should be considered only in areas where rainwater is very scarce and other sources of water are not available. They are more suited to small communities than individual families and often some form of treatment is necessary if the source is to be used for human consumption. If properly designed, ground catchments can collect large quantities of rainwater.

Water propspection and evaluation

The importance of refugee site selection based on water availability and quality

46. The selection of all settlements for refugees should be based on a comprehensive evaluation of the

availability, quality and seasonality of water supplies. However in reality many refugee sites are designated by local authorities often based on other factors than water availability.

47. Specialist expertise is essential to identify and evaluate potential water sources for refugee settings. Water prospection and evaluation is an inherently challenging process due to the complexity of nature. It requires experienced professionals to allow a step-by-step reduction of uncertainty, making use of a rational that always follows the fundamental physics underlying groundwater flow. If existing groundwater sources are available the possibility of extending or upgrading these existing sources to supply the refugee population should be given priority, but this has to be combined with groundwater monitoring in order to evaluate the impact of increased exploitation.

48. In all refugee drilling programmes, regardless of context, UNHCR and WASH actors must ensure that an experienced hydrogeologist is recruited to supervise the programme. A budget line for a project hydrogeologist that covers the duration of the project must therefore be included in project proposals, along with funding for hydrogeological investigations, such as geophysics, or pumping tests etc. The hydrogeologist has to come up with a site-specific and convincing investigation strategy before the drilling campaign starts, clearly stating the rationale behind any proposed investigation technique. Considering that the life span of a well-designed water source can be up to 20-50 years, a lot of effort should be put into maximising the quality of the water prospection phase, which will save money in the long run.

Key steps for water prospection and evaluation

49. The flow chart below describes the typical sequence of activities to be undertaken during the water prospection and evaluation phase. It represents an idealised situation that will need to be adapted for emergency situations.

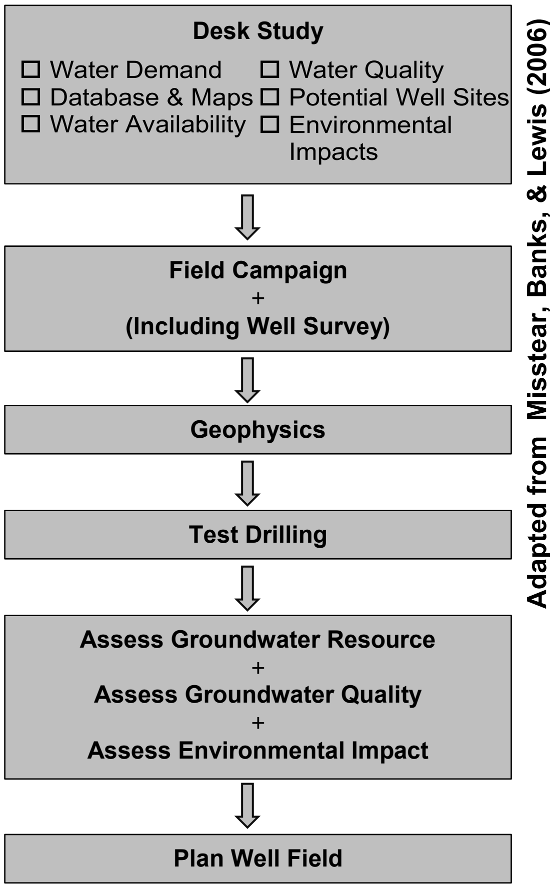

Figure 3-5 Groundwater investigation

Desk studies

50. The first stage of any water evaluation is a desk study of readily available information. A desk study should be undertaken regardless of whether the investigation is in response to an

emergency situation or longer-term supply, however in emergency situations the depth of the study is likely to be significantly reduced. The starting point for any desk study is to understand how much water is likely to be available as opposed to how much will be required for the refugee setting, taking into account potential population size, livestock, future economic and livelihood activities, and population growth.

51. Topographic maps and remote sensing data (aerial photos and satellite imagery) may be extremely useful in areas where there is very limited data available. Detailed images are able to provide information such as vegetation cover, drainage patterns and surface water courses. It is important that as much local knowledge and expertise as possible is included in the desk study. Likely additional sources of expertise include technicians from the relevant ministries, water boards and local drilling contractors.

52. The desk study should result in a desk report that includes:

- ☐ A literature review of hydrological (in particular stream flow and rainfall patterns), geological and hydrogeological data for the region and the proposed site.
- ☐ Compilation of hydrogeological data from water points in the regions of the proposed site (e.g. water level data, water quality, pumping tests and borehole logs).
- ☐ Elaboration of a conceptual model of the aquifer system, identifying (1) potential exploitable aquifers, (2) recharge processes, (3) potential pollution sources, in order to estimate the following:
  - a. Groundwater flow directions and estimated velocities.
  - b. Estimates of likely depths to exploitable groundwater and aquifer material (lithology).
  - c. Estimates of likely yields and of the costs of pumping.
  - d. Description of interactions between surface water and groundwater.
  - e. Assessment of the likely quality of groundwater.
  - f. Elaboration of a water balance.
- ☐ A description of available applicable water abstraction technologies.
- ☐ A description of any regulatory requirements.
- ☐ An analysis of data gaps in addition to a clear investigation strategy to close these gaps.

53. Sources of secondary data for the desk study include:

- ☐ International organisations (international geological and hydrogeological societies, environmental bodies, mapping agencies).
- ☐ National government ministries (water and energy, water resources, environment, geological, land survey, mines and energy, public works, meteorological).
- ☐ National universities (water resources, geography, geology, environmental science, mining)

- ☐ National drilling companies and hydrogeological consultants.
- ☐ Vendors of maps, aerial photos, high definition satellite imagery.
- ☐ Literature searches (i.e. scholarly articles via internet).

54. The duration of the desk study will vary depending on how much information is already available, the complexity of the hydrogeological setting, the time available and the scale of the water demand. Generally the amount of information available on water conditions at the location will depend on the extent to which water has been exploited locally.

Field campaign

55. Following the desk study a field campaign is required to fill the data gaps identified during the desk study and to carefully plan any exploratory investigations (e.g. geophysics). The activities involved in the preliminary field campaign should always include a survey of all water points (wells, springs and boreholes, rivers, lakes and marshes) in the region of the study area, measuring the following basic parameters:

- ☐ Water source and aquifer type.
- ☐ GPS location, elevation, diameter, depth, well equipment, pump type and capacity, operational hours.
- ☐ Static and dynamic water levels, flow measurement , water quality
- ☐ An assessment of the feasibility of meeting the demand from existing sources through rehabilitation or upgrading.
- ☐ Identification of locally appropriate technologies for water abstraction.
- ☐ Carrying out pumping tests in existing boreholes in the region in order to get the hydraulic properties of the aquifer.

56. The area for the field campaign will be defined during the desk study and its size and extent depend on the geology and hydrology of the area, more than on the amount of the planned abstraction. It is highly recommended that the field reconnaissance and well survey phase is carried out jointly with local water authorities and representatives from local communities who know the potential locations for water sources in addition to any potential causes of dispute.

Geophysical methods

57. Following the desk study and field campaign it is usually necessary to undertake local geophysical investigations for exact positioning of well locations. Geophysical methods should always target promising locations which were identified as a result of the desk study and field campaign.

If carefully planned, surface based geophysics may reduce uncertainty in favourable geological settings. Under the most favourable conditions, such investigations may allow inferring the depth of the water table, the location of faults, the depth to the basement rocks, or the location of freshwater/saline water interface. Their main use in an area with limited geological information is likely to be as an aid in identifying potential sites for drilling.

58. The most frequently used surface based geophysical methods in hydrogeological investigations are based on electrical resistivity measurements. These geophysical methods seek to relate electrical properties of the earth to hydraulic properties. The relationship between the two properties is by far not linear, rendering interpretation of such investigations very delicate. In order to be meaningful, some of the measurements within a campaign have to be calibrated with borehole logs and other data (e.g. water level), i.e. have to be carried out next to boreholes where the subsurface conditions are known. As a rule of thumb, dry materials have a higher resistivity than wet ones and gravels have a higher resistivity than silts or gravels. Saline water has a low resistivity.

59. In any drilling campaign, within a refugee setting programme, a specialized hydrogeologist should be hired to oversee the geophysics and drilling activities for the whole duration of the drilling campaign. Since interpretation of geophysical measurements is delicate, it is of high importance for the clients (usually non-specialists) to insist on the following elements as integral parts of the investigation report:

- ☐ All raw data have to be included in the report.
- ☐ The interpretation of the results, based on mathematical inversion has to be plotted against the measured raw data.
- ☐ The interpretation of the results has to include a list in which the local transformation of electrical properties to hydraulic properties is shown and based on calibrated data (compared with borehole logs or other available information).

Test drilling and pumping tests

60. Following the desk study, field reconnaissance, well survey and geophysical study, the most favourable sites may be selected for test drilling. Test drilling and pumping tests should be carried out to fully document the characteristics and yield of the aquifer. However in many cases it may make economic sense to go ahead a drill a production well as the costs are likely to be similar. UNHC guidelines for test drilling and pumping tests can be found on the **wash.unhcr.org** website.

Final water source selection

61. At the end of the prospection and evaluation phase the Hydrogeologist should have established a list of potential water supply options for the refugee setting ranked from 'most favourable' to 'least favourable' according to the following selection factors:

- ☐ Predicted yield and seasonal variations.
- ☐ Ease and cost of abstraction and transmission (taking into account distance from the refugee setting).
- ☐ Existing water quality and ease and cost of treatment.
- ☐ Ownership, security and legal considerations.
- ☐ Ease and costs of operation and maintenance and human resources needs.

☐ Impact of abstraction on aquifers, local population and the environment.

Water abstraction

Surface water abstraction

62. Water can be abstracted from surface water bodies by direct pumping, pumping via an infiltration gallery or stilling well, or diverting part of the flow into an off-take channel or pipe. Intake pipes should be at least 1m above the floor of the riverbed to avoid drawing in silt, stones, or suspended matter, and at least 0.5m below the water surface to reduce problems with air vortices being drawn into the pumped water flow. Surface water intake structures should be designed to abstract the better quality water which is usually found as far as possible from the surface water body's edge.

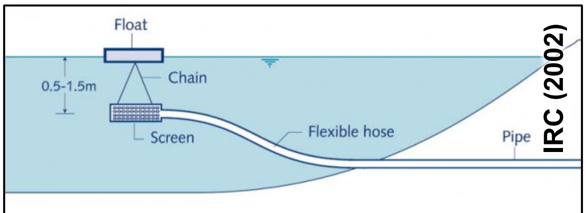

Figure 3-6 Floating water intake

63. Stilling wells and infiltration galleries take advantage of alluvial material in the bank or bed of the river or lake to partially treat the water as it is abstracted. Stilling well can be made by installing a lined well within the bank or next to the river or lake. Infiltration galleries are constructed by installing slotted pipes into a gravel filled trench in the river or lake bed and abstracting water through the river or lake bed.

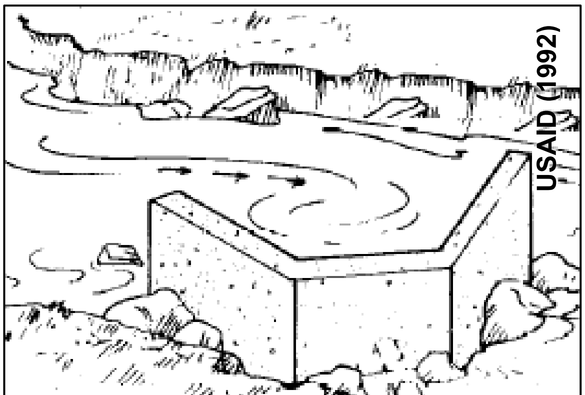

Figure 3-7 Diversion Intake Structure

64. Diversion structures channel part of the river flow into an off-take trench or pipe. They should be constructed of durable enough materials (e.g. concrete, stone masonry, or heavy gauge iron) to withstand the river flow forces exerted on them, in addition to risks of flooding, erosion and silting. They should be optimized to collect the best quality water, at the design flow, all year round.

65. The design of surface water intake structures for long term refugee settlements requires specialist engineering knowledge and experience and should ideally be based on the analysis long term historical flow records, carried out by a hydrologist with local knowledge.

Spring protection and abstraction

66. Springs form wherever the groundwater table intersects the earth's surface either as a spring 'eye' or generally as seepage. Springs can also be formed where high permeability layers are found on top of layers of lower permeability. These kinds of springs often occur as a line of springs, reflecting the topographical level of the impermeable layer. The source of water in springs may be either as a

result of the main water table or a perched water table. Springs can also be formed where fracture zones intersect the ground surface. The discharge and quality of these springs is often reasonably constant as their flow is due to the head in the underlying aquifer. The major advantages of exploiting springs in refugee settings are..

- They usually yield high quality water requiring no treatment other than chlorination.
- They can be relatively cheap to construct and are a low tech option, which can easily be transferred.
- They have very low operation and maintenance costs.
- In many cases, a gravity network can be used to deliver water directly to the users with no pumping requirements.

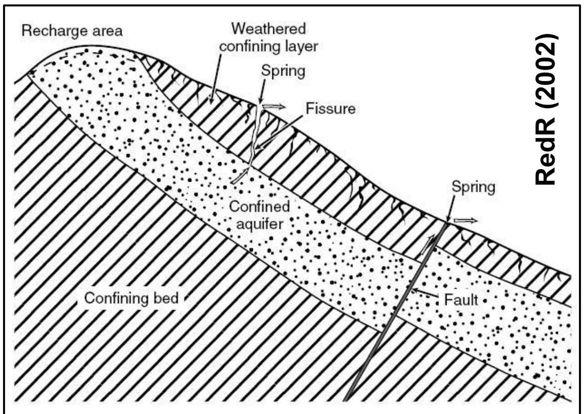

Figure 3-8 Spring Locations

67. When evaluating a spring it is critical to assess the seasonality of water discharge rates and water quality. Springs that have a constant discharge are the ideal source of water for refugee emergency situations, particularly where their point of emergence is elevated to allow distribution of the water to the refugee setting by gravity.

Figure 3-9 Spring Protection

68. Geological maps (if available) may help locate springs between outcropping lines of impermeable and permeable layers. Local people often know the locations of springs in their vicinity. Ownership of the spring must be identified to avoid potential conflict.

69. The quality of water from springs is dependent on the underlying spring geology but is usually of high quality. However, springs that are seasonal and rely mainly on shallow groundwater and rainfall recharge may require a higher degree of treatment. Regular monitoring of the spring discharge and water quality parameters should be made over time.

70. Discharge rates from springs can be calculated by measuring the time taken to fill a container of known volume. The average from three runs is usually enough to obtain a fairly accurate figure. If the spring is unprotected, the potential yield from the spring can be found by excavating down to the spring eye, constructing a temporary dam

using available earth, installing a discharge pipe of sufficient diameter, and measuring the time to fill a known volume when the water levels have reached a steady state.

71. Normally discharge will be highest at the end of the rainy season and lowest at the end of the dry season. If possible, it is preferable to measure the highest and lowest discharges in the spring's cycle in order to determine its suitability for development as a long term source of water. Observing the spring's resilience to impulses such as rainfall events is important if the opportunity arises.

72. Protecting the spring from surface contamination is an urgent priority. In the initial stages of a refugee emergency feasible protection measures include:

- Fencing
- Working with the community to ensure that water is abstracted and animals watered downstream of the spring eye;
- Construction of a surface water runoff diversion canal upstream of the spring eye;
- In consultation with the community establishing a protection zone around the spring catchment

73. Every spring capture is unique, however there are several principles that should be adhered to while working on springs. Firstly, the eye of the spring must be located. This can be a difficult process and will often entail careful and extensive excavation. Once excavation of the spring eye has been completed is should be permanently protected using a spring box or a small sealed gravel filled dam.

74. Back pressure on the spring eye can disrupt the flow paths and may cause the spring to be lost. It is imperative that the levels in the collection dam or spring box are maintained below the level of the spring eye. If there is uncertainty in the flow rate a large diameter overflow pipe should be used.

75. A spring box is recommended for springs that have low or variable discharges or a moderate suspended solids load. The spring box provides a settlement chamber that allows periodic access for cleaning and maintenance. Spring boxes often require extensive and expensive construction. A decision on the layout and final design of the spring catchment should seek to balance the cost of development against the potential yield of the spring. Excavation of the spring box foundations must extend to the impervious layer to prevent loss of water under the spring box. The bottom of the spring box is often left as a permeable layer. In an emergency, rapid spring captures can be constructed by excavating a simple earth barrage covered in plastic sheeting and backfilled with gravel.

Hand dug wells

76. Hand dug wells can provide a low-tech solution to accessing groundwater in low density settlements where contamination of the shallow groundwater is limited. In many cases, hand dug wells are similar to traditional abstraction methods and are readily accepted by the refugee

community. Hand dug well diameters can range from less than one metre to tens of meters and wells can be successfully excavated to depths of up to 60m and beyond. Hand dug wells have relatively low operation and maintenance requirements which are generally more related to maintaining the water abstraction device. Even if the hand pump breaks down, water can still be abstracted by the community by access through the head works.

Figure 3-10 Concrete Well Rings

77. The disadvantages of hand dug wells are that they are often not suited to hard ground formations and take time to dig and line. In addition, construction of hand dug wells can be dangerous due to collapsing soils, falling objects and asphyxiation from dewatering equipment. Hand dug well construction generally requires the use of a trained well construction team. Finally, construction of hand dug wells can require large capital costs for equipment such as concrete ring moulds, heavy lifting equipment, well shaft formwork, motorized de-watering pumps and fuel.

78. Hand dug wells are generally constructed by digging and lining a pit down to the water table and then by telescoping the lining further down into the aquifer. Yields are generally dependent upon how deep the construction crew is able to penetrate into the aquifer and if construction is taking place during the dry season when groundwater table levels are at their lowest. Yields may be significantly increased if the well is deepened up to the maximum limit of the dewatering pump and may even be improved by introducing vertical tunnels or perforated pipes. Hand dug wells that have low yields can be easily deepened by telescoping the lining further down into the aquifer.

All hand dug wells in refugee settings should be excavated using dewatering pumps rather than rope and buckets. This is critical to be able to meet the water demand all year round in particularly in the dry season.

79. Since most hand dug wells exploit shallow aquifers, the well may be susceptible to yield fluctuations and possible surface contamination. The quality of the well water can be significantly increased by lining the well, sealing the well head, fitting a self-priming hand pump, constructing an apron, ensuring the area is kept

clean and free from stagnant water and animals, moving sources of contamination (latrines, garbage pits) and carrying out hygiene education. The well should be cleaned with 1% chlorine solution after construction and a sanitary survey should be carried out as the situation demands. Bacteriological testing of water from a sample of hand dug wells should be carried out on a monthly basis (see **section 3.112**).

Figure 3-11 Hand Dug Well - Chad

80. Before excavation is planned, information about the geology, water table depth, seasonal fluctuations, recharge area and rate must be found. Wells should be sited in locations that are known to be favourable for example in low lying areas close to alluvial river plains. The use of reinforced concrete instead of plain concrete results in pre-cast well rings that are thinner, lighter and easier to install. Safety during hand dug well construction is of paramount importance.

Drilled wells and boreholes

81. Drilling is often the only water solution for deep consolidated aquifers. Machine drilled boreholes are always costly to construct, and often risky in case of failure. Before drilling begins, information about the geology, water table depth, seasonal fluctuations, recharge area and rate must be found. Sources of information include local expertise, existing records, aerial imagery, geological maps and geophysical investigations (see section on water prospection and evaluation). The drilling of production wells is expensive and it is makes economic sense to mitigate the cost of a dry hole by conducting a geophysical investigation (usually electrical resistivity). Groundwater yields are likely to be higher in aquifers of alluvium, unconsolidated sediments and weathered zones of bedrock. Ground water in hard rock fracture systems can be difficult to hit. Drilling a deep borehole is time consuming, expensive and risky in that there is no guarantee that there will be water. Large truck mounted drilling rigs may not be able to access difficult or remote locations. Water from deep boreholes may have high levels of arsenic, fluorides or dissolved salts, requiring sophisticated treatment.

Figure 3-12 Rotary Drilling Rig – S. Sudan

Drilling options

82. Drilling systems can be broadly divided into percussion, rotary, and rotary with down the hole hammer. Percussion rigs consist of a drill bit and weighted drill pipe which is attached to a strong cable that is raised and dropped repeatedly. Material is drilled then removed with a bailer. Rotary rigs achieve drilling through the use of weighted rotating cutting tool. Drilled material is flushed to the surface by recirculating drilling fluid. Compressed air driven down the hole hammers are used to drill through hard rock. Their faces have tungsten carbide 'buttons' which strike the drilling face at high frequency. Drilling rigs have capacities based on the maximum depth (pullback) they can extract the drill string. Drilling contractors and drilling rigs should be selected based on their ability to meet the required depths.

Manual drilling

83. In soft formations, with a shallow water table, and high permeability, it may be possible to use low-cost manual drilling technologies for small handpump installations in refugee settings during the post-emergency phases. Hand drilling rigs are relatively cheap, and simple to operate and maintain. Equipment can be fabricated locally. Data shows that hand drilled boreholes can be constructed in 1/5 of the time, for lower capital costs, than hand dug wells. Rapid penetration rates are possible however hand drilling is not suited to hard ground formations and even in soft formations boulders can stop further drilling completely. Hand drilling methods can encounter problems in unstable formations. Some hand drilling methods (jetting, sludging) require a source of water, which in dry regions may have to be transported to the site. Options for manual drilling include:

Driven wells. Constructing driven wells involve driving a specially designed, but inexpensive, well point and screen of hard steel into the ground connected to sections of casing. Borehole construction is straightforward, requiring little specialist equipment (sledge hammer and drill pipe).

Jetted wells. Constructing jetted wells involves using a motorized pump to drive water down a drill pipe equipped with a jetting drill bit. As the drill pipe is driven into the ground material is flushed to the surface. The technique is very effective in unconsolidated material but equipment costs are comparatively high.

Hand percussion. This technique drilling is identical to standard percussion drilling but uses lighter equipment and manual labour. At a minimum it requires a tripod, a pulley lifting mechanism, heavy drill bits and a bailer. Hand percussion drilling can achieve impressive depths in both unconsolidated and (time permitting) consolidated formations.

Hand auger drilling. This technique requires auger equipment, a raised platform and drill pipe. Augured wells are relatively easy to construct, however their practical depth is limited to 15m – 20m.

Hand sludging. This technique requires a raised platform, drill pipe, a steel cutting shoe and a source of water. The drill hole is kept filled with water and as the pipe is raised the water column inside the pipe is released, slowly evacuating the cuttings.

Figure 3-13 Vonder Rig Manual Auger

Borehole design, development, pump testing and equipping

84. Guidance for the design of boreholes fin crystalline, consolidated, and unconsolidated aquifers along with guidance for conductor casing, pump casing, well screens, natural and artificial gravel packs, well development, pump testing, and borehole equipping can be found in additional more detailed guidance notes on the **wash.unhcr.org** website.

Water source protection

85. UNHCR and WASH actors should ensure that in refugee settings steps are taken to immediately protect all water sources from contamination. The most effective way to achieve this is to undertake a series of sanitary surveys at each step of the water chain to assess public health risks, and identify a list of corrective actions. The list of corrective actions should be prioritized into those that need to be carried out immediately and those that require a longer term approach.

Evaluation of existing water sources using sanitary surveys

86. A sanitary survey is a systematic assessment of the different factors that create a risk of faecal contamination of a water source. A WHO sanitary survey form consisting of a drawing and set of questions should be used for each type of water source and installation that is monitored. The full range of sanitary survey forms can be found in Annex 2 (page 150) of Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of Community Supplies (WHO, 2011).

87. The sanitary survey forms take the same layout and are completed in an identical manner. On one side is a numbered list of sanitary risk questions which are phrased in such a way that a 'yes' answer indicates a sanitary risk factor. On the other side of the form there is a simple representation of the water infrastructure that is being assessed (e.g. a water source,

abstraction point, treatment process, or distribution system).

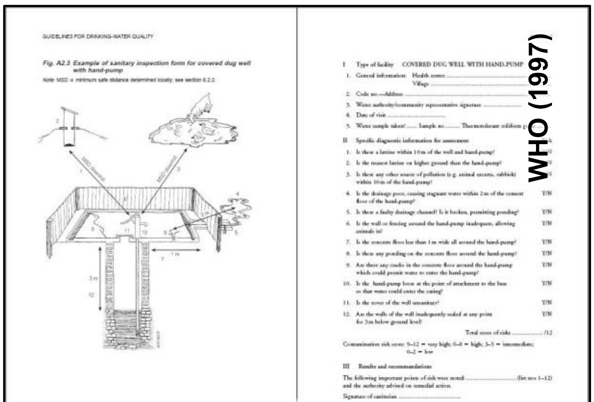

Figure 3-14 Sanitary Survey Form

88. Each of the numbered sanitary risk questions is also marked on the illustration using the same number. To complete the sanitary survey, each of the questions is answered in turn. At the end of the sanitary survey, the contamination risk score is calculated by adding together the sanitary risks. A score of 1-3 indicates an intermediate risk, 4-6 intermediate to high, and 7-10 very high.

Box: Sanitary Inspection Risk Scores

7-10	High risk
4-6	Intermediate to high risk
1-3	Low risk
0	No observed risk

Source: Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of Community Supplies (WHO, 1997)

89. The sanitary survey form requires no specialist equipment or qualifications to carry out, and provides instant information that allows the risk of contamination to be estimated and corrective measures to be identified. The people carrying out the sanitary survey should be trained and supervised so that the information they produce is reliable and allows comparisons to be made between different water sources and monitor change over time. In all refugee settings, the risk scores from a sanitary inspections should be combined with the results from faecal coliform tests to create a framework for prioritising any remedial action (see table below).

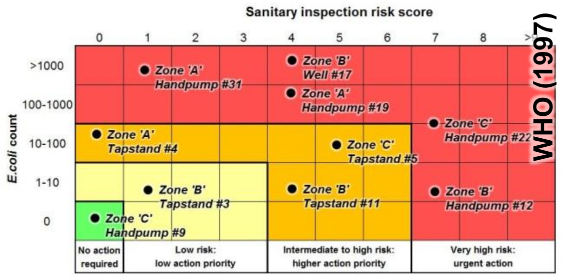

Figure 3-15 Water point risk analysis

90. Examples of corrective actions that are likely to come out of sanitary surveys include

Springs

- ☐ Ensuring minimum safe distances to latrines or sources of contamination
- ☐ Installing a surface water diversion trench
- ☐ Fencing the spring capture area to prevent entry by animals and people

Hand dug wells and boreholes

- ☐ Ensuring minimum safe distances to latrines or sources of contamination
- ☐ Installing or upgrading the sanitary seal
- ☐ Ensuring the apron is at least 3m in diameter
- ☐ Fencing the well apron to prevent entry by animals

Water quality monitoring and testing

The importance of water quality monitoring in refugee settings

91. UNHCR and WASH actors must ensure that all water supplies in the refugee setting, regardless of their intended use, are fit for human consumption. Due to the risks from diarrhoeal diseases, steps must be taken to ensure all water supplies have a free chlorine residual of at least 0.5mg/l at water collection locations (to be raised up to 0.8-1 mg/l in case of outbreaks depending on the acceptability of the users). Free chlorine residual levels must be constantly monitored and the results must be updated in the water quality monitoring section of the site WASH plan/strategy. Steps must be taken to immediately protect all water sources from contamination. Sanitary surveys should be conducted at each step of the water chain to assess risks, and identify corrective actions. A water safety plan that includes a water quality surveillance framework must be in place for every refugee setting.

92. UNHCR and WASH actors should not only ensure that water supplies are safe to drink but also that the taste, colour and smell of water supplied is acceptable. If water supplies are unacceptable there is a high risk that the population may seek out unprotected sources. Water supplies that are treated with chlorine should not have excessive levels of chloramines.

Figure 3-16 Water quality testing

93. All refugee settings should have an fully documented and active water quality surveillance system in place that is able to provide up to date water quality data, in addition to an analysis of historical water quality trends

Measurement of chlorine residuals

94. In all settings, UNHCR and WASH actors must ensure that total and free chlorine residual levels are being measured using N,N-diethyl-p-phenylenediamine based DPD1 and DPD3 tablets and a simple ‘pool tester’. The UNHCR approved procedure for measuring chlorine residual using a ‘pool tester’ can be found in Annex 9 (page 226) of Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of Community Supplies (WHO, 1997). Decay of free chlorine levels increases in warm temperatures or if the water is left in the sun therefore free chlorine levels should not only be tested at the point of collection but also the household level.

95. The UNHCR approved procedures for selecting the location of sampling points and sampling frequency for refugee settings can be found in Chapter 4 (page 51) of Guidelines for Drinking Water Quality, Volume 3 –

Surveillance and Control of Community Supplies (WHO, 1997). However, UNHCR and WASH actors must ensure that chlorine residuals are monitored on a daily basis for the first eight weeks, before moving to the monthly monitoring schedule suggested by WHO. UNHCR and WASH actors must ensure that all water quality testing results are updated in the site Water Safety Plan.

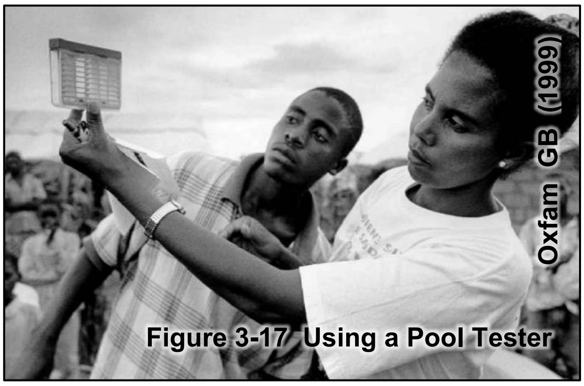

Figure 3-17 Using a Pool Tester

Measurement of turbidity

96. Turbidity is caused by the scattering of light due to the presence of colloids and fine suspended particles. Microbiological contaminants adhere to these particles, which can reduce the efficiency of disinfection in waters with turbidity in excess of 5 NTU. A precondition for effective chlorination is that the turbidity of the water is less than 5 NTU. This generally means that water supplies will requires some form of pre-treatment (such as sedimentation or filtration) to lower turbidity values to effective levels. The turbidity of the water can be verified using a colour comparator or a Jackson Tube. The UNHCR approved procedure for measuring turbidity can be found in Annex 10 (page 231) of Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of Community Supplies (WHO, 1997).

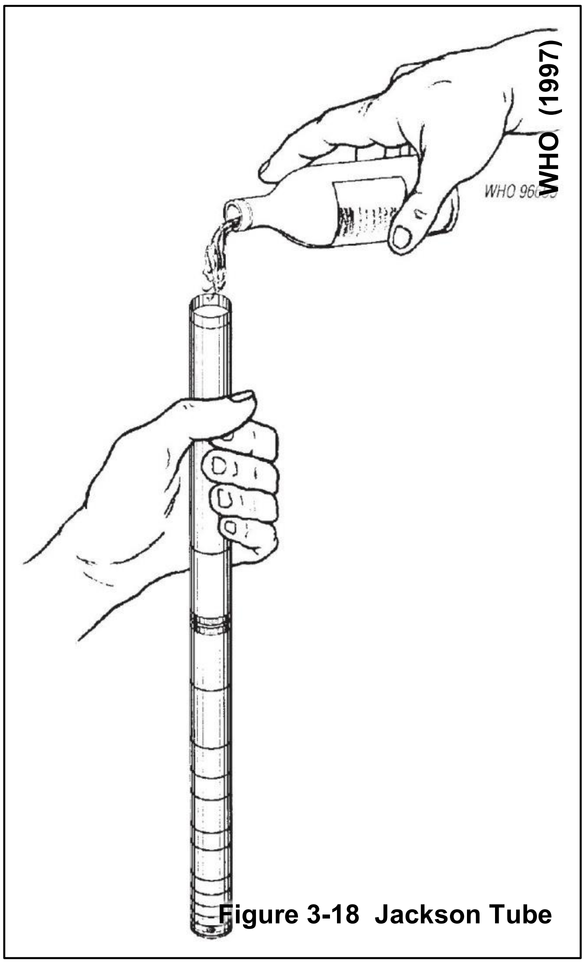

Figure 3-18 Jackson Tube

Measurement of pH

97. The pH of natural waters ranges between 5.7 (rainwater) to 8.5 (some groundwaters). For effective chlorination the pH of the water supplies being treated must be less than 8.0. If the pH is greater than 8.0 then the contact time must be significantly increased (refer to increased contact times in the section of water treatment with chlorine). Chlorine has very little disinfecting power above pH 9.0. The pH of the water can be determined using a 'pool tester' and phenol red. The UNHCR approved procedure for measuring pH can be found in Annex 10 (page 231) of Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of

Community Supplies (WHO, 1997). Alternatively the pH may be measured using a recently calibrated handheld, digital meter that measures the potential difference between two electrodes immersed in the water.

Measurement of faecal contamination

98. Faecal contamination of drinking-water is a transmission route for many diarrhoeal diseases, including cholera and shigellosis, and other diseases such as hepatitis A and E, and typhoid. Even if water supplies have been chlorinated there is a risk that faecal pathogens may still be present resulting from insufficient contact times, inadequate chlorination procedures, water network leaks, and post-delivery contamination.

99. Faecally derived pathogenic microorganisms represent the greatest acute risk to human health associated with water quality. These microorganisms include bacteria, viruses and protozoa. It is not feasible to analyse water for the presence of specific pathogens therefore the approach adopted by WHO is to test the water for the presence of indicator organisms that are easily identifiable as bacteria that are present in human faeces. The detection of indicator organisms in a sample of water is taken as an indication of faecal contamination. E. Coli. and the Thermo-tolerant coliforms species, are the most commonly used indicator organisms.

100. The Membrane Filtration test has become the accepted standard for testing for indicator organisms. Standard test kits such as the Oxfam Delagua and the Wagtech Potatest are commercially available for field use. The results are normally expressed as Colony Forming Units per 100 ml. The UNHCR approved methodology can be found in the OXFAM Delagua (1993) Portable Water Testing Kit, User's Manual and Annex 7 (page 219) of Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of Community Supplies (WHO, 1997).

Figure 3-19 Membrane Filtration Kit

Figure 3-20 Membrane Filtration Colonies

101. The detection of faecal contamination must always be met by a response. Typically this will entail a rapid sanitary inspection of water point or source from which the sample was taken to identify the possible source of the contamination, cleaning, and possibly shock dosing with a strong chlorine solution.


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Measurement of chemical water quality parameters

102. Water supplies in refugee settings must be free from chemical contaminants that are harmful to health either in the short or long term. Consumption of water contaminated with harmful chemicals present in the aquifer geology, or from domestic, agricultural, or commercial activity can put the population at risk from lethal, acute, or chronic toxic effects including:

Bone fluorosis: from Fluoride (F) naturally present in some geological formations or as a result of industrial activity such aluminium manufacture.

Cancers: from Arsenic (As), Uranium (U), or Radon (Rn) naturally present in some geological formations.

Neurological and nervous system toxicity: from Lead (Pb), Mercury (Hg), Cadmium (Cd), Aluminium (Al), or Manganese (Mn) present in some geological formations and domestic and industrial wastes (for example dumping of used batteries or electronic waste). Also from saline water with high levels of Total Dissolved Solids (TDS).

Methaemoglobinaemia: also known as blue baby syndrome caused by feeding infants with water containing high levels of Nitrates (NO3) and Nitrite (NO2) originating from fertilizers, livestock wastes, or leachates from unlined septic tanks or latrines.

103. It is important to seek agreement among the actors working in the refugee setting concerning the standards used to determine the quality of drinking-water. National standards, which are commonly derived from the WHO drinking-water quality guidelines, should be the primary reference. However, most national standards are determined for stable contexts, on the basis of consumption of the water over a lifetime and may be slightly relaxed in life threating situations for short period of time only.

Box: Common WHO water quality parameters

Parameter	Standard
Arsenic	0.05 mg/l
Fluoride	1 – 1.5 mg/l
Iron	0.3 mg/l
Manganese	0.1 mg/l
TDS	1000 mg/l
Turbidity	< 5 NTU
Nitrates	10 mg/l
pH	6.5 – 8.5
Thermotolerant Faecal Coliforms	0 FCU /100ml

Source: 'Guidelines for drinking-water quality, fourth edition', WHO (2011)

104. As soon as possible, UNHCR and WASH actors should ensure that the quality of water supplied complies with national water quality guidelines and the recommendations and guideline values contained in the WHO Water Quality Guidelines (2011). A summary of some of the more common guideline values can be found in the box above.

105. In addition to monitoring for natural contaminants, UNHCR and WASH actors should also ensure


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that drinking water supplies are free from man-made chemical contaminants such as pesticides and herbicides. In urban areas industrial pollution and petroleum products may be of particular concern although the majority of pollutants associated with petroleum based products can be detected through tastes and smells at concentrations that are well below those required to cause illness (World Health Organisation, 2011).

106. Identification of pollution hazards due to man-made chemicals must begin with a catchment land-use mapping exercise. The exercise should identify chemicals that are likely to be present, their major sources and the potential pathways by which they could enter the water chain. This information is required to design a strategy for water testing. The most comprehensive reference for identifying the risks to human health associated with a given chemical is the Guidelines for Drinking water quality Chemical Fact Sheets. (World Health Organisation, 2011).

Measurement of physical water quality parameters

107. UNHCR and WASH actors should ensure that the taste, colour and smell of water supplied is acceptable to the refugee population. If water supplies are unacceptable there is a high risk that the population may seek out unprotected sources. Problems with taste may be caused by dissolved minerals (salinity), dissolved chemicals including iron and manganese, water treatment chemicals (in particular chloramines from incorrect chlorination), and occasionally dissolved gases. Water supplies that are high in suspended solids, iron, or manganese, may be rejected on the basis of colour - especially for drinking or the laundering of clothes. Water supplies with a Total Dissolved Solids (TDS) mineral concentration of up to about 500 ppm are generally considered to have a good taste (World Health Organisation, 2011). However, as the TDS concentration rises the water becomes increasingly saline and may be rejected on the grounds of taste and health as TDS concentrations approach 1000 ppm.

Minimum water quality testing equipment for refugee settings

108. All refugee settings should be in possession of UNHCR's minimum equipment for water quality testing that includes:

- A turbidity tube
- Portable ‘pool testers’ capable of measuring pH and free and total chlorine
- Portable TDS meter
- H2S presence/absence tests
- Portable membrane filtration field kits with incubators.

All refugee settings must be able to demonstrate that the equipment is functional, there are adequate consumables for the next three months, and there are trained staff that have sufficient technical capacity to use the equipment. An analysis of any recent water quality data, in addition to any historical trends must be included as part of the site WASH plan/strategy.

Water quality surveillance

109. To maintain a supply of safe water, a systematic approach to water safety surveillance is required. Sanitary surveys and microbiological testing provide a means of determining how safe a water source is at a single moment in time only, and systematic surveillance, linked to a response plan is required to maintain water safety. It is the responsibility of the UNHCR WASH Officer to ensure that these plans are documented and agreed with WASH actors.

110. Recommended frequencies for water safety surveillance are provided in the table below. In addition, detailed information on microbiological sampling and testing, sanitary inspections, including detailed reporting formats can be found in Guidelines for Drinking Water Quality Volume 3 - Surveillance and Control of Community Supplies (WHO, 1997), which also presents a detailed description of the elements of a water quality surveillance plan.

Water safety plans

111. A Water Safety Plan (WSP) is a concept for risk assessment and risk management throughout the water cycle from catchment to consumer. It includes the identification of hazards and introduction of control points that serve to minimize these potential hazards, providing more effective control of drinking-water quality. The approach was unveiled in the third edition of the World Health Organization's "Guidelines for Drinking Water Quality" (WHO, 2004) and the approach marks a fundamental shift away from just water testing. Further details were outlined in the 2009 WHO "Water Safety Plan Manual", the 2012 WHO "WSP Training Package", and the 2012 WHO "Water Safety Planning for Small Community Water Supplies" book. The approach draws on many of the principles and concepts from other risk management approaches in particular the multiple-barrier approach and Hazard Analysis and

Table: Recommended frequencies for water quality testing.

Population	Interval between sanitary inspections	Interval between catchment risk mapping and broad spectrum contaminant testing	Interval between free residual chlorine and turbidity testing	Interval between bacteriological testing and number of samples
Piped network >100,000	1 year	1 x rainy season 1 x dry season	1 sample per 10,000 per day	1 sample per 10,000 per week
Piped network 5,000-100,000	1 year	1 x rainy season 1 x dry season	1 sample per 5,000 per day	1 sample per 5,000 per week
Piped network <5,000	3-5 years	3-5 years	1 sample per day	4 samples per month
Wells, springs, & handpumps	Initial, then as situation demands			1 per structure per month

Notes: All water sources to be tested for chemical and biological contamination at time of development. Source: Adapted from Surveillance of Drinking Water Quality in Rural Areas (Lloyd, 1991), table 5.2, pg. 66

Critical Control Points (HACCP) which has been used for decades in the food industry.

112. All refugee sites should have an up to date water safety plan that includes:

- ☐ A clear 'water supply chain' flow diagram describing water provision from catchment-to-consumer.
- ☐ Results from sanitary surveys at each stage in the water chain with current public health risks and an analysis of potential public health risks and their impacts.
- ☐ A plan of short, medium and long term mitigating activities for each stage in the 'water supply chain'.
- ☐ A description of the water quality monitoring framework (which parameters, critical control points, when, how, how often)
- ☐ Results from the water quality monitoring framework along with an analysis of any trends and discrepancies.
- ☐ A list of emergency preparedness actions for each stage in the 'water supply chain'.
- ☐ A catchment risk assessment map describing local industrial, agricultural and human activity water contamination risks.

Example water safety plans from refugee settings can be found in the **references** section.

Ensure reliability, backup and reserve capacity

113. Interruptions to either the quality or quantity of water supplies in refugee settings for any period of time can be potentially disastrous. Therefore UNHCR and WASH actors should ensure that every major piece of water abstraction, treatment and distribution equipment or machinery has at least one backup. All refugee sites should ensure they have at least three months reserve in fuel supplies and water treatment chemicals. In addition, all refugee sites should ensure they have at least half a day of reserve water storage capacity to cover system breakdowns and fire fighting. The strategy to ensure water reliability should be fully described in the site WASH plan/strategy.

Technical options for water treatment

The importance of water treatment in refugee settings

114. UNHCR and WASH actors must ensure that all water supplies used by the refugee population are free from faecal pathogens, suspended solids and harmful chemicals. Water supplies should be selected that require the least amount of treatment. In most cases, a minimal amount of water treatment will be required to ensure that supplies are fit for human consumption.

115. Treatment of water supplies generally involves two steps:

- i) Removal of suspended material and contaminants.
- ii) Removal of pathogens and system protection through some form of terminal disinfection.

116. A number of treatment processes can be used depending upon the nature of the raw water

and the type and concentrations of the contaminants. Treatment processes can be used on their own or in combination as a series of steps. Treatment processes can be scaled up or down in size to treat water supplies at the community or household levels. The main processes include:

- ☐ Screening (**see 3.118**)
- ☐ Sedimentation (**see 3.0**)
- ☐ Coagulation and flocculation (**see 3.123**)
- ☐ Roughing filtration (**see 3.129**)
- ☐ Slow sand filtration (**see 3.136**)
- ☐ Microfiltration, ultrafiltration and nanofiltration (**see 3.140**)
- ☐ Chemical disinfection (**see 3.141**)
- ☐ Aeration (**see 3.157**)
- ☐ UV disinfection (**see 3.158**)

Water treatment costs are prohibitively expensive over the lifetime of a refugee settlement and in general, water sources should be selected that require the least amount of treatment.

117. Treatment may be required to improve the taste, colour and smell of water supplies. UNHCR and WASH actors must ensure that the aesthetic parameters of water supplies are acceptable to the refugee population. If water supplies are unacceptable there is a high risk that the population may seek out unprotected sources. A simple flow-chart for helping determine the optimum treatment type can be found in the box on the following page

Pre-treatment and screening

118. Pre-treatment is an essential step to remove coarse material before the main treatment stage. A large degree of pre-treatment can be achieved by selecting a location for the raw water intake that minimises the ingress of suspended materials, careful design of the structure, and the use of coarse screening.

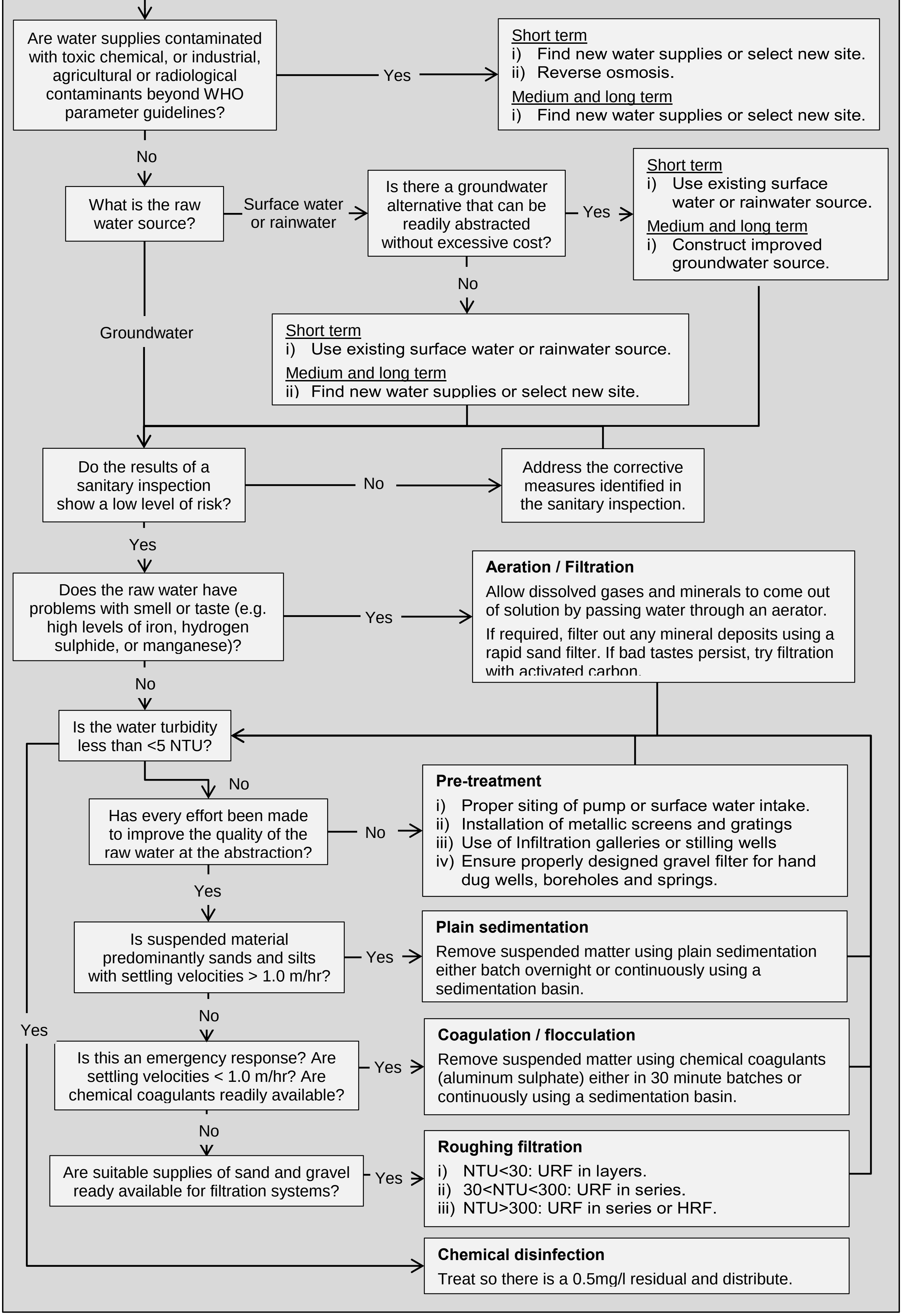
In order to reduce the burden and costs involved in water treatment, UNHCR and WASH actors should ensure that every effort has been made to incorporate properly designed pre-treatment measures for all bulk water systems.

119. In the case hand dug wells, boreholes, or spring boxes, a correctly designed gravel filter or geotextile mesh can significantly reduce the ingress of fines. In the case of a surface water source, careful positioning of intakes, the use of screens, or construction of infiltration galleries or stilling wells, can significantly reduce the levels of suspended materials before the main treatment.

Plain sedimentation

120. Plain sedimentation removes suspended particles in water by creating adequate conditions for removal by gravity. Removal of suspended particles is important as they can block pipes, clog filters and damage pumps. Removal has the advantage of not only reducing turbidity but also improving the biological and chemical quality of the water as many contaminants are in suspension or attached to particles. Plain sedimentation does not render water completely free

Box: Bulk water treatment options flowchart



from faecal pathogens and must always be followed by chlorination.

Box: Typical settling velocities of suspended particles

The following values represent the settling velocities of various suspended particles.

Material	Particle Diameter	Settling velocity
Sand	1.0 mm 0.5 mm	364 m/hr 194 m/hr
Fine sand	0.25 mm 0.10 mm	97.5 m/hr 29.0 m/hr
Silt	0.5 mm 0.005 mm	10.6 m/hr 0.14 m/hr
Fine clay	0.001 mm 0.0001 mm	5 mm/hr 0.005 mm/hr

Source: USAID (1984) *'Designing a small community sedimentation basin'*. Water for the world technical note, USAID, Washington.

121. Plain sedimentation can be carried out on a batch basis (for example simply storing water overnight) or on a continuous basis in a sedimentation basin. Sedimentation basins feature a large area diffuser inlet that minimizes re-suspension of settled particles. A perfectly level weir outlet at the opposite end skims off the top few millimetres of clarified water from the basin. The floor is gently inclined so that settled particles collect in a drain.

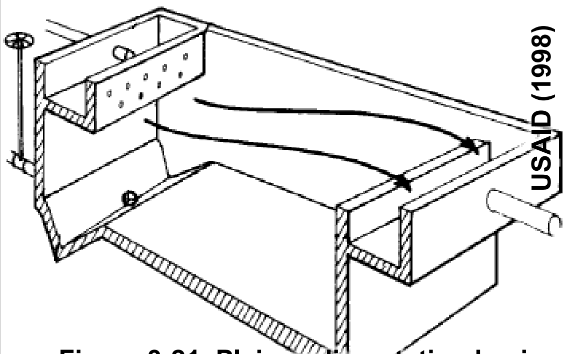


Figure 3-21 Plain sedimentation basin

122. The dimensions of a plain sedimentation basin are calculated according to the characteristics of the water to be treated in particular by the settling velocity of particles in the water source. The settling velocity can be measured by a laboratory or with a clear graduated measuring cylinder. The plan area of the basin is calculated by dividing the flow rate by the settling velocity. Sedimentation is not appropriate if the water contains very fine particles with settling velocities of less than 1.0 m/hr as the size and cost of the basin would not be justifiable and there is a risk that particles could easily become re-suspended. The process may not work at all if there are colloidal particles.

Coagulation and flocculation

123. If the raw waters contain fine particles in suspension then plain sedimentation alone will not be effective. Addition of a chemical coagulant helps to remove the electrostatic charges repelling colloidal particles and facilitates the formation of groups of particles called flocs. The most common coagulants are aluminium sulphate (alum) and ferric sulphate. Alum is generally more common and cheaper, however it has a much smaller effective pH operating range of pH 6.0 to 8.0 compared to pH 4.5 to 9.0 for ferric sulphate. In some cases it may be necessary to adjust the raw water pH so that it falls within the operating range of the chemical coagulant.

Box: Sedimentation basin design calculation example

A settlement with capacity for 20,000 refugees is to be established on the banks of the Blue Nile. It is not possible to pre-treat water via an infiltration gallery or stilling well because of rocky ground so a decision has been taken to build a sedimentation basin. Raw water is diverted upstream and conveyed a short distance by an open concrete channel to a single sedimentation basin. As the water passes along the length of the sedimentation basin, suspended particles will settle out to form sludge on the basin floor which will be evacuated back into the river. As raw water enters the sedimentation basin an equivalent volume of clarified water will be displaced and conveyed by gravity to two horizontal flow roughing filters for further treatment. River water tests give Total Suspended Solids (TSS) of 5.2 mg/litre and shows 90% of particles having a settling velocity of greater than 1.0 m/hr. What are the dimensions of the sedimentation basins?

Flow rate (Q) = N x V x F_1 x F_2 / 24 hours
Flow rate (Q) = 20000 x 20 x 1.1 x 1.1 / 24
Flow rate (Q) = 20,167 litres / hour
where

Q = the design flow rate
N = the design population
V = water demand (20 litres/per/day)
F_1 = 10% factor for leaks and wastage
F_2 = 10% factor for communal services

It follows that for the sedimentation basin..

Surface Area (A) = Q / Vs
Surface Area (A) = 20.1 m^3/hr / 1.0 m/hr
Surface Area (A) = 20.1 m^2

where

A = plan surface are of the basin
Q = design flow rate (20.1 m^3/hr)
Vs = design settling velocity (1.0 m/hr)

The ideal ratio of length to width should be around 3, therefore..

Basin length (L) = (20.1 m^2 x 3)$^{0.5}$
Basin length (L) = 7.7 m

Basin width (W) = 20.1 m^2 / 7.7 m
Basin width (W) = 2.6 m

The ideal depth of the basin should be 2.0m to avoid turbulence and scour.

124. Coagulant solutions of 1% strength should be dispersed uniformly throughout the raw water at a location where the flow is turbulent; either on the suction side of a raw water pump (before the water enters the impellor blades), or at the inlet to the mixing tank. Coagulant solution addition can be carried out manually or better still using a dosing pump. In some cases, alum will only be available as chips, rather than powder form, and dosing will need to be carried out by running the water through a correctly sized dosing cage.

Figure 3-22 Alum dosing cage

125. Flocculation involves a period of slow gently mixing to encourage floc formation. It can be facilitated by directing the flow parallel to the tank to encourage a gentle circular motion. Care must be taken to ensure that the water is not moving faster than 0.3 m/s which can cause flocs to break apart.

Figure 3-23 Rapid coagulant mixing

126. The optimum amount of coagulant will depend upon the nature of the particles suspended in the water, the type of coagulant and pH of the raw water. The lowest effective dose can be determined by the use of a jar test (see Box). In all cases, UNHCR field staff and their partners must ensure that a jar test is performed at least every 3 months or more often if there are large fluctuations in the levels of suspended particles (for example during the rainy season).

UNHCR field staff and their partners must ensure that all water supplies that are treated using chemicals are tested for treatment chemical carry over. WHO guidelines recommend that alum carry over should be no greater than 2mg/l. Levels can be easily monitored using a colour comparator and the correct reagents.

127. In emergency situations, assisted sedimentation using coagulation and flocculation can be used very quickly to treat turbid waters. Demountable steel tanks or PVC onion tanks can be rapidly erected and large volumes of heavily turbid surface waters can be treated on a batch basis in a matter of hours. However, if the emergency is likely to continue into the long term then it is much better to use a water source that does not require treatment (e.g. groundwater) or a water treatment method that does not rely on chemicals (for example roughing filters). It should be noted that coagulation and flocculation does not render water completely free from faecal pathogens and must always be followed by chlorination.

Box: Jar test procedure to determine the correct alum dose

1. Check the raw water pH is within the effective pH range of the coagulant using a pool tester.
2. Prepare a 1% solution of alum by mixing 10g of alum in 1 litre of water.
3. Prepare and label six (6) (preferably white) buckets each containing 10 litres of raw water.
4. The optimum alum dose will lie between 20mg/l and 120mg/l. Using a syringe, add a dose of 20ml, 40ml, 60ml, 80ml, 100ml and 120ml of 1% stock solution to each of the 10 litre samples to obtain doses of 20mg/l, 40mg/l, 60mg/l, 80mg/l, 100mg/l and 120mg/l.
5. Rapidly stir each bucket for 30 seconds with a wooden spoon. Continue very gently stirring for 5 minutes.
6. After 30 minutes extract a sample of water from each bucket and compare with a turbidity tube or electronic colorimeter.
7. Pick the lowest dose that produces a sample with less than 5 NTU.

Source: ACF (1996) '*Water, sanitation and hygiene for populations at risk – second ed*'. ACF, Paris, France.

128. Sludge accumulated from chemical coagulants has a high aluminium content. In all contexts, UNHCR field staff and their partners must ensure that all water treatment sludges are dewatered

in shallow basins, dried into cake, and disposed of safely in a landfill where the impact on the environment can be controlled, minimized and monitored.

Figure 3-24 Coagulant jar test

Roughing filtration

129. Roughing filters are used to remove suspended solids, by passing water through compartments containing progressively finer media typically graded between 25-15 mm, 15-10 mm and 10-5 mm. Their main advantages are their ability to reduce turbidity in a low tech and simple manner without the use of chemicals. Any durable, non-toxic media can be used including gravel, broken bricks and broken plastic. The different compartments containing the media can be arranged either horizontally (HRF) or vertically. In the vertical configuration, the flow can be arranged either upflow (URF) or downflow (DRF).

The upflow roughing filtration configuration uses gravity for backwashing and therefore is the simplest solution, often having the greatest performance over time. UNHCR field staff and their partners should take this into consideration when planning any surface water treatment facilities.

130. During HRF the length of each section is normally 3-4 m, 2-3 m and 1-2 m. Water depth is usually 1.2 m. The cross sectional area of a horizontal flow roughing filter can be calculated by dividing the demand flow rate by the design filtration rate (usually 0.5–1.0 m/h).

Figure 3-25 Horizontal flow roughing filter

131. Vertical roughing filters are either made up of individual units each containing different media, or a single unit containing several layers of media. The depth of the media in a single unit is usually 60cm – 1m and in a multi-layered filter it is usually 60cm (coarse), 30cm (med) and 30cm (fine).

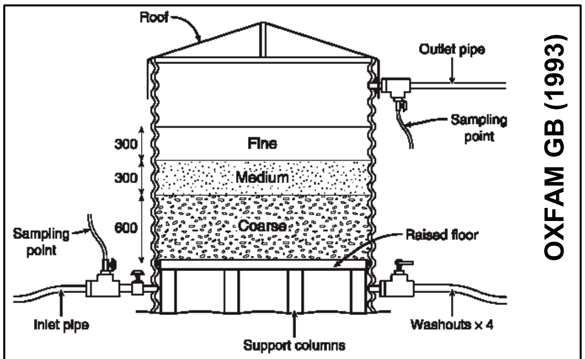


Figure 3-26 Layered upflow roughing filter

132. Roughing filters are cleaned by backwashing at high velocities (60-90 m/hr) to re-distribute filtered particles and flush them out. In upflow and horizontal roughing filters this is achieved by opening several large diameter outlet valves simultaneously. Backwash velocities can be increased by

installing drive pipes on the outlets or by adding additional driving head using a pump. Backwash velocities should be monitored by timing how long it takes the roughing filter water level to drop by one metre.

133. The frequency of roughing filter backwash depends upon the sediment loading and can range from daily to every three weeks. The quality of the water and resistance head should be closely monitored at the entrance and exit to each filter stage.

Where possible, all water treatment infrastructure should take advantage of natural gradients to provide flow through each stage of treatment without the additional costs and complexity of pumping.

134. In all cases it is highly recommended that roughing filtration is preceded with pre-treatment to remove any large particles before treatment begins. For example, if the raw water contains suspended matter with settling velocities of greater than 1m/hr, it is highly advantages to precede roughing filtration with a sedimentation basin. Selection of the roughing filter type depends upon the levels of suspended solids in the raw water. Single multi-layered URF units are recommended for raw waters with less than 30 NTU. URF units in series are recommended for raw waters of with 30 - 300 NTU. URF in series or HRF units are recommended for raw waters with more than 300 NTU. Calculations should use the highest annual turbidity levels that are typically experienced during the rainy season. In waters of high turbidity, multiple URF or HRF treatment units are often required in series to reduce turbidity to levels where the water can be directly chlorinated.

Box: Typical removal efficiencies of roughing filtration

	% Removal NTU	
Filtration Type	**0.3 m/hr**	**0.6 m/hr**
URF in layers	85%	75%
URF in series	92%	87%
DRF in series	88%	86%
HRF	92%	91%

Source: Weglin M. (1996) *'Surface water treatment by roughing filters*. EAWAG, SANDEC and SKAT, Switzerland.

135. The major disadvantage of roughing filters is that they can take considerable time to locate, grade and install filter media. Manual grading of filter media (sieving) can take a large amount of manpower.

Box: Upflow roughing filter design calculation example

A settlement with capacity for 20,000 refugees is to be established close to a large river. Water is partially treated using an infiltration gallery. It is estimated that during the rainy season, raw water will not fluctuate beyond 320 NTU. The water needs to be treated to a sufficient level for chlorination. How many URF units are required? What are their dimensions?

Daily Demand (D) = N x C x F_1 x F_2
Daily Demand (D) = 20000 x 20 x 1.1 x 1.1
Daily Demand (D) = 484,000 litres

where

N = the design population (20,000 pers)
C = per capita cons. (20 litres/per/day)
F_1 = 10% factor for leaks and wastage
F_2 = 10% factor for communal services

Assuming continuous water treatment..

Flow rate (Q) = 484,000 litres / 24 hours
Flow rate (Q) = 20,167 litres / hour

The raw water turbidity is greater than 300 NTU so use either URF with media in series or HRF units. The number of URF units required …

URF units = log [T_W / T_R] / log [1-R]
URF units = log [5 / 320] / log [1-0.87]
URF units = 2.04 units

Where..

Treated water turbidity (T_W) = 5 NTU
Raw water turbidity (T_R) = 320 NTU
URF removal efficiency (R) = 87%

i.e. at least 2 URF in series are required to reduce the turbidity from 320 to 5 NTU. Calculate the area of the URF units..

URF area (A) = Q / V_F
URF area (A) = 20.2 / 0.6 = 34.3 m^2

Where ..

Q = the design flow rate (20.2 m^3/hr)
V_F = filtration rate (0.6 m/hr)

A T45 demountable steel tank has a diameter of 6.4m, an area of 32.2m^2 and a height of 1.5m. Therefore a single URF with media in series can be constructed using 3 x T45 reservoirs filled with gravel of 12-18mm, 8-12mm and 4-8mm. Two URF units (6 x T45 reservoirs) are needed to reduce the turbidity of 484,000 litres of water from 320 NTU to 5 NTU.

Slow sand filtration

136. Slow sand filters produce high quality water drinking water 99.9% free from pathogens without the use of chemicals. They consist of a bed of specially graded sand that water is passed through at a very slow rate. Pathogens are removed by a combination of filtration, adsorption and the action of predatory organisms that are present in a biologically active layer (schmutzdecker).

Figure 3-27 Urban slow sand filter

137. Continuous filtration slowly blocks the pores of the top layer of sand increasing the driving head. When the driving head has reached a maximum the filter needs cleaning. Cleaning is carried out by scraping off the top 2cm of sand. Dirty sand can be washed in a large fluidizing drum or by high pressure hosing, flushing out the dirt. Cleaned sand can be returned to the filter. After scraping, the filter needs several days to re-establish the biological layer.

Figure 3-28 Slow sand filter cleaning

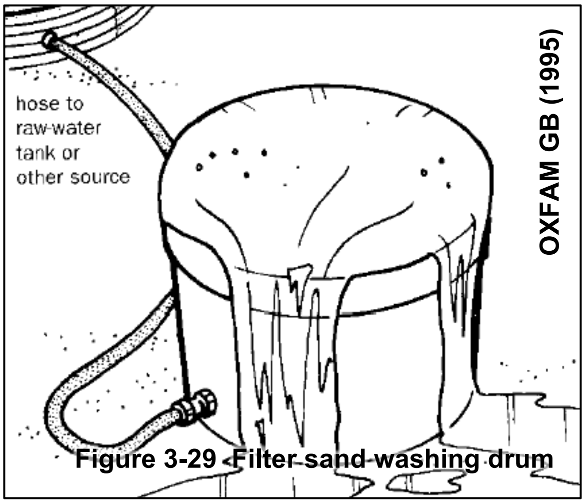


Figure 3-29 Filter sand washing drum

138. The size of the slow sand filter unit can be calculated by dividing the demand flow rate by the design filtration rate (usually 0.1 – 0.3 m/h). The depth is typically around 1.2m allowing a minimum of 0.6m for effective filtration plus an additional 0.3m – 0.5m for cleaning. Slow sand filtration usually requires specially graded sand with a uniformity coefficient (D60/D10) of less than three and effective size (D10) between 0.15 - 0.35mm. A filter under drain is installed of either supported perforated slabs or a network of perforated pipes inside a graded gravel bed. When the filter is commissioned, the sand bed can take two to four weeks to ripen and chlorination must be carried out.

UNHCR and WASH actors should not consider installing slow sand filtration infrastructure in most refugee setting. They are not suitable for emergency responses and in most refugee settings are superfluous to water treatment due the UNHCR mandatory requirement that all water supplies need to be chlorinated.

139. Despite producing drinking water of very high quality without the use of chemicals, slow sand filters are not appropriate in emergencies as locating suitable sand for the filter and the filter ripening period takes a significant amount of time. Slow sand filters also yield small amounts of water for the relative size and cost of the treatment installation. In addition, they cannot tolerate water over 20 NTU and often need extensive pre-treatment. Finally, they require careful attention and constant monitoring from skilled staff.

Membrane filtration

140. Membrane filtration processes are used for large scale water treatment in developed settings. Depending on the pore-sizes that are deployed, membrane filters are able to remove virtually all contaminants from water supplies including viruses, endotoxins and organic contaminants. They are also useful in some settings where specific pathogens have developed resistance to chlorine (such as cryptosporidium and Giardia lambila).

Microfiltration (MF) membranes have pore sizes from 0.1 µm to 10 µm and are used to filter out microorganisms and suspended particles. MF is commonly used as a pre-treatment for ultrafiltration (UF) and reverse osmosis (RO).

Ultrafiltration (UF) membranes have pore sizes ranging from 0.1 µm to 0.01 µm and are able to filter out proteins, endotoxins and viruses.

Nanofiltration (NF) membranes have pores sized from 0.001 µm to 0.01 µm allowing monovalent ions such as sodium or potassium to pass but divalent ions such as calcium and magnesium and some higher molecular weight organic contaminants to be rejected.

Reverse Osmosis (RO) is the finest separation membrane process available, where the pore sizes range from 0.0001 µm to 0.001 µm. RO is able to filter out almost all molecules except for water. Reverse osmosis is fundamentally different to nanofiltration since the flow goes against the concentration gradient using pressure as a means of forcing water to go from low to high concentration. Reverse osmosis requires extremely high pressures in the range 15 – 50 bar. The most common application for reverse osmosis is desalination of brackish water and seawater.

Membrane filtration equipment and approaches is generally not recommended for refugee settings as the high operating costs and dependency on expensive imported materials and expertise renders the approach prohibitive. In all settings, membrane filtration should be considered as a last option and if water supplies require this level of treatment it is often better to move the refugee population to a site with water supplies that have less of a treatment burden.

Chlorination

141. Chlorine is the most readily available and widely used chemical disinfectant for water supplies in the world and is the only treatment method that leaves a residual that continues to protect supplies from further contamination. UNHCR and WASH actors must ensure that all water supplies in refugee settings are immediately chlorinated, regardless of use.

UNHCR and WASH actors must ensure that at all times there are sufficient stocks of chlorine to cover the water treatment needs for the following three months.

142. The aim of chlorination is to supply a sufficiently high dose of chlorine to oxidise any pathogens and organic matter present in the water and leave a residual that will continue to protect the water supply network and water itself up to the point of consumption. UNHCR and WASH actors must ensure that a dose is selected to meet the 'chlorine demand' and leave a free chlorine residual of 0.5 mg/litre at the point of collection following a contact time of 30 minutes (or longer if the pH is greater than 8.0 – see box below). Care should be undertaken to ensure that the required free chlorine residual is available at the furthest water network branches.

Box: Minimum contact time requirements for water supplies with pH greater than 8.0

pH	Chlorine residual (mg/l)	Minimum contact time
8.0	0.2 0.5	30 mins
8.5	0.2 0.5	206 mins 82.5 mins
9.0	0.2 0.5	412 mins 165 mins

Note: Contact times must be increased for water supplies less than 20C.

Source: Oxfam (2001) *'Instruction Manual for Coagulation and Disinfection Equipment'*.

143. In all refugee settings, a multiple barrier water treatment approach should be adopted. During diarrhoeal disease outbreaks or times of risk of disease outbreaks, the free chlorine residual must be increased to 0.8 – 1.0 mg/litre. Where there are decentralized systems (i.e. hand dug wells, springs, handpumps, surface water

collection) a strategy of managed chlorination must be adopted; either through the use of chlorination posts or household water treatment (e.g. aquatabs).

144. Chlorine is available in many forms with varying strengths of available chlorine. The most common source of chlorine for treating water supplies is calcium high test hypochlorite (HTH - 70% available chlorine). Other common sources of chlorine include…

- High Test Hypochlorite - 70%
- Bleaching Powder - 34%
- Household Disinfectant - 10%
- Liquid Laundry Bleach - 5%
- Antiseptic Solution - 1%

Figure 3-30 Stockpiles of HTH

145. In all settings, UNHCR and WASH actors must ensure that total and free chlorine residual levels are being measured using DPD1 and DPD3 tablets and a simple 'pool tester'. The UNHCR approved procedure for measuring chlorine residual using a 'pool tester' can be found in Annex 9 (page 226) of Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of Community Supplies (WHO, 1997). Decay of free chlorine levels increases in warm temperatures or if the water is left in the sun therefore free chlorine levels should not only be tested at the point of collection but also the household level.

146. The UNHCR approved procedures for selecting the location of sampling points and sampling frequency for refugee settings can be found in Chapter 4 (page 51) of Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of Community Supplies (WHO, 1997). However, UNHCR and WASH actors must ensure that chlorine residuals are monitored on a daily basis in all settings. In addition, UNHCR and WASH actors must ensure that all water quality testing results are updated in the site Water Safety Plan.

147. A precondition for effective chlorination is that the turbidity of the water is less than 5 NTU. This generally means that water supplies will require some form of pre-treatment (such as sedimentation or filtration). The turbidity of the water can be verified using a colour comparator or a Jackson Tube. The UNHCR approved procedure for measuring turbidity can be found in Annex 10 (page 231) of Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of Community Supplies (WHO, 1997).

148. For effective chlorination the pH of the water supplies being treated

must be less than 8.0. If the pH is greater than 8.0 then the contact time must be significantly increased following the guidance in the box on the previous page. Chlorine has very little disinfecting power above pH 9.0. The pH of the water can be determined using a 'pool tester' and phenol red. The UNHCR approved procedure for measuring pH can be found in Annex 10 (page 231) of Guidelines for Drinking Water Quality, Volume 3 – Surveillance and Control of Community Supplies (WHO, 1997).

149. The actual chlorine dose will depend on the raw water quality but can be expected to be in the range of 1 – 5 mg/l. The dose can be determined by carrying out a 'Jar Test' using plastic buckets. The UNHCR approved procedure for a 'Jar Test' can be found on page 448 of Water and Sanitation for Populations at Risk (ACF, 2005). The water quality of surface water and some groundwater is temporal and so the 'Jar Test' procedure should be repeated at different times of the year to ensure the optimum dose is being used.

150. Care must be taken to ensure that the water is not over-chlorinated as this may leave an unpleasant taste and users may return to traditional unprotected sources. Combined chlorine should be monitored using DPD3 tablets and a pool tester. Most individuals are able to taste or smell chloramine generated from the reaction of chlorine with ammonia in drinking water supplies at concentrations as low as 0.3mg/l.

Box: Calculation of chlorine stocks required for three months of water treatment

A large camp is providing water to 40,000 refugees. An jar test has indicated the chlorine demand of the water to be 4 mg/l to provide a free chlorine residual of 0.5 mg/l. How much HTH (70% available chlorine) should be procured to ensure a 3 month contingency supply is always on hand?

Daily Demand (D) = N x C x F_1 x F_2
Daily Demand (D) = 40000 x 20 x 1.1 x 1.1
Daily Demand (D) = 968,000 litres

where

N = the design population (40,000 pers)
C = per capita cons. (20 litres/per/day)
F_1 = 10% factor for leaks and wastage
F_2 = 10% factor for communal services

The daily amount of chlorine (X_{DAY}) required for water treatment is given by.

X_{DAY} = D x Y x (100 / C_{ACTIVE})

Where..

D = Daily Demand (968,000 litres)
Y = Chlorine Demand (4 mg/l)
C_{ACTIVE} = percent active chlorine (70%)

It follows that

X_{DAY} = D x Y x (100 / C_{ACTIVE})
X_{DAY} = 986,000 x 4 mg/l x (100/70)
X_{DAY} = 5.5 kg / day

Therefore the amount of HTH required for 90 days is…

Chlorine Amount (X_{90}) = X_D x 90 days
Chlorine Amount (X_{90}) = 5.5 kg x 90 days
Chlorine Amount (X_{90}) = 495 kg

In conclusion, 495 kgs of HTH chlorine (70% active chlorine) would be required to treat 20 litres of water a day for 40,000 people at a rate of 20 litres per person per day for 3 months.

151. UNHCR and WASH actors must ensure that there is always at least three months of chlorine stock on hand to ensure sufficient supplies for new influxes or disease outbreaks. An approximate calculation of the amount of chlorine stock required for three


cK

months use in a refugee setting with 40,000 people can be found in the box on the previous page.

Box: Calculation of chlorine required to batch dose a 15,000 litre water tanker

An influx of refugees is putting additional stress on a local city public water supply network. It has been decided to assist the municipal water authorities by establishing additional temporary water distribution points supplied with tankers in districts with high numbers of refugee families. Water will be collected from the town's groundwater production facility which has a low turbidity of 4 NTU. The water has a small chlorine demand of 1mg/litre to ensure a free chlorine residual of 0.5mg/l. How much HTH powder should be added to each 15,000 litre water tanker before it takes the water to the distribution point?

Dose (X) = Q x Y x (100 / C_{ACTIVE})

where

Q = water quantity (15,000 litres)
Y = chlorine demand (1 mg/l)
C_{ACTIVE} = percent active chlorine (70%)

It follows that

Dose (X) = Q x Y x (100 / C_{ACTIVE})
Dose (X) = 15,000 x 1 x (100 / 70)
Dose (X) = 21,428 mg = 21.4 g

In conclusion, 21.4 g of HTH chlorine (70% active chlorine) should be added to each 15,000 litre tanker.

Note: The chlorine residual should be routinely measured and the dose slightly increased or decreased to ensure a residual of 0.5mg/l at the point of distribution

152. Water supplies can be chlorinated either on a batch or a continuous basis. During batch chlorination the required amount of chlorine is prepared in a bucket as a liquid paste and is applied directly to the water tanker or water reservoir, agitated and allowed to react for the minimum contact time. An example of batch dosing can be found in the box below.

Box: Preparation of a 200 litre drum of 1% chlorine solution

Water supplies are to be continuously dosed with 1% chlorine solution from a 200 litre drum. How much HTH should be added to the drum to create the 1% solution? If 180,000 litres of water are treated every day and the water has a chlorine demand of 3mg/l, how long will the drum of 1% solution last?

A 1% chlorine solution contains 10g of active chlorine for every 1 litre, therefore…

Dose (X) = Q x Y x (100 / C_{ACTIVE})

where

Q = water quantity (200 litres)
Y = chlorine concentration (10 g/l)
C_{ACTIVE} = percent active chlorine (70%)

It follows that

Dose (X) = 200 x 10g x (100 / 70)
Dose (X) = 2,857 g = 2.85 kg

In conclusion, 2.85 kg of HTH chlorine (70% active chlorine) should be added to 200 litres of water to make a 1% solution.

Part 2: How long will the drum of 1% solution last? A 1% chlorine solution contains 10g of active chlorine for every 1 litre, therefore for 200 litres of water..

Active chlorine = 200 litres x 10 g
Active chlorine = 2,000 g = 2,000,000 mg

If each litre of water requires 3mg of active chlorine we can treat (2,000,000 mg / 3 mg) = 666,667 litres of water in total. If 180,000 litres of water are treated every day, the 200 litre drum will last approximately (666,667 litres / 180,000 litres) = 3.7 days.

153. During continuous chlorination, a 1% chlorine solution is slowly added to the water supply typically before final storage. A 1% solution is prepared by mixing 10g of active chlorine for every litre of water. It is comparatively stable and can readily be used to dose water for short periods. An example calculation for preparing a 200 litre

drum of 1% solution can be found in the box on the previous page.

154. Chlorine is dangerous and only trained personnel should be allowed near stocks of chlorine or chlorinating equipment. Chlorine can cause burning and must not come into contact with skin or clothing. UNHCR and WASH actors must ensure that all staff working with chlorine use protective clothing when working with chlorine (gloves, goggles, apron, boots). Chlorine must be stored under dry, cool dark and ventilated conditions. Chlorine gas is heavier than air and corrosive.

155. Automatic chlorinating units allow water supplies to be continuously chlorinated. They are available in a wide variety of sizes and types for small and large scale water systems including..

- Drip feed gravity fed
- Constant head gravity fed
- Suction doser
- Venturi doser
- Proportional doser
- Floating chlorinator
- Pot chlorinator

156. Recent technological advances have led to the development of solar powered units capable of manufacturing sodium hypochlorite through the electrolysis of a saturated solution of common household salt. These electrolytic chlorine units solve many of the sustainability issues related to the challenges and costs of procuring supplies of chlorine in refugee settings and it is highly recommended that all water systems use these systems.

Figure 3-31 Emergency chlorine doser

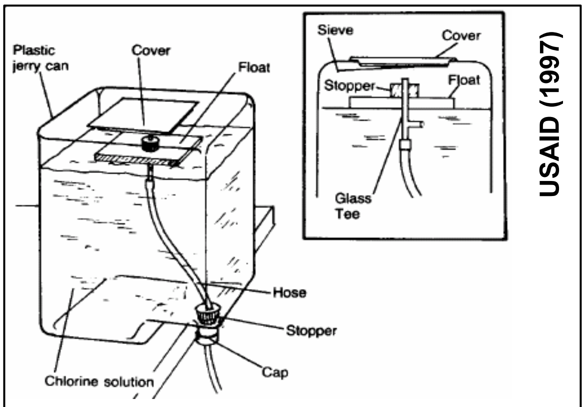


Figure 3-32 Constant head chlorinator

Figure 3-33 Floating pot chlorinator

Figure 3-34 Electrolytic chlorine generator

Aeration

157. Bad tastes and smells in water supplies can be reduced by creating an environment in which gases can escape and any dissolved minerals can come out of solution. An aerator allows this exchange to occur in a controlled manner before the water reaches the consumer. Simple systems typically maximize water/air contact time and contact area by cascading water supplies through a stack of aerating trays. As the water is aerated, minerals dissolved in the water are allowed to come out of solution and typically need to be filtered out of the water supplies using a rapid sand filter arrangement. Gravity aerator designs can be made that are simple enough to be maintained locally using no specialist knowledge or tools.

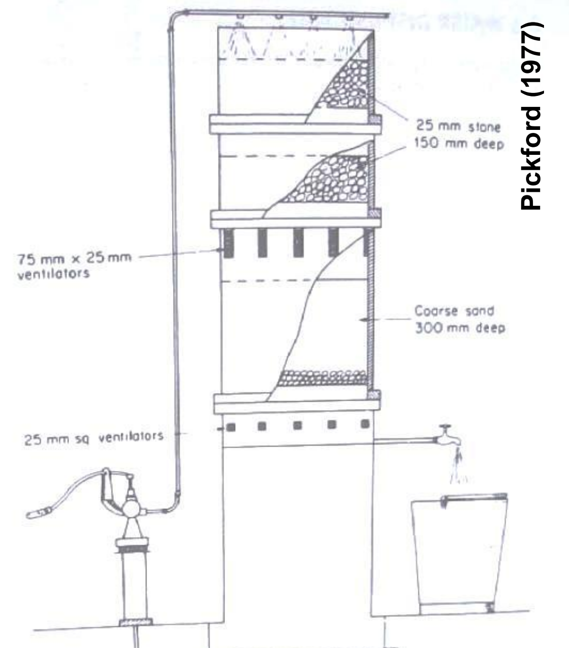


Figure 3-35 Simple manganese aerator

Ultraviolet irradiation

158. UV irradiation provides a quick and effective way of deactivating harmful pathogens in water supplies without the use of chemicals. UV light of the correct dosage has demonstrated efficacy at deactivating pathogenic bacteria, virus, protozoa and helminths. It is particularly effective at deactivating organisms that are resistant to chlorination such as cryptosporidium and giardia. It is usually used as a final step in water treatment before residual chlorination and distribution.

If there is a risk of chlorine-resistant protozoans, in particular Cryptosporidium and Giardia lambia cysts. Then UNHCR and WASH actors must ensure that water supplies are irradiated to at least 10mJ/cm^2 before final residual chlorination.

159. UV disinfection is achieved by allowing a thin layer of water to enter into contact with either submerged or air mounted low-pressure mercury vapour lamps that produce UV radiation at the optimal wavelength for pathogen destruction. Water can be treated on a batch or continuous basis by placing the lamp in a container of water for several minutes or longer, or on a flow-through basis in a housing or channel, with the water flowing parallel or perpendicular to the lamp(s).

160. UV irradiation does not create taste, odors or chemical by-products; however, the lamps require stable electrical energy supplies and need to be cleaned and replaced periodically. UV irradiation can be successfully scaled to treat water supplies at the bulk or household treatment levels.

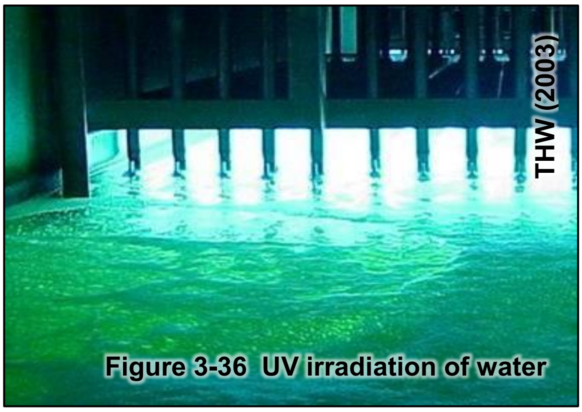


Figure 3-36 UV irradiation of water

Use of compact packages water treatment systems

161. A number of emergency response NGOs and commercial organisations have developed pre-packaged water treatment kits that allow water sources to be quickly treated and distributed in a matter of hours during a refugee emergency. These units are typically small, self-contained and portable (often trailer or skid mounted) that can be rapidly set up to produce large amounts of treated water.

Figure 3-37 Compact water treatment unit

162. The disadvantage of these units is that they are often highly complex, highly mechanized, expensive and heavily reliant on spare parts, chemicals, energy, and imported specialist expertise for operation, maintenance and repair. Most compact water treatment units are sensitive to turbid waters and may need pre-treatment to reduce turbidity to acceptable levels.

163. While these water treatment units are useful during the emergency phases of a refugee scenario, they are not appropriate for the post-emergency phases. Where treatment is required, UNHCR and WASH actors should aim to use simple techniques such as screening, plain sedimentation, infiltration galleries, stilling wells, and multiple stage filtration using correctly designed gravel and sand filters (roughing filtration and rapid sand filtration). Slow sand filtration should generally redundant due to the mandatory requirement of chlorinating all water supplies. Where possible water treatment systems should avoid or minimize dependence on fuel or electric pumping, using gravity to move water between all treatment stages. All water treatment systems should be capable of being operated and maintained by local water authorities or the refugees themselves at minimum on no cost by staff with low levels of formal education.

Figure 3-38 Compact water treatment unit

Household water treatment and safe storage

When and when not to consider household water treatment

164. In some refugee settings, centralized water treatment is not practical or feasible and simple, inexpensive household treatment products can ensure that refugees instantly have access to safe drinking water. Scenarios when household water treatment products may be used include:

- ☐ Acute emergency situations where bulk water supply and treatment has not yet been established.
- ☐ Rural dispersed settings where it is infeasible to establish bulk water supply and treatment.
- ☐ Unplanned camp settings where UNHCR or WASH actors are unable to establish bulk water supply and treatment and water tankering is infeasible.
- ☐ Urban non-camp settings where the population is staying in rented accommodation, with host families, or congregated in public (or private) buildings or land.

In camp based settings, UNHCR and WASH actors should ensure that bulk water treatment methods are prioritised over household water treatment methods to ensure that all refugees have access to safe water supplies.

Emergency phase household water treatment options

165. All water supplies during epidemics, or during times of risk of epidemics, should be treated with chlorine so there is a free chlorine residual. Therefore in emergency settings, UNHCR and WASH actors should only consider the following household water treatment options:

- ☐ Chlorination with tablets (e.g. aquatabs), chlorine solutions, or equivalent.
- ☐ Treatment with a coagulant /flocculant/disinfectant (e.g. PUR, Watermaker).

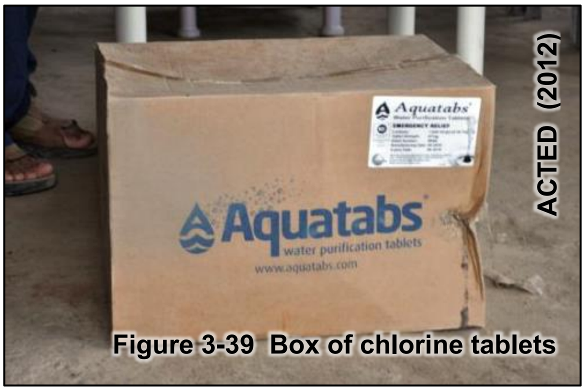


Figure 3-39 Box of chlorine tablets

Figure 3-40 Coagulant/ flocculant sachet

166. POU interventions in emergencies are most likely to succeed when the products that are being distributed are familiar or known to the affected population. There is a risk that distribution of POU water treatment products that are unknown may lead to low adoption rates (Lantagne, 2011).

Practical demonstrations of household water treatment products

167. If household water treatment products are distributed (such as chlorine tablets, flocculant/ disinfectant sachets, or water filters) then UNHCR and WASH actors must ensure that the first distribution of the product is accompanied with a visual demonstration in small groups. If use of the water treatment products requires additional household items (such as cutting, measuring, stirring, filtering, decanting, or storage items) then these additional items should be supplied as a kit. Alternatively UNHCR and WASH actors should verify that these products are available at the household level. In addition, a visual flyer illustrating the key steps should be distributed with the kit.

Flocculant/disinfectant sachets

168. PUR is a household water treatment product produced by Procter and Gamble. The product contains a combination of powdered ferric sulphate that acts as a flocculant removing dirt particles and calcium hypochlorite that acts as a disinfectant. PUR comes in a 4 gram sachet that treats 10 liters of water as a batch. The sachets arrive from the manufacturing facility in cartons containing 20 strips of 12 sachets each, for a total of 240 sachets per carton. Each carton is 25 cm x 11 cm x 15.5 cm.

169. Flocculant/disinfectant sachets should only be distributed as a HWT option where the main drinking water sources are turbid (i.e. river water, marsh water, or

Figure 3-41 PUR treatment steps

water from traditional open wells). Flocculant/disinfectants are not recommended for non-turbid drinking water sources (i.e. piped water networks, or water from handpumps). It is recommended that aquatabs or chlorine solutions (eau de javel) are distributed where the main drinking water sources are non-turbid.

Box: Recommended supplies to be distributed with flocculant/ disinfectant sachets

If communities have never used PUR before then UNHCR field staff and their partners must ensure the first distribution of the product is accompanied with the following equipment:

ITEM	PURPOSE
1 x Scissors (or a Knife)	PUR sachets are made from rip-proof material to prevent accidentally ingestion. The sachets can only be opened with scissors or a knife.
1 x 10 litre Plastic Bucket	Used during the treatment process.
1 x Wooden Stick (50cm)	Used to gently stir the flocs during treatment.
1 x Straining Cloth (1m^2)	Used to separate the flocs from the treated water.
1 x 10 litre Plastic Bucket (with cover)	Used to store the treated water safely.

170. It is recommended that a one month's supply of flocculant/ disinfectant sachets are distributed to each family at-risk at a time to ensure sufficient coverage. It is recommended that during the emergencies the flocculant/ disinfectant is only used to treat the drinking water component (estimated at 5 liters/person/day) of the daily water requirement. Therefore the following estimate shows that 90 PUR sachets are sufficient for a family of 6 people for one month of emergency household water treatment…

= 1 months x 30 days x 6 people x 5 liters/per/day
= 900 liters / 10 liters
= 90 sachets / month

Post-emergency phase household water treatment options

171. During the post-emergency and protracted phases, and provided there is no risk of disease outbreaks, UNHCR and WASH actors may consider the following household water treatment options in dispersed refugee settings provided that they are followed by chlorination:

- ☐ Plain / Assisted Sedimentation
- ☐ UV Disinfection by Sunlight
- ☐ Ceramic Filters
- ☐ Slow Sand Filtration (e.g. Biosand Filters)

172. In all cases, the decision to promote a household water treatment solution should be based on the raw water quality, the availability of household water treatment products, and the level of acceptance of the refugee population. Only water that is for drinking and food preparation may need treatment. Water for bathing, laundering and cleaning may be left untreated.

173. Household water treatment programmes need significant input in terms of social education in order to be a success. The success of a household water treatment is fully dependent on the motivation of the refugee population to adopt, operate, and if necessary, ensure the cleanliness of the system.

Plain sedimentation

174. Plain sedimentation can be carried out by storing four or five days water supply. Storage for 24 hours can reduce the microbiological contamination levels by 50%. Storage for 48 hours can block the transmission of schistosomiasis. Assisted sedimentation can be carried out if natural or chemical coagulants are available locally. Chlorination or some other form of disinfection, is still needed after treatment to effectively kill all pathogens.

Household biosand filters

175. Household biosand filters can be effective at removing pathogens provided sand of the correct specifications and depth, and constant flow rates of 0.1 – 0.3 m/h are respected. The water must be <20 NTU, and the filter should be allowed several weeks to mature. Cleaning can be carried out by scraping off the top 5 mm of sand.

Figure 4-42 Household biosand filter

176. Oil drums, plastic drums, clay pots, or ferrocement jars can all be used for household treatment systems. Containers should be cleaned thoroughly as they may have held pesticides or chemicals. Final water storage containers should be covered and fitted with a tap to prevent contamination from utensils being dipped inside.

Household rapid sand filters

177. Household rapid filtration can be effective at reducing turbidity provided sand of the correct specification is used. Chlorination or some other form of disinfection, is still needed after treatment to effectively kill all pathogens.

Chlorine water treatment solutions

178. Chlorination is a very successful household treatment provided chlorine compounds are available, the water has <5 NTU, and the chlorine is applied in sufficient dose with enough contact time.

Figure 3-43 Household chlorine solutions

Household ceramic filters

179. Ceramic filters can be effective at filtering out suspended solids and killing pathogens (if treated with colloidal silver). Ceramic filters often become clogged with suspended particles after frequent use and need scrubbing. Use of household filters is generally not the preferred method for household water treatment in


INTERNATIONAL
RESCUE
COMMITTEE
Happy
Family
Water
System

180. refugee settings unless it is followed by chlorination.

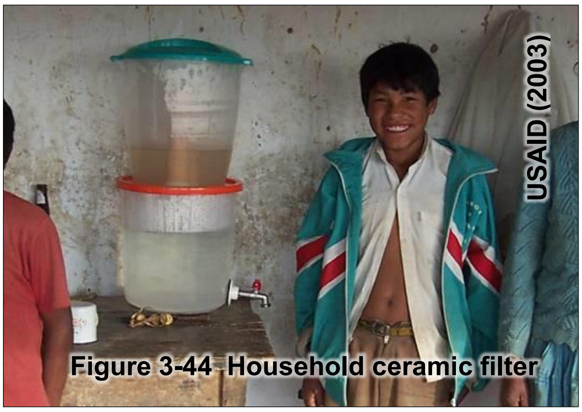


Figure 3-44 Household ceramic filter

SODIS

181. Plastic bottles half painted black and filled 3⁄4 full with low turbidity water <30NTU can be treated by the dual processes of UV irradiation and pasteurization if left in the sun for a full day. Vigorously shaking for several minutes helps dissolve oxygen in the water which reportedly aids the process disinfection process. SODIS is generally not the preferred method for household water treatment in refugee settings unless it is followed by chlorination.

Figure 3-45 SODIS system

Boiling (Pasteurisation)

182. Boiling is one of the oldest and most common methods for treating water supplies. A rolling boil of at least one minute is recommended in order to deactivate all bacteria, viruses, protozoa (including cysts) and helminths that cause diarrheal disease. In mountainous regions water boils at much lower temperatures than 100°C and must be boiled for 1 minute plus an additional 1 minute per 1000 metres of elevation. Boiling of water supplies is easy to carry out in almost all settings as almost all households will have the required equipment and knowledge to carry out the practice. In addition, many populations have a strong culture surrounding tea or coffee preparation.

Figure 3-46 Boiling Water

183. Despite the simplicity and effectiveness of boiling water it should not be considered as the main drinking water treatment strategy in refugee settings as it has many disadvantages including the following.

- Boiling of water requires a considerable amount of wood, charcoal, biomass, or kerosene. It is very inefficient in terms of cost per litre of treated water when compared to other treatment techniques. Boiling of water may contribute to deforestation of refugee settings.
- Boiling of water has an opportunity cost in terms of collection of fuel and water preparation. Boiled water needs to be cooled and stored and cannot be consumed immediately.


NHCR

- Collection of firewood is time consuming and may put women and girls at risk.
- Boiled water lacks residual protection and is often re-contaminated if poorly handled or stored. Boiled water should generally be stored in the same container in which it was boiled, handled carefully and consumed within 24 hours.
- Boiled water often tastes 'flat' when cooled and stored for drinking purposes due to dissolved oxygen escaping as part of the boiling process. Most cultures have objections to the taste of plain boiled water.
- Boiling water carries a high risk of domestic burn injuries putting children in particular at risk.
- Boiling of water does not remove suspended or dissolved chemical contaminants.
- Smoke pollution from indoor stoves present an increased risk to respiratory infections.

UNHCR and WASH actors should not promote boiling as the main drinking water treatment strategy in a refugee setting due to the associated environmental, protection, recontamination domestic burn injury risks, and respiratory disease risks. In addition, boiling of water is generally highly inefficient, costly and labour intensive compared to other methods.

Documenting the household water treatment strategy

184. A full description of the household water treatment strategy, including tracking of distribution rates, usage rates, transcripts from focus group discussions concerning the approach, and exit strategies should be included as part of the site WASH plan/strategy.

Technical options for water storage

The importance of bulk water storage in refugee settings

185. Water storage is an essential requirement in all refugee settings to buffer peaks in water demand and supply and also ensure there is at least half a day of reserve water storage and more if possible for emergencies and contingencies. Water reservoirs should be located at the highest point in the refugee setting to facilitate distribution by gravity. Alternatively if the site is flat reservoirs may be decentralized to provide localized storage for smaller WASH facilities.

186. During the emergency phase, emergency water storage kits may be deployed that include demountable tanks, bladder tanks, onion tanks, and large polyethylene (rototanks). However, all emergency water storage reservoirs should be replaced with permanent water reservoirs within 6 months if it is clear that the refugee emergency is going to last more than six months. Options for permanent water reservoirs include stone masonry, ferro-cement,

rototanks, or reinforced concrete. The emergency kits should be disassembled, serviced and put back into contingency stocks.

Demountable water tanks

187. Demountable tanks are used extensively in emergency refugee settings and consist of a kit of curved corrugated steel panels that are bolted together and lined with an inner rubber liner. The tanks come in various sizes including 11m3, 45m3, 70m3 and 95m3. Assembly can take anything from several hours to half a day depending upon the size of the tank and size of the assembly crew.

Polyethylene tanks (rototanks)

188. Polyethylene tanks (rototanks) are locally manufactured in almost every country in the world and are used extensively in emergency refugee settings. The tanks come in various sizes typically up to 20m3. The advantages of polyethylene tanks are that they are cheap, lights, durable, require no assembly, and can be used as both an emergency and post-emergency water storage solution.

Bladder tanks

189. Bladder tanks are very easy to transport and install and come in various sizes including 2.5m3, 5m3, 10m3 and 20m3. To ensure sufficient head for distribution the bladders should be placed at least 80cm higher that the tapstand on higher ground or a raised platform. The raised platform can be made of various materials but should be strong enough to support the weight (up to 20 tonnes). Options include:

- ☐ Backfilled earth platforms
- ☐ Sandbag platforms
- ☐ Masonry platforms
- ☐ Wooden platforms
- ☐ Oil drum platforms

190. Care must be taken on any ground that is sloped to ensure the space allocated is perfectly flat (or ideally surrounded by an earth bank) and the bladder is secured. Bladder tanks have been known to roll and cause extensive damage and loss of life. The site for the bladder should be free of sharp objects that could puncture the material. Smaller bladders can be installed on the back of flatbed or pickup trucks and used as temporary water tankers. The main disadvantage of bladders is their need for a raised platform, which takes time and resources. In addition, they are very difficult to clean effectively.

Onion tanks

191. Onion tanks are made from the same material as bladder tanks (high tensile PVC coated polyester fabric) and are equipped with a floating collar that allows them to contain water without the need for an external support structure. The advantage of onion tanks over bladder tanks is that they can easily be used for water treatment processes for example batch coagulation/flocculation.

Figure 3-47 Onion Tank, Dadaab


IRC

Figure 3-48 Bladder Platform Options

Post-emergency phase water storage

192. If it is clear that the refugee emergency is going to last for more than six months then plans should be made to upgrade all emergency water reservoirs with permanent structures made from reinforced concrete, ferro-cement, polyethylene, or stone masonry. Post-emergency phase water storage solutions generally requires the use of specialized construction expertise and experienced local contractors.

Technical options for water distribution

Water tankering

193. Water tankering can be a very quick method of getting water to the refugee population during an emergency response, providing suitable resources exist. In order to carry out water tankering, suitable tankers must be available locally of suitable quality for transporting drinking water. Make sure that the tanker is cleaned and chlorinated before use. Other options for tankering water include:

- ☐ Rigid tanker trucks.
- ☐ Flat-bed trucks fitted with reservoirs.
- ☐ Tractor pulled trailers.
- ☐ Animal pulled trailers.

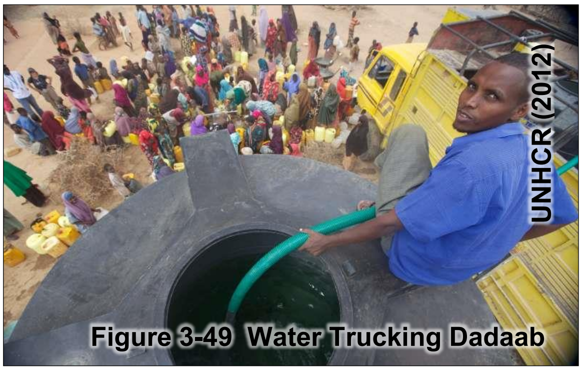


Figure 3-49 Water Trucking Dadaab

194. Tankering of water requires adequate access and road infrastructure for tankers to bring water to the affected population. In addition, a local water resource must be identified with sufficient quantity and quality to support the local and beneficiary populations. The water should be regularly tested for feacal and chemical contamination. The source water should be non-turbid, (NTU < 5) and properly chlorinated.

Figure 3-50 Water Trucking Bangladesh

195. The water tankers must be scheduled to deliver water regularly. The population must be reassured that water will arrive regularly. A back-up plan must be developed in case of tanker breakdown. Time must be allocated for maintenance and repairs of the tanker.

Figure 3-51 Water Trucking Zaatri

196. Water storage and distribution points should be installed as soon as possible. Tanker hire is expensive and the tanker should be used to transport water, not as a static distribution point. In emergency situations the water distribution points may require supervision and roped queues to control crowds.

197. The main advantage of water tankering is that the approach can be mobilized in a very short period of time getting water to refugees in need in the initial stages of an emergency, or when the refugee population is on the move. The main disadvantages of water tankering is its cost (up to 20 - 40 USD$ per m3 depending on distances). In addition it can be logistically difficult to organize and it is not economically feasible to tanker water over great distances. Water tankering can also be unsafe depending on road conditions, tanker loading and the driver's capabilities.

Figure 3-52 Flatbed Truck Tanker

Piped water distribution

198. A piped water network uses gravity or a pump to move water from the point of storage to point(s) of distribution. Materials for piped distribution networks commonly used in refugee settings include:

- ☐ High Density Polyethylene (HDPE)

- ☐ UnPlasticized Polyvinyl Chloride (U-PVC)
- ☐ Galvanized Iron (GI)
- ☐ Lay-Flat Hose

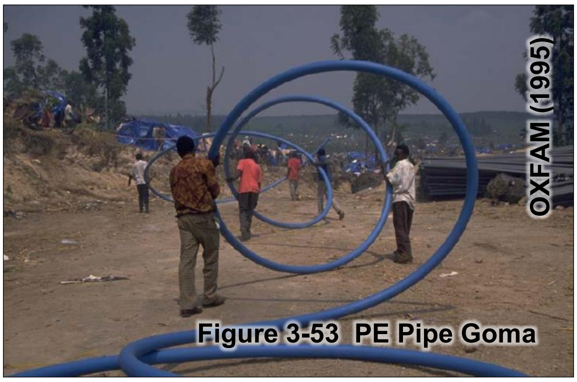


Figure 3-53 PE Pipe Goma

199. The advantages of piped water distribution networks is that despite higher capital costs, they are significantly more cost effective and simpler solution to providing water to a refugee setting in the short, medium and long terms than water tankering. Gravity flow systems do not rely on external power sources and can convey water over great distances for very little cost. The main disadvantage of piped water networks is they can take time to construct, especially if pipe materials need to be imported and pipe trenches need to be excavated.

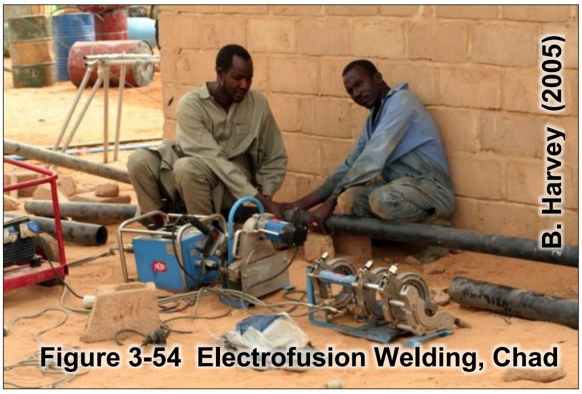


Figure 3-54 Electrofusion Welding, Chad

200. All water systems installed in refugee settings should be designed by a qualified engineer to meet UNHCR's design guidelines for piped water networks (see **wash.unhcr.org**). A package of detailed design calculations, material specifications, technical drawings, and bills of quantity should be submitted to UNHCR for verification before any medium or long-term project is initiated.

Motorized water pumping

201. Motorized (pumped) water system uses energy to move water around a distribution network or against gravity to a water storage reservoir. Water pumping options for refugee settings include:

- ☐ Surface mounted centrifugal pumps
- ☐ Electrical submersible centrifugal pumps
- ☐ Hydraulic ram pumps
- ☐ Helical rotor
- ☐ Reciprocating pump
- ☐ Solar powered pumps

202. Surface mounted centrifugal pumps and reciprocating (piston) pumps are typically used for pumping from surface water sources (e.g. lakes or rivers) or pumping water from reservoirs around a water distribution network. Electrical submersible centrifugal and helical rotor pumps are typically used to abstract water out of boreholes or wells. Hydraulic ram pumps use the energy of falling water, and the water hammer effect, to lift water to a higher elevation than the source.

Figure 3-55 Pump Installation,

203. Pump selection and pump system designs should be designed by a qualified engineer to meet UNHCR's design guidelines (see **wash.unhcr.org**). A package of detailed design calculations, material specifications, technical drawings, and bills of quantity should be submitted to UNHCR for verification before any medium or long-term project is initiated.

204. Pumped water systems need significant cash inputs for fuel, electricity, maintenance, skilled staff and spare parts. Wherever possible, motorized water pumps should always be selected that can be repaired and maintained locally. Spares should be available in country.

Figure 3-56 Pump Installation, Chad

Guidance for water collection points

205. Water collection points (also known as tapstands) typically come as a kit made from 2" GI Pipe supplying four to six taps and can be quickly erected during an emergency response. The water collection point should be free from standing water and should have a non-slip surface to facilitate use by all users. During the post-emergency phase, these may be improved by encasing the exposed pipes in a concrete pillar, constructing a concrete apron (at least 3m) and installing fencing.

Figure 3-57 Jammam Camp, Ethiopia

Figure 3-58 IFO Camp, Dadaab, Kenya

Management of wastewater and drainage

206. Proper drainage at water collection points, bathing and laundering areas is essential to ensure that tapstands don't rapidly become dangerous or unhygienic places to collect water, or breeding sites for mosquitoes. All wastewater should be disposed of in properly designed drainage systems designed to eliminate the risk of pathogen transmission or vector breeding.

207. Wastewater may be diverted into small communal garden areas provided the system is designed to eliminate the risk of pathogen transmission using sub-surface infiltration. Wastewater should not be used to supply animal drinking troughs as it is undesirable to encourage animals to enter the habitable part of the camp. Another reason to avoid this practice is that in some settings refugees have been observed collecting drinking


WATER POINT NO 17
ZONE C BLOCK 1

water directly from the animal watering point. Blackwater (water from septic tank overflows) should not be used in any wastewater reuse projects in any circumstances. The strategy for waste water management and reuse is fully described in the site WASH plan/strategy.

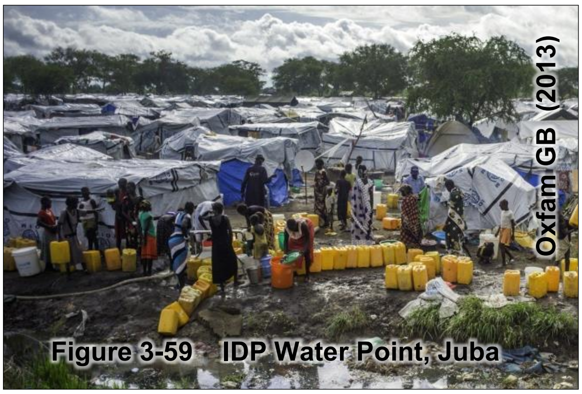


Figure 3-59 IDP Water Point, Juba