

5. Treatment methods for rural water supply

Outline

5.1 Introduction

5.2 Treatment of saline/solid water

5.3 Treatment of waste water

Introduction

- Safe, adequate water and accessible supplies of water, combined with proper sanitation are surely basic needs and essential components of primary health care.
- 75- 80% of public health problems come from inadequate quality of water
- so community water supply programs need to cooperate with improved sanitation and hygiene behavior.
- Water provision is of the major tasks of nations.
- Communities in developing countries that want to establish and run an improved domestic water supplies vary greatly

Cont...

- ❖ Some are small and rather isolated
 - Scattered population, Limited demand for water
 - Strong social cohesion
 - Subsistence economy
 - strong self help and mutual support
- ❖ Others are bustling trading centers
 - Cash economy and on major roads etc..
- ❖ Some are on outskirts of major cities, or are low income communities in inner cities- their socio-economic character also varies

In 2010 according to UNICEF/WHO (2012) 660 million people in the world did not have access to improved water systems, which are systems with a higher likelihood that the water is not polluted (Table 1). Ethiopia was one of the countries with lowest coverage and particularly in rural areas where coverage was only 34% in 2004.

Table 1.1 Qualification of water supply technologies (WHO/UNICEF JMP 2000)

Technologies considered "improved"	Technologies considered not "improved"
Household connection	Unprotected well
Public standpipe	Unprotected spring
Borehole	Vendor-provided water
Protected dug well	Bottled water ¹
Protected spring	Tanker truck provision of water
Rainwater collection	
¹ Not considered 'improved' because of potential limitations in water quantity, not the quality	

In Ethiopia access in rural areas is defined as the percentage of the population that can obtain 15 litres per person per day living within 1.5 km from an improved water source (Universal Access Plan). So if in a community of 5000 people only 3000 live within 1.5 km from an improved water source the access is $100 \times 3000 / 5000 = 60\%$, provided the source can supply $3000 \times 15 = 45000$ litres per day ($45 \text{ m}^3/\text{day}$). If in this case the improved source only has a capacity $30 \text{ m}^3/\text{day}$ then it can serve only $30000 / 15 = 2000$ people (less than live within 1.5 km). In that case access is only $100 \times 2000 / 5000 = 40\%$. This approach looks at installed capacity but does not explore whether people actually use the system what we define as coverage (% of people actually using a specific system).

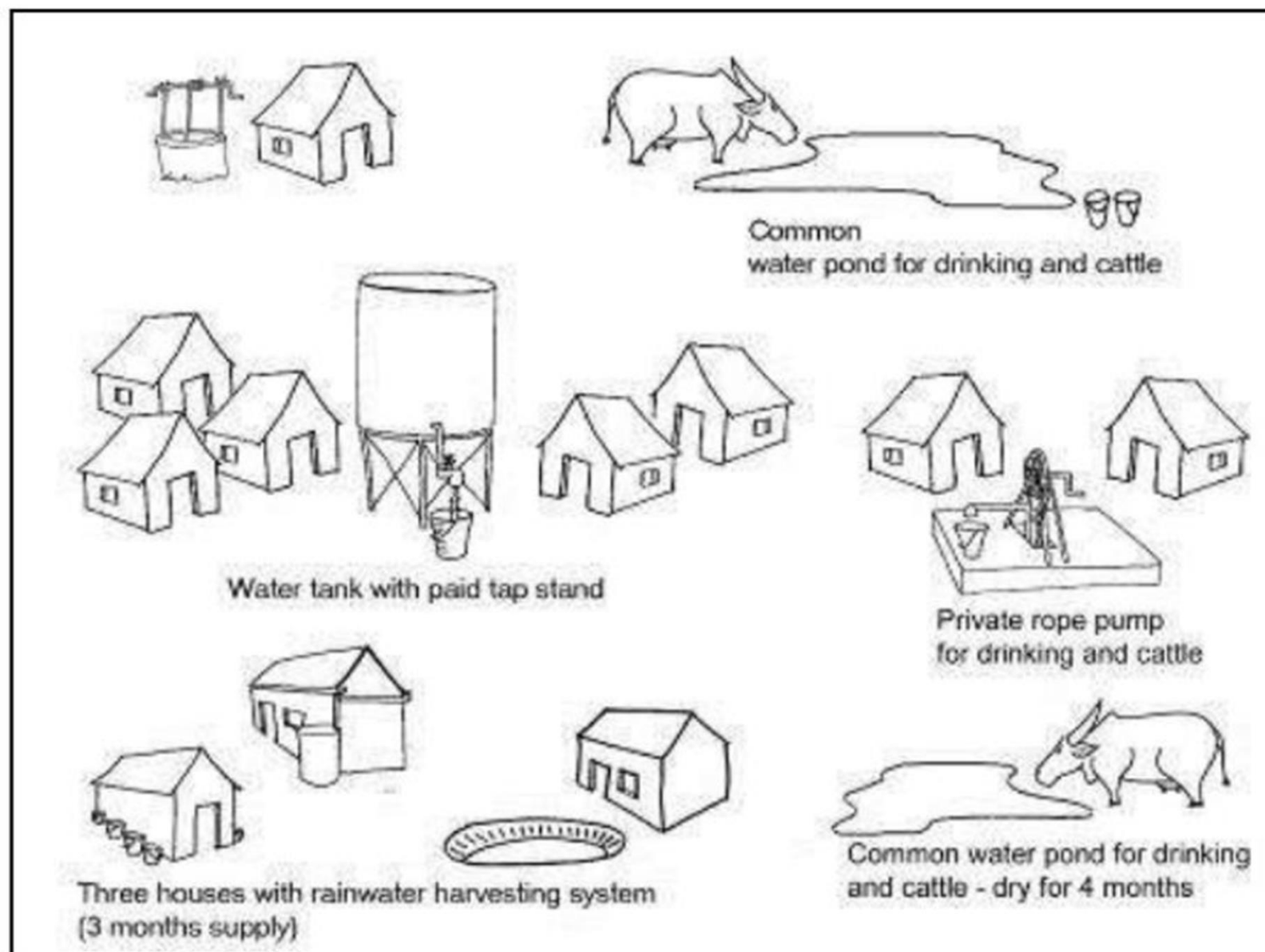


Ethiopia, queuing for water



People and cattle can contaminate the water source





Example of a water supply system of a rural community

Water quality and water treatment at household and rural level

❖water quality

- Water quality is an important issue that may determine whether the water can be used for specific purposes such as drinking water, personal hygiene, cattle and/or irrigation, etc.
- Water quality can be described in terms of its physical, chemical, and biological characteristics.
- The information is kept concise and primarily relates to rural water supply.

Cont....

- Insufficient protection of water sources, or inadequate treatment, handling and storage, thus puts the community at risk of contracting infectious diseases.
- An important problem is that the risk of bacteriological contamination may not be perceived by the community as the pollution is often not visible.
- Local people may value the taste and appearance of the water, but not its bacteriological quality unless they understand the risks.

Treatment methods for rural water supply

- **Water treatment** may be needed to as much as possible to reduce the potential risk involved in ground water or surface water supply.
- The level of treatment should maintain harmony with aspects such as:
 - ✓ the type of risk existing in the water source and
 - ✓ water supply system
 - ✓ the socio-economic conditions in the community.
- ❖ **Five** issues are essential to take into account.

Cont...

1. Select and protect the best water source you can find.

Water catchment and water source protection is in fact the first step in water treatment as this will allow you to prevent harmful materials entering the water.

- E.g. Banning construction of latrines close to wells etc.
- Source selection may also be an option to avoid fluoride problems.
- Prioritizing the ‘safest’ source for drinking water then may be a feasible option to reduce the problem.

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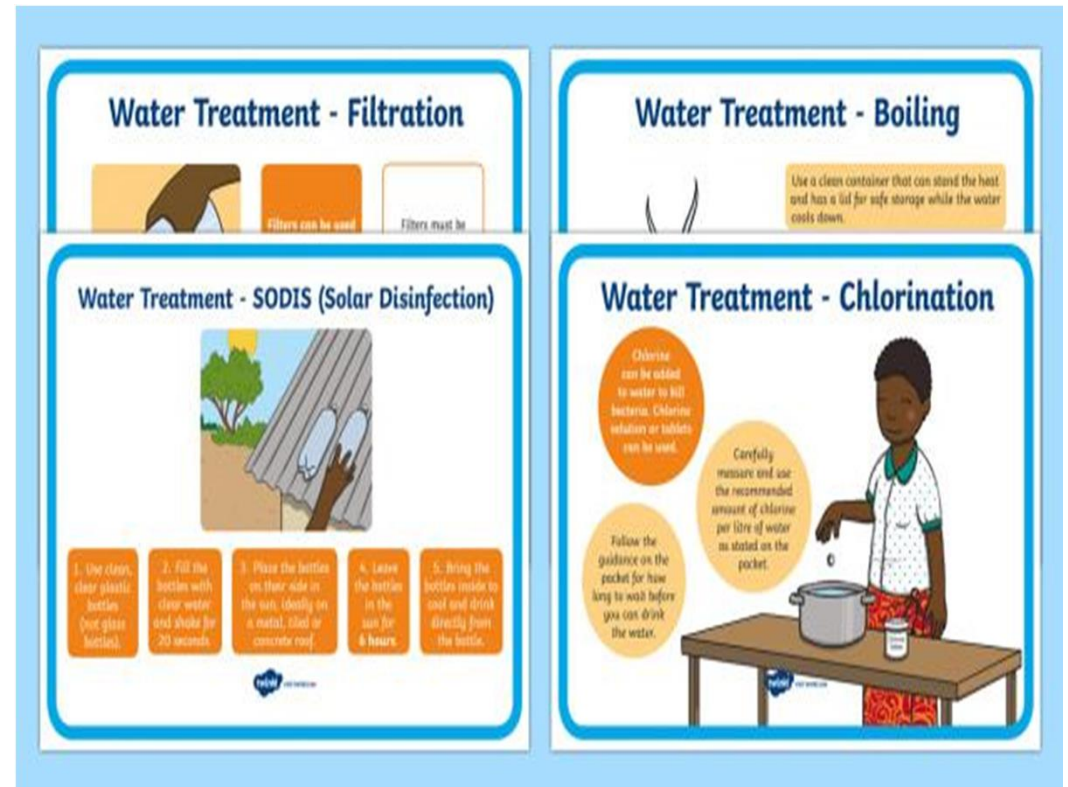
- 2. Make sure that possible treatment works.** If no experience exists with a specific treatment system first try it out or have it tried out carefully before you depend on it.
 - Particularly explore the assurance that possible chemicals and spare parts are readily available.
- 3. Disinfection** requires that the water is already of reasonable quality and does not contain a lot of pathogenic micro-organisms or substances such as organic matter that can interfere with the disinfection process.

Cont...

4. **Avoid recontamination of the water.** Unfortunately recontamination of water after treatment is rather common either through leaking pipes or inadequate collection transport and storage of the water.
5. **Household water treatment.** In many situations water treatment may not be included in the water supply, or water is being re-contaminated in the water chain prior to its use.
 - In such situations household water treatment needs to be explored as the quickest option.

Small scale water treatment

- Methods, used singly or in combination, depending on the reliability of each method.
1. Boiling
 2. Filtration
 3. Solar disinfection
 4. Chemical disinfection and
 5. Households Water Storage



1. Boiling

- is highly effective as it destroys pathogenic micro-organisms such as viruses, bacteria, cercariae, cysts and helminthes ova.
- It is recommended to filter the water through a cloth when cloudy and to boil for one minute or a bit longer at high altitude where boiling is lower.
- Particularly for vulnerable groups such as babies, and young children water boiling may prevent a lot of problems.

On the down side

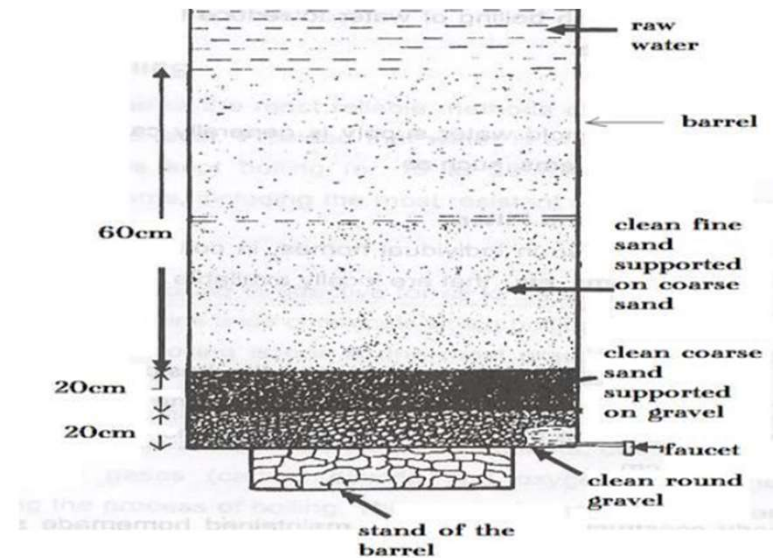
- it may be expensive as it involves considerable fuel consumption.
- consumers may not like the taste of boiled water
- it takes a long time for the water to cool.
- Shaking the water when it has cooled down may improve the taste.

2. Filtration

- One option to improve the transparency of water and partly remove impurities is plain sedimentation.
- By adding chemicals this process can be further improved. Filtration however gives much better results.
- Its simple filtration systems

A. Homemade sand filters

- in containers such as steel barrels, drums, etc
 - depth of filter sand should not be less than 60 cm
- **Can remove:** =>
- turbidity
 - taste and odor
 - cysts and ova of parasites and
 - other relatively larger organisms.



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➤ **Some of the limitations of a homemade sand filter are:-**

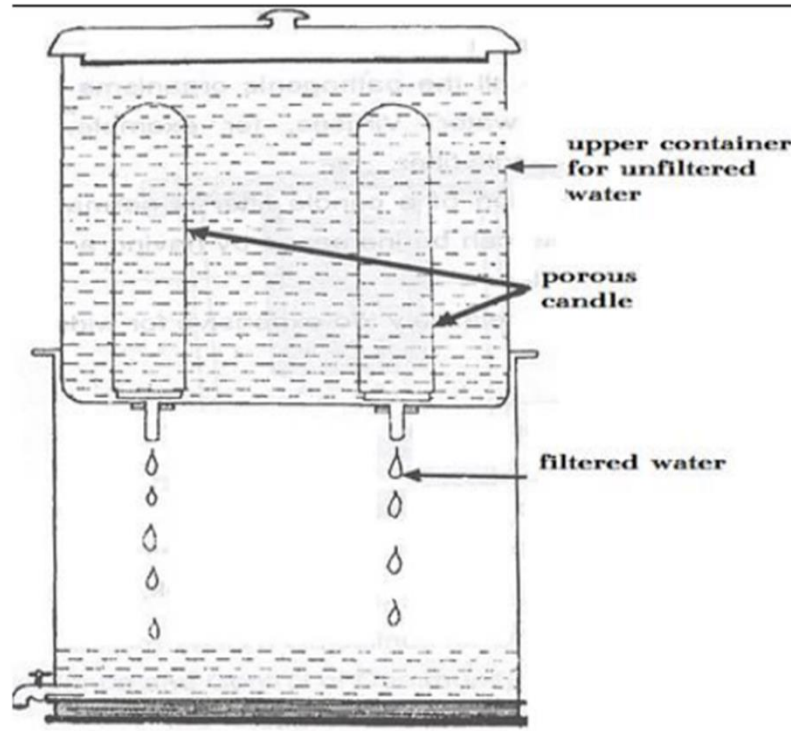
- It cannot be relied upon to remove of **viruses** and some of the **very small-sized bacteria**
- It frequently gets **clogged**, particularly if the raw water to be filtered is **turbid**.

➤ **Maintenance of a homemade sand filter**

- There must be a **continuous flow of raw water** over the filter bed
- The rate of filtration should normally be controlled not to be more than **1.5 liters per minute**.
- This rate will be achieved after the filter has been in operation for a few days.
- The top-most layer of the sand must be **scraped off, cleaned and replaced at fixed periods**.

cont...

B. Home candle filters



- The core of the filter is a porous cylinder
- commercially made
- various types and sizes,
- 0.3 micron-50 microns

Cont...

Some of the limitations of candle filters

- The average size of a bacterium is about **1.5 microns**.
- Thus, may **not remove all the pathogenic organisms**
- Viruses, for example, cannot be removed by a candle filter.
- The **rate of filtration** of a candle filter is normally very low
- the rate can be increased by having a three-candle or four-candle
- Candle filters are relatively **too expensive** for wide use by the general public.

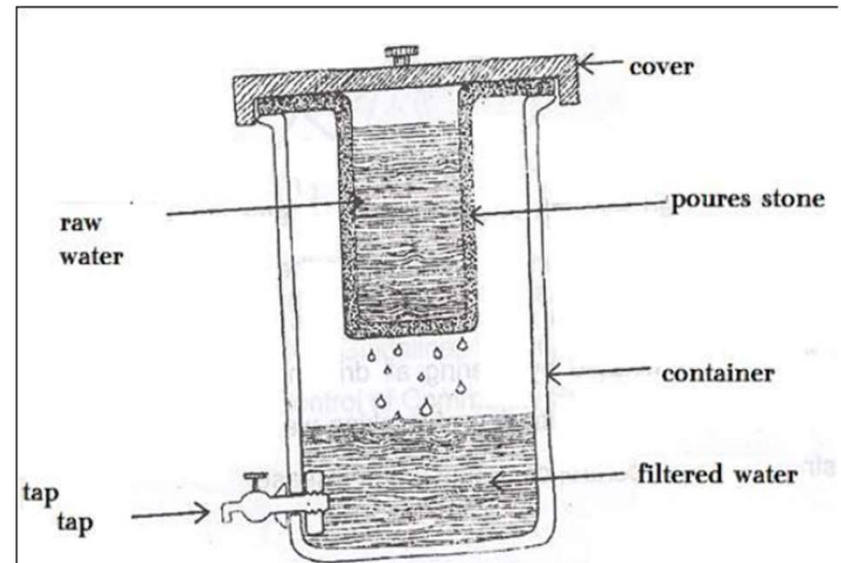
Maintenance during operation

- The raw water to be filtered must be reasonably clear
 - to reduce clogging of the candle pores
- The candle needs dismantling once a week, for washing and sterilizing in boiling water.

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C. Stone filters

- Stone filters are similar to candle filters
– but are carved from porous local stone
- They are generally difficult to clean and heavy to lift,
- relatively inexpensive if they can be produced locally
- This method of filtration could be possible in Ethiopia using the local “Beha” stone



Cont...

Cloth Filtration

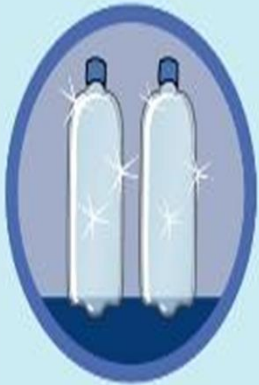
- By pouring water through a piece of fine, clean cotton cloth part of the suspended solids and pathogens are removed.
- This contributes to improving the water quality but is not ensuring the complete removal of the contamination and
- therefore some chlorine dosing, solar disinfection or boiling of the water is needed.
- An important advantage is that chlorine and solar disinfection will be more effective as the water is cleaner.
- The cloth can be washed between uses to maintain the flow that can be used in the straining.

3. Solar disinfection (SODIS)

- works on the principle of combination of UV disinfection and heating.
 - Exposing water to sunlight will destroy most germs that cause disease.
 - This is even more effective at higher temperature.
 - To also effectively inactivate amoeba species the water temperature needs to rise above 50°C for at least an hour.
 - One easy method of treating the water is to expose plastic or glass bottles of water to the sun.
- The recommended time of exposure is six hours on a sunny day.
- The amount of time the bottle is exposed to the sun will need to be doubled (two days instead of one) when the water is cloudy.

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- The exposure time should also be increased if there is not sunny weather (rainy season).
- For greater effectiveness place the bottle on a corrugated-iron roof which will help to increase the temperature.



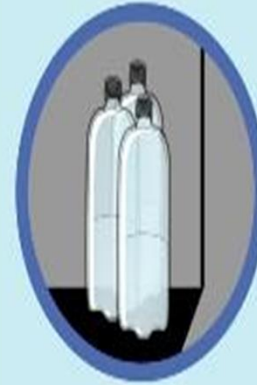
Use clean PET bottles



Fill bottles with water, and close the cap



Expose bottles to direct sunlight for at least 6 hours (or for two days under very cloudy conditions)



Store water in the SODIS bottles



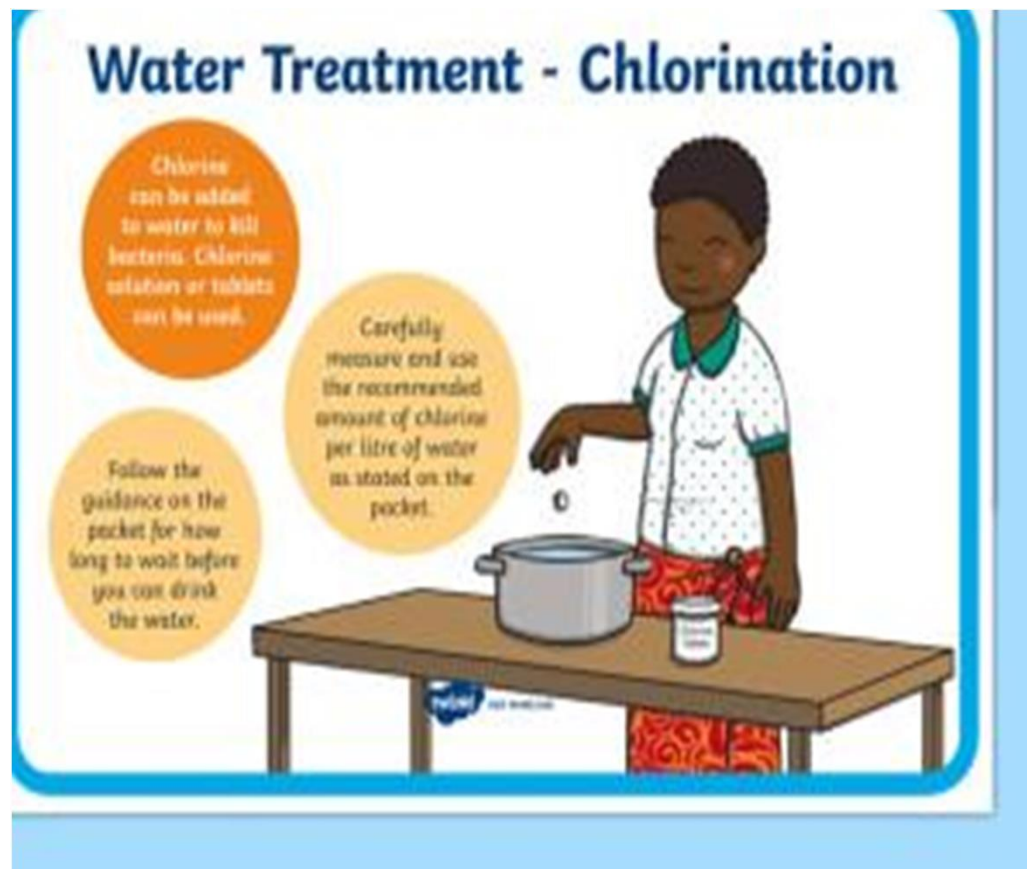
Drink SODIS water directly from the bottles, or from clean cups

4. Chemical Disinfection

- Several chemicals, acting as strong oxidants, can destroy micro-organisms including for example chlorine, ozone and iodine.
- Here we will focus on water disinfection by chlorination widely used
 - Chlorine is effective, available and the has ability to produce a good persistent residue that can be easily measured and monitored in networks and after delivery to users.
- Chlorination of drinking water is carried out in practice by dissolving chlorine compounds in the water.
- At household level the approach is to add a tablet or some chlorine solution to a container of water.

Cont...

- Different chlorine compounds are available in the market such as Aquatab, Water Guard, Bishangari, and Pure and come with a description of use on the package.



5. Households Water Storage

- **Turbidity** will be reduced
- **bacteria and eggs of parasites** will be sediment
- The principal health risk associated with household water storage is the **ease of recontamination during transport and storage**, particularly if the members of a family or community do not all follow good hygiene practices.

Cont...

□ The most important elements of water storage can be summarized as follows:-

- Use a clean water source or treat the water, either at home or in a storage tank.
- Store water in an earthenware or plastic container with a cover.
- Store the water container at a height that puts it beyond the reach of children and animals.
- Fit a tap to the container for drawing clean water in order to prevent contamination by dirty cups, ladles, or hands.

5.2 Treatment of saline/solid water

- Water is essential to sustain human life; however, most of the water on the planet contains high concentrations of salts, making it unsuitable for human consumption.
- The ocean is an obvious example of a saline source but even among groundwater sources, which provide most of the world's drinking water supply, more is saline than fresh water.
- Salinity is a term used to describe the amount of salt in a given water sample.

Cont...

- It usually is referred to in terms of total dissolved solids (TDS) and is measured in milligrams of solids per liter (mg/L).
- Water with a TDS concentration greater than 1,000 mg/L commonly is considered saline.
- This somewhat arbitrary upper limit of freshwater is based on the suitability of water for human consumption.
- Saline water is classified as either brackish water or seawater depending on the salinity and water source.

cont...

□ Desalination

- refers to the process by which pure water is recovered from saline water using different forms of energy.
- is a water-treatment process that removes salts from water.
- Desalination presents the possibility of providing freshwater not only from the ocean, but also from saline ground water.
- Water is desalinated in order to obtain fresh water suitable for animal consumption or irrigation, or, if almost all of the salt is removed, for human consumption.
- Sometimes the process produces table salt as a by-product.

Cont...

- ❖ In most desalination processes, feed water is treated and two streams of water are produced:
 - Treated fresh water that has low concentrations of salts and minerals
 - Concentrate or brine, which has salt and mineral concentrations higher than that of the feed water
- The basic process of desalination is to take a saline water source and invest energy to output two separate streams, a stream of salt-free fresh water and a stream of salty brine.



Desalination Technologies

1. Thermal desalination

- Thermal desalination relies on phase change: thermal energy is used to evaporate water, leaving salt behind; the water vapor is then condensed to collect fresh water.
- The most common methods are:
 - ✓ **multiple-effect distillation (MED),**
 - ✓ **multi-stage flash distillation (MSF) and**
 - ✓ **vapor compression distillation (VCD).**
- They require high energy inputs (in the range of 23–27kWh/m³) and are best suited for seawater desalination at high volume (more than 3,000m³/day).
- Their high capital costs and high energy requirements make them unsuitable for Oxfam's target areas.

Cont...

- ❖ Another thermal method,
 - **solar still distillation (SSD)**, has the advantage of being powered directly by the sun with no additional energy input.
 - It is a proven, low-maintenance technology, which can work in most environments.
 - However, its relatively low output demands large systems for production of even nominal volumes of freshwater
 - These barriers make SSD inappropriate for desalination of large quantities of water at a community level.

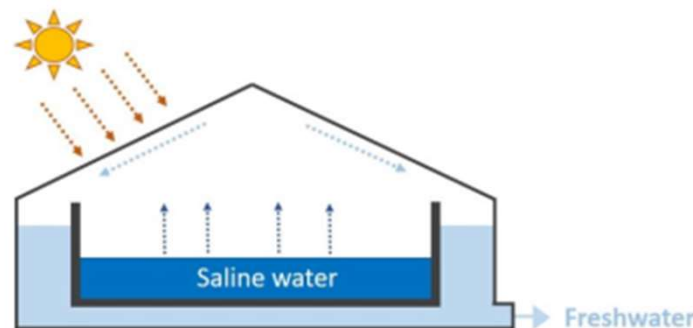


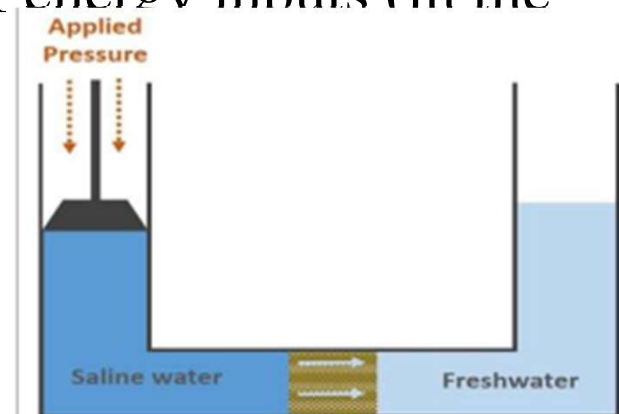
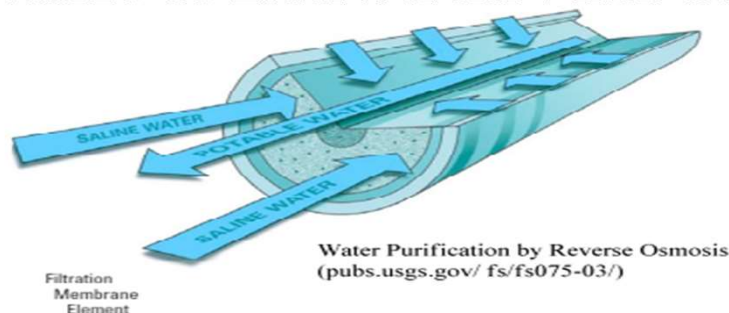
Figure 6: Schematic of SSD technology

Saline water is evaporated directly by the heat of the sun and condenses in a separate fresh water catchment. Source: adapted from Mechell and Lesikar (2014)

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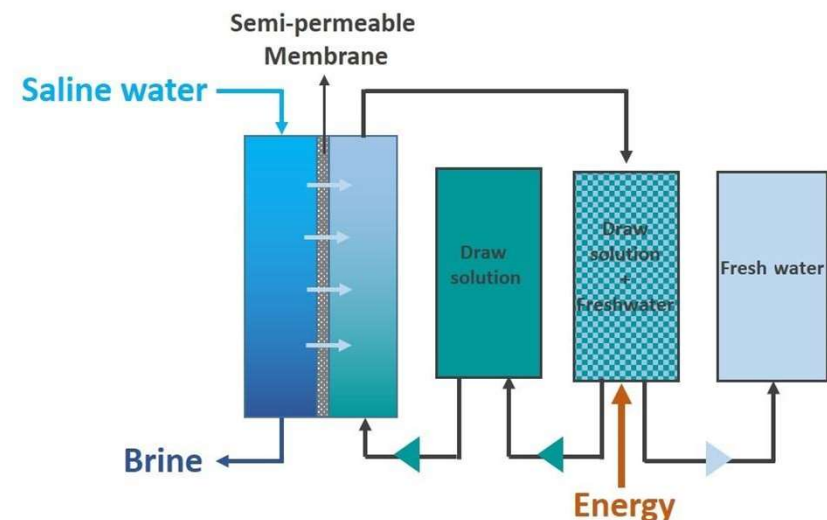
2. Membrane desalination

- Membrane desalination physically separates salt from water using differences in chemical potentials across a semi-permeable polymer membrane.
- **Reverse osmosis (RO)** is a common desalination technology, widely available around the world,
- which has been commercialized at household, community and industrial scales over the past 50 years.
- Communities can easily find local distributors, replacement parts and partners willing to help install, operate and maintain facilities.
- However, this method requires high levels of energy inputs (in the range of 2.8kWh/m³) and high capital costs.



cont...

- **Forward osmosis (FO):** Forward osmosis is an emerging membrane-based desalination technology that relies on natural osmotic pressure to separate salt and water.
- The osmotic pressure difference between the saline water on one side of the membrane and a highly-concentrated draw solution on the other leads to the flow of water molecules across the semi-permeable membrane
- In a subsequent step, the water is separated from the draw solute using thermal energy.



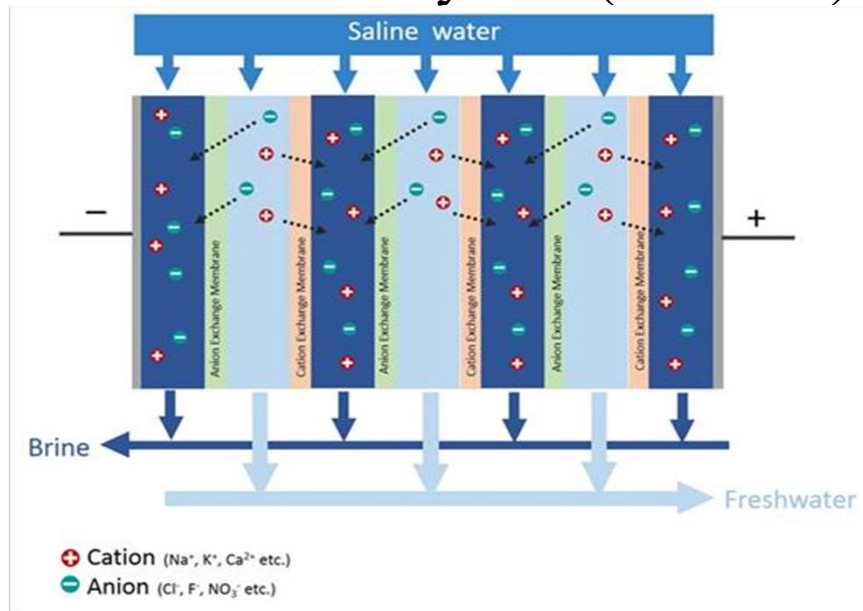
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3.Charge-based desalination

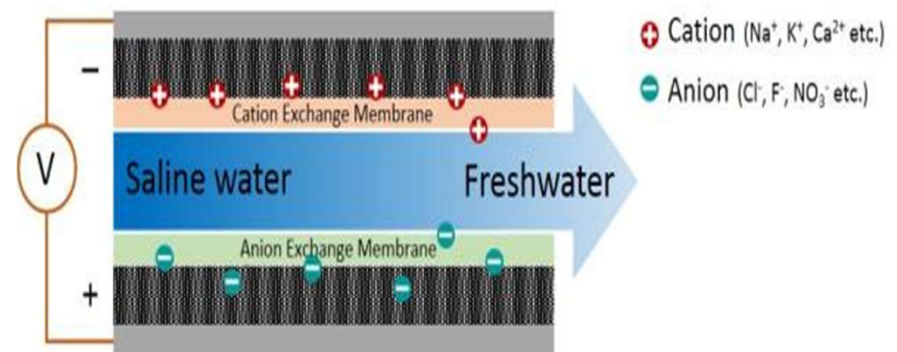
- Charge-based desalination takes advantage of the fact that salt is comprised of charged ions,
- which can be separated from water simply by applying a small electric potential.
- Theory suggests charge-based separation as more energy-efficient for sources up to 5000ppm;
- however, in practice this salinity max will be considerably lower.
- **Electro dialysis (ED)** and **electro dialysis reversal (EDR)** are charge-based methods which can provide water recovery rates of 85 – 90%.
- While mature in terms of technology, ED and EDR have been optimized for industrial processes and are not widely used to produce freshwater for drinking

Cont...

- While smaller-scale electro dialysis units have been developed for the production of freshwater for drinking, they rely on the use of expensive materials resulting in relatively high capital costs
- **Membrane capacitive deionization (mCDI)**, on the other hand, is based on inexpensive materials, requires minimal energy for brackish water treatment, low maintenance and maintains the high water recovery rate (85–90%).



Schematic of ED technology



Schematic of mCDI technology

5.3 Treatment of waste water

- Wastewater, also known as Sewage, is the combination of liquid or water-carried wastes originating:
 - ✓ in the sanitary conveniences of dwellings,
 - ✓ commercial or industrial facilities and
 - ✓ institutions,
 - ✓ in addition to any groundwater, surface water and storm water that may be present.
- It is mostly water by mass (99.9%).
- The remaining 0.1% is contaminants such as suspended solids, biodegradable dissolved organic compounds, nutrients, metals, and pathogenic organisms.

Introduction to wastewater treatment

General About WWT

What is Wastewater?

Wastewater collected from urban areas and from different industries must ultimately be returned to receiving water bodies or to the land.

What is wastewater treatment?

- Removing contaminants/pollutants from wastewater.
- The contaminants (pollutants) in wastewater are removed by physical, chemical and/or biological means, and the individual methods usually are classified as physical, chemical and biological unit processes or operations.



Fig. 1.1. Improperly disposed ww.

Categories of wastewater

1. Storm Sewage:

Surface runoff developed during and immediately after rainfall .

2. Sanitary Sewage:

liquid wastes of domestic and industrial places. This sewage is extremely foul in nature and required to be disposed off very carefully.

General About WWT

Some contaminants in WW.

- Suspended solids: lead to the development of sludge(residuals) deposits and anaerobic conditions
- Pathogens: cause diseases
- Nutrients: essential for growth (N, P,...).
- Refractory organics: resist conventional methods of wastewater treatment.
- Heavy metals :may have to be removed if the wastewater is to be reused
- Dissolved inorganic solids (calcium, sodium, and sulfate): may have to be removed if the wastewater is to be reused
- Organic matters

General About WWT

- ❖ Therefore, Wastewater should be collected and treated before its ultimate disposal in order to :
 - Reduce spread of **communicable diseases**
 - Prevent surface and ground water **pollution**.

General About WWT

- WWT comprises of the following stages of treatment:
 1. Conventional treatment
 - I. Preliminary treatment
 - II. Primary treatment
 - III. Secondary/biological
 2. Advanced/tertiary treatment

General About WWT

- ❑ Methods of treatment in which the application of physical forces dominates are called **unit operation**
 - screening, mixing, flocculation, sedimentation, flotation, and filtration and membrane filter operations
- ❑ Methods of treatment in which chemical or biological activity are involved are known as **unit process**.
 - Removal or conversion of contaminants is brought about by the addition of chemicals or by other chemical reactions. Neutralization, oxidation, reduction, precipitation-----
 - removal of contaminants is brought about by biological activity are known as **biological unit processes**.
 - aerobic processes such as trickling filters, activated sludge, oxidation ponds (or lagoons), and anaerobic processes such as anaerobic lagoons, sludge digestion, etc.
- ❑ WWT applies any of this operations, processes or combination of both.
- ❑ WWT is the combination of **physical, chemical and biological processes**.

Objectives of WWT

- removal of pollutants and the protection and preservation of our natural resources.
- protection of human health by the destruction of pathogenic organisms prior to treated effluent being discharged to receiving water bodies and land.

Wastewater Treatment Standards

- ❖ Environmental standards are developed to ensure that the impacts of treated wastewater discharges into ambient waters are acceptable.

Effluents from different establishments should be:

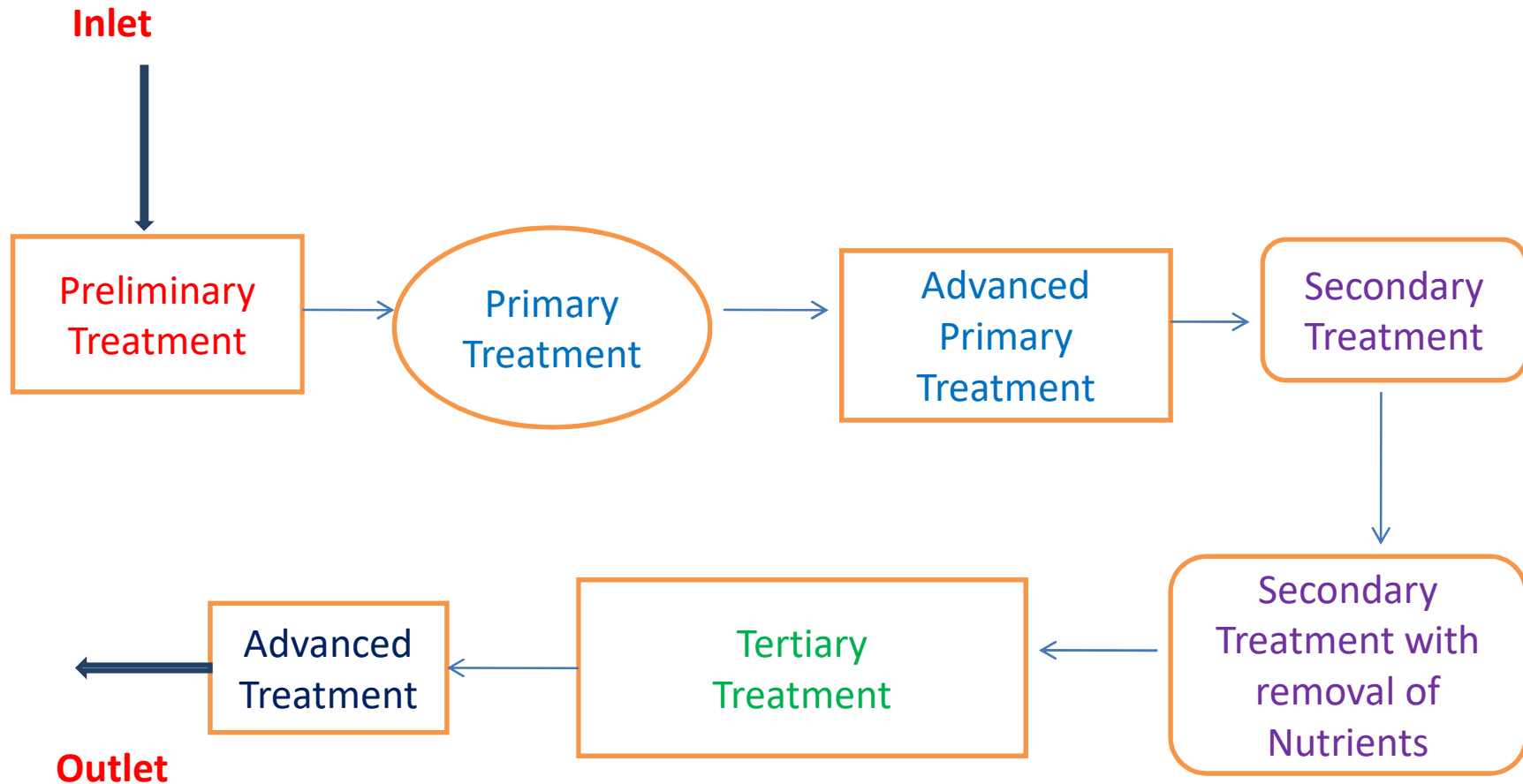
1. Free from materials and heat in quantities, concentrations or combinations which are toxic or **harmful to human, animal, or aquatic life.**
2. Free from anything that will **settle in receiving waters forming putrescence** or that will adversely affect aquatic life.
3. Free from floating debris, oil, scum and other materials;

Wastewater Treatment Standards

4. Free from materials and heat that **produce color, turbidity, taste or odor** in sufficient concentration to create a nuisance or adversely affect aquatic life in receiving waters;
5. Free from **nutrients** in concentrations that create nuisance growths of aquatic weeds or algae in the receiving waters.

Cont...

👉 Flow diagram of waste water treatment process



5.3 Rural Treatment of waste water

- In many places, a rural home has a pressurized water system and its own sewer with a complete treatment plant and disposal arrangement. This is usually the septic tank system.
- In some cases, more sophisticated treatment units replace the septic tank, but still utilize a customary subsurface disposal field.
- Sometimes in rural areas, several homes are served by a community sewer
- which may either terminate at the nearest water course or at a scaled-down version of a municipal treatment plant, commonly referred to as the package plant.

Cont...

- Package plants are often unreliable in operation and wastewater treatment is frequently incomplete even when they do operate properly.
- Water quality control boards are demanding better treatment.



Figure 3: Recommended integrated decentralised rural wastewater treatment system

Cont...

- In many places, disposal to water courses has been forbidden.
- Some rural homes do not have pressurized water systems.
- In such instances, a pit privy provides a relatively complete system, which in practice constitutes an excellent device.
- Rather than a pit privy, sometimes disposal of human waste can be managed by incineration or other sophisticated techniques.
- Maintenance in rural situations is generally not provided,
- and the life of almost any wastewater management system will be prematurely terminated by a combination of poor design and near total neglect .

Cont...

Rural Decentralized Wastewater Treatment Technologies

- In decentralized wastewater treatment, there are numerous approaches for the collection, treatment and dispersal/reuse of wastewater
- for clusters of homes or businesses, individual dwellings and entire communities.
- Treatment options range from simple and cost effective, passive treatments with soil dispersion,
- usually referred to as septic or on-site systems, to complex and mechanized or biological approaches providing advanced treatment
- by collecting and treating waste from buildings and discharging to either soil or surface waters.
- They usually treat the wastewater near the point where the wastewater is generated.

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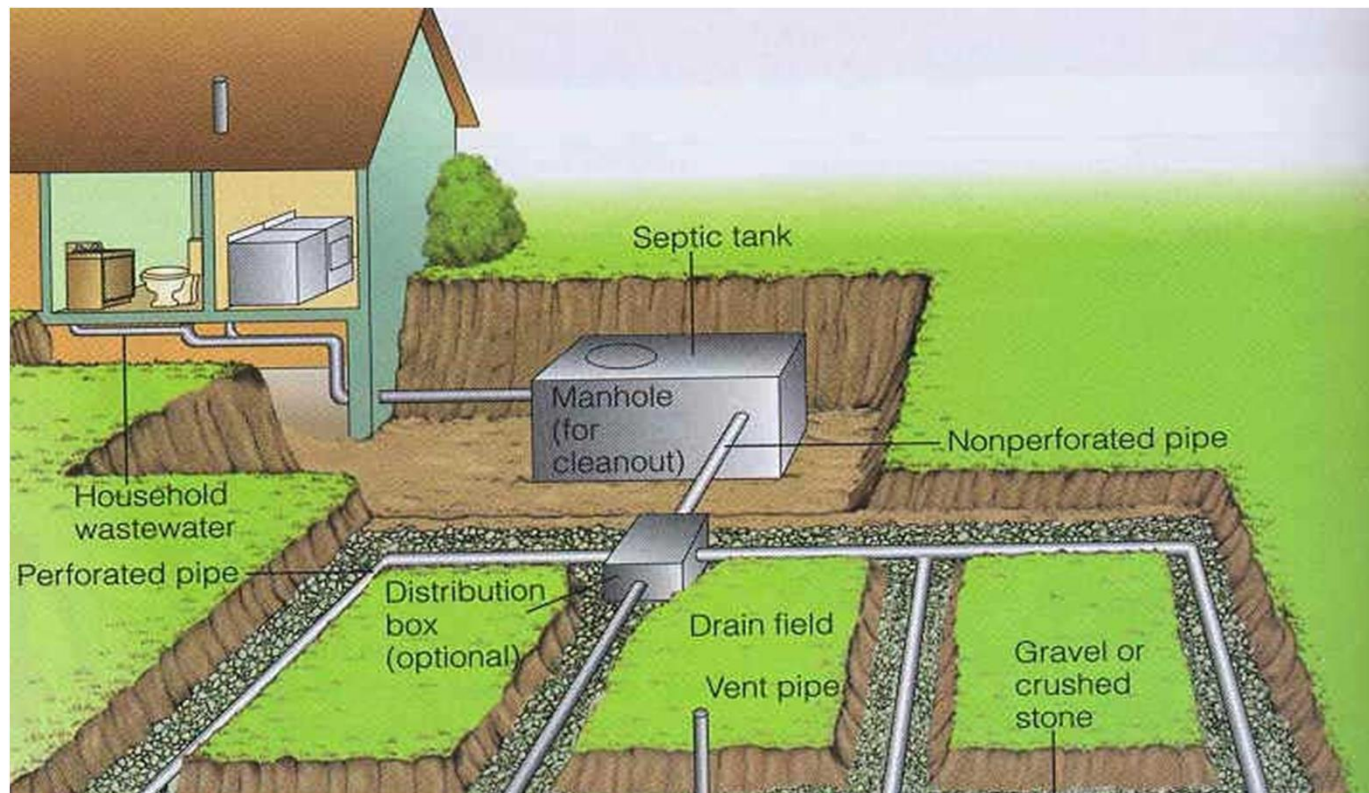
- The most typical primary treatment methods are discussed as follows

□ Septic Tanks

- A septic tank is an underground watertight settling chamber into which raw sewage is delivered through a pipe from plumbing fixtures inside a house or other building .
- The sewage is partially treated in the tank by separation of solids to form sludge and scum.
- Effluent from the tank infiltrates into the ground through drains or a soak pit.
- The system works well where the soil is permeable and not liable to flooding or water logging
- The sludge is removed at appropriate intervals to ensure that it does not occupy too great a proportion of the tank capacity.

Cont...

- The septic tank receives and anaerobically degrades the wastewater generated in the house by trapping the solids, allowing only liquid waste to exit through the tank outlet pipe.



Cont...

□ Cesspools

- Cesspools are old fashioned systems
- that retain waste from a dwelling and allow the liquid portion to seep into the surrounding soil while the solid portion is retained in the cesspool interior.
- Cesspools usually consist of a covered pit with loose, dry fitted rock sidewalls and a concrete leaching chamber or leaking steel tank.
- Cesspools are considered a high risk to water quality and public health because of the potential for direct, concentrated discharge of untreated waste to groundwater.

Cont...

□ Holding Tanks

- also called a tight tank, can be used if permitted by local codes on very difficult sites.
- It is simply a watertight septic tank without an outlet to a drain field, which must be pumped when full.
- Usually regulatory programs completely prohibit the use of holding tanks; they may be only used as a temporary solution
- while a repair for a site is completed, or as a permanent system for extremely difficult sites where advanced treatment systems are extremely expensive or are impractical .

Cont...

□ Ecological sanitation

- generally referred as Ecosan & can be defined as four step process dealing with human excreta
 - ✓ Source separation
 - ✓ Containment
 - ✓ Sanitization
 - ✓ Recycling
- It helps:
 - to protect human health and the environment
 - to reduce the use of water in sanitation systems and
 - to recycle the nutrient to reduce the need for chemical fertilizer in agricultural sector
- Ecosan represents the conceptual shift of the relationship between the people and the environment.
- It is built on the strong foundation of **closing the loop concept**

Cont...

- The typical secondary treatment options are discussed as follows.

□ Waste stabilization ponds

- Waste stabilization ponds include simple systems such as aerobic, anaerobic and facultative ponds that combine aerobic and anaerobic processes .
- The obvious advantage of pond systems is their simplicity and a long retention time, constituting an effective treatment option for reduction of pathogen levels.
- They provide additional economic benefits by facilitating a good environment for growing fish such as tilapia.
-

Cont...

- The effluent from ponds has high algae concentrations, and therefore serves as a good resource for irrigation.
- One of the major disadvantages of waste stabilization ponds is that they require a relatively large area of land .



Cont...

□ Media Filters

- Media filters include a lined or watertight structure filled with media that treats wastewater by incorporating physical and biological processes.
- The effluent, after being collected in a septic tank, is pumped to the top of the filter, and is distributed over the media surface.
- Regardless of the filter type, the media provides a surface area for the degradation of wastewater
- by bacteria and other microorganisms, which are responsible for treating the wastewater.
- The conventional type of media filter bed, long serving as the industry standard, is single pass sand filter.

Cont...

❑ Constructed Wetlands

- Constructed wetlands have been proven as a cost effective method for rural wastewater treatment.
- CWs are artificial wetland systems that exploit the physical, chemical, and biological treatment processes that occur in natural wetlands and
- reduce the organic material, total suspended solids, nutrients, and pathogenic organisms in the wastewater stream .
- In constructed wetlands, wastewater flows through an artificially planted soil filter responsible for the biological and physical treatment of the wastewater.

Cont...

- To improve the biological activity and to enhance the efficiency of the process, the soil filter is planted with plants such as reed.

