Household Water Treatment and Safe Storage (HWTS) Options

Learning Expectations

By the end of this session, you will be able to:

1. Describe different sedimentation options
   • Settling, coagulation
2. Describe different filtration options
   • Straining, biosand filter, ceramic pot filters, ceramic candle filters, membrane filters
3. Describe different disinfection options
   • Chlorination, solar disinfection (SODIS), boiling, pasteurization, distillation
4. Describe how to handle and store water to prevent it from recontamination
Multi-Barrier Approach to Safe Water

- Best way to reduce the health risk of drinking unsafe water.
- Each step in the process, from source protection, to water treatment and safe storage, provides an incremental health risk reduction.

WHO Guidelines for Drinking-water Quality: Background

- **History** 1984–85 first edition published
- **Aim** Protection of human health
  - Support setting of national standards and regulations
- **Approach** Risk/benefit, advisory in nature, multiple barriers, incremental improvements
- **Target audience** Regulators, water suppliers, implementers
- **Risk Framework, health based**
  - Risk assessment, i.e. quantitative microbial risk assessment (QMRA)
The Stockholm Framework

In its simplest form, key elements are:

- Assessment of public health
- Assessment of risks
- Health targets
- Risk management
- Informed by environmental exposure and acceptable risk


- Integrated management system: source to consumption
- Preventive, proactive approach to achieve/maintain safe water
- Focus: know your system, monitor conditions & performance, recognize & take actions for extreme events, communicate, recognize & adapt to changes, plan to improve over time
- Flexible & adaptable to context
- Internationally recognized preventive approach for consistent delivery of safe drinking-water
- Widespread adoption of WSPs by water suppliers will contribute to improved public health, poverty reduction and attaining the Millennium Development Goals (MDGs)
**Water Treatment Process**

- Is a practice or process
  - Specific technologies are generally directed to one stage of the process.
- Both community and household systems follow the same basic process
  - Sedimentation to remove larger particles and often >50% of pathogens
  - Filtration to remove smaller particles and often >90% of pathogens
  - Disinfection to remove, deactivate or kill any remaining pathogens

**HWTS in Country**

- What HWTS options are currently being used in your country?
Sedimentation

• Physical treatment to reduce turbidity
• Can also remove protozoa, helminths and some bacteria
• Different methods:
  – Settling
  – Natural Coagulants
  – Chemical Coagulants

Settling

Effectiveness
• Microbiological quality: Not effective in removing pathogens
• Turbidity: Can reduce turbidity
• Quantity: Depends on the size of container being used
• Applicability to local water: Can be used with any water source
• Safe Storage: None

Appropriateness
• Local availability: Can use any container
• Time: 24−72 hours
• Operation and maintenance: Simple; need to wash container after decanting clear water
• Lifespan: Containers may need to be replaced if they develop leaks

Acceptability
• Taste, smell, colour: May be improved
• Ease of use: Very easy

Direct Cost
• Initial purchase cost: None
• Operating cost: None
Natural Coagulants

• Moringa oleifera
  – Seeds are dried and ground into powder
• Strychnos potatorum
  – Also known as clearing nuts, nirmali
• Prickly pear cactus
  – Sap from leaves is used
• Other
Natural Coagulants

Effectiveness
- **Microbiological quality**: Not effective in removing pathogens
- **Turbidity**: Can reduce turbidity; varies depending on the water to be treated
- **Quantity**: Depends on the size of container being used
- **Applicability to local water**: Can be used with any water source
- **Safe storage**: None. Must be provided as water immediately subject to recontamination

Appropriateness
- **Local availability**: Natural coagulants are not always available; can use any container
- **Time**: 2+ hours
- **Operation and maintenance**: Need to dry and grind seeds before adding them to water; need to wash container after decanting clear water
- **Lifespan**: Dried beans and seeds can be stored for a long time; prickly pear cactus needs to be used before the sap dries; containers may need to be replaced if they develop leaks

Acceptability
- **Taste, smell, colour**: May improve colour; may cause an objectionable taste
- **Ease of use**: Need to prepare natural coagulants beforehand; easy to mix coagulants with water

Direct Cost
- **Initial purchase cost**: None if they can be gathered locally; usually must be purchased
- **Operating cost**: Replacement

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Dried clearing nuts
(Credit: www.farmwealthgroup.com)

Prickly pear cactus
(Credit: Tennant)
Chemical Coagulants

- Commonly used in community water treatment, some use in households
- Aluminium sulphate (alum)
- Polyaluminium chloride (PAC, liquid alum)
- Alum potash
- Iron salts (ferric sulphate, ferric chloride)
### Chemical Coagulants

**Effectiveness**
- **Microbiological quality**: Not effective in removing pathogens
- **Turbidity**: Can reduce turbidity; varies depending on the water to be treated
- **Quantity**: Depends on the size of container being used
- **Applicability to local water**: Can be used with any water source
- **Safe Storage**: None

**Appropriateness**
- **Local availability**: Chemical coagulants are not always available; can use any container
- **Time**: 2+ hours
- **Operation and maintenance**: Follow manufacturer’s instructions for specific products; need to wash container after decanting clear water
- **Lifespan**: 6 months in liquid form and 1 year in solid form; containers may need to be replaced

**Acceptability**
- **Taste, smell, colour**: May be improved
- **Ease of use**: Follow manufacturer’s instructions for specific products

**Direct Cost**
- **Initial purchase cost**: None
- **Operating cost**: On-going cost to buy chemical coagulants as they are used

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### Filtration

- **Physical process that passes water through filter media**
- **Used after sedimentation to further reduce turbidity and remove pathogens**
- **Different methods**:
  - Biosand filter
  - Ceramic pot filter
  - Ceramic candle filter
Biosand Filter

- Adaptation of traditional slow sand filter
- Smaller and adapted for intermittent use
  - Suitable for households
- Container can be concrete or plastic
- Filled with layers of sieved and washed sand and gravel
- Biological layer develops at the sand surface, contributes to water treatment
  - Also known as the biolayer or *schmutzdecke*
### Biosand Filter

**Effectiveness**
- **Microbiological quality:** Moderately effective in removing most pathogens (up to 98%)
- **Turbidity:** Can reduce turbidity
- **Quantity:** Can filter 12–18 litres each batch; recommended to use at least once daily, must wait at least 1 hour after water has been filtered before using again
- **Applicability to local water:** Can be used with any water source, but pre-sedimentation may be needed
- **Safe Storage:** Must be supplied separately via dedicated jerry can, etc.

**Appropriateness**
- **Local availability:** Concrete filters can be constructed anywhere in the world; plastic filters are imported from the United States
- **Time:** Concrete filter flow rate is 0.4 litres/minute; plastic filter flow rate is 0.8 litres/minute
- **Operation and maintenance:** Simple maintenance to clean sand when the flow rate slows down
- **Lifespan:** Concrete filters 30+ years; plastic filters 10+ years; lids and diffusers may need to be replaced over time

**Acceptability**
- **Taste, smell, colour:** May be improved
- **Ease of use:** Easy for adults; may be difficult for small children to pour water into the filter; most rapid flow rate among filters

**Direct Cost**
- **Initial purchase cost:** US$12–US$40 for concrete filters; US$75 for plastic filters
- **Operating cost:** None

### Ceramic Pot Filter

- **Made from clay mixed with a combustible material like sawdust, rice husks or coffee husks**
- **Colloidal silver is necessary to help with pathogen removal and prevent growth of bacteria in filter media**
- **Water is poured into a ceramic pot, and is collected in another container that has a tap at the bottom**
- **Provides safe storage**
Ceramic Pot Filters

Effectiveness
- **Microbiological quality:** Moderately effective in removing protozoa and bacteria; minimally effective in removing viruses
- **Turbidity:** Can reduce turbidity
- **Quantity:** Can filter up to 8 litres each batch
- **Applicability to local water:** Can be used with any water source, pre-sedimentation may be needed; frequently cleaning may be necessary
- **Safe storage:** Normally included as part of filter system

Appropriateness
- **Local availability:** Can sometimes be manufactured and purchased locally
- **Time:** Flow rate is 1–3 litres/hour
- **Operation and maintenance:** Simple maintenance to clean the pot when the flow rate slows down
- **Lifespan:** Up to 5 years, generally 1–2 years; needs to be replaced if there are visible cracks

Acceptability
- **Taste, smell, colour:** Little improvement
- **Ease of use:** Easy, subject to potential need for frequent cleaning; very slow flow rate

Direct Cost
- **Initial purchase cost:** US$12–US$25
- **Operating cost:** Filter elements must be replaced when broken or walls become thin
Ceramic Candle Filters

• Hollow cylindrical forms fastened into the bottom of a container
• Water seeps through the ceramic candle and falls into a lower container
• Provides safe storage
• Colloidal silver sometimes used as antibacterial
• Quality control
  – Ensure small filter pore size
  – Seal between the candle and container is critical
Ceramic Candle Filter

Effectiveness
- Microbiological quality: Moderately effective in removing protozoa and bacteria; minimally effective in removing viruses. Effectiveness varies depending on the manufacturer.
- Turbidity: Can remove turbidity varies depending on the manufacturer.
- Quantity: Can filter up to 10 litres.
- Applicability to local water: Can be used with any water source, may need to sediment water before using the filter; frequently cleaning may be necessary.
- Safe storage: Provides safe storage to prevent recontamination.

Appropriateness
- Local availability: Can sometimes be manufactured and purchased locally.
- Time: Flow rate is 0.1−1 litre/hour.
- Operation and maintenance: Simple maintenance to clean the candle when the flow rate slows down.
- Lifespan: Up to 3 years; usually 6 months to 1 year; candle needs to be replaced if there are visible cracks or leaks.

Acceptability
- Taste, smell, colour: Little improvement.
- Ease of use: Easy, subject to potential need for frequent cleaning.

Direct Cost
- Operating cost: Filter elements must be replaced when broken or walls become thin.

Disinfection
- Another approach in household water treatment process is to remove or kill any remaining pathogens.
- Does not reduce turbidity.
- Different methods:
  - Boiling
  - Chlorine
  - Solar disinfection (SODIS)
  - Solar pasteurization
  - Ultraviolet (UV) disinfection.
- Solar distillation.
Boiling

- Oldest and most common method
- Bring water to a rolling boil
- Different fuel sources can be used
- Boiling kills or deactivates all pathogens
- Effectiveness not impacted by turbidity, pH, water chemistry

Boiling kettles (Credit: Philtar)

Effectiveness
- Microbiological quality: Very effective in killing all pathogens
- Turbidity: not effective to treat turbidity
- Quantity: Depends on the size of pot being used
- Applicability to local water: Can be used with any water source
- Safe storage: None. Must be provided since water is immediately subject to recontamination

Appropriateness
- Local availability: Different fuel sources may be locally available (e.g. wood, charcoal, biomass, biogas, kerosene, propane, solar panels, electricity)
- Time: Need to heat water until it boils for 1 minute
- Operation and maintenance: Water is heated over a fire or stove until it boils; potential for burn injuries; cause of respiratory infections associated with poor indoor air quality
- Lifespan: Pots may need to be replaced

Acceptability
- Taste, smell, colour: Some people believe that boiled water tastes flat; does not change smell or colour; waiting time required while water cools
- Ease of use: Takes time and fuel, though often part of cooking routine

Cost
- Initial purchase cost: Free or low cost since households can use existing pots
- Operating cost: On-going cost for fuel; cost varies depending on the type of fuel
Chlorine

- Widely used for disinfection
- Provides protection against recontamination
- Effectiveness affected by turbidity, organic matter, ammonia, temperature and pH
- For high turbidity levels, the water should first be sedimented or filtered
- Some protozoa and helminths are resistant to chlorine
  - *Toxoplasma*, *Cryptosporidium parvum*, *Ascariasis lumbricoides*, *Schistosoma*

Sodium Hypochlorite

- Various products available, including household bleach
- Chlorine concentrations of liquid products range from 0.5% to 10%
- Each product should have instructions for dosing and contact time

Air Rahmat, Indonesia
(Credit: Tirta/JHUCCP)
NaDCC Tablets

- Often used in emergencies, now widely available for household water treatment
- Different NaDCC contents (e.g. 3.5 mg to 8.68 g) to treat different volumes of water (e.g. 1 to 2500 litres)
- Various manufacturers

Flocculation/Disinfection

- Sachets that contain both coagulants and a timed-release form of chlorine
- Reduces turbidity and disinfects
- Some products also provide moderate effectiveness against arsenic
- Sold in single packets designed to treat 10–15 litres
- Manufactured by various commercial companies
Chlorine

Effectiveness
- **Microbiological quality**: Very effective in removing most bacteria and viruses; not effective certain types of protozoa; protects water against recontamination; effectiveness impacted by chlorine demand (turbidity), non-neutral pH and some natural chemical conditions
- **Turbidity**: does not remove turbidity
- **Quantity**: Depends on the size of container being used
- **Applicability to local water**: Should only be used with clear water; may need to sediment and filter water before using chlorine
- **Safe Storage**: Should be provided, though residual free chlorine will help protect against recontamination.

Appropriateness
- **Local availability**: Available for purchase in many places, more difficult to purchase in rural areas
- **Time**: Need to wait at least 30 minutes after adding chlorine
- **Operation and maintenance**: Follow manufacturer’s instructions for specific products; store chlorine away from children
- **Lifespan**: Up to 5 years for tablets; liquid chlorine expiry is 6 weeks without pH stabilization and 1 year if the pH of the solution is above 11.9

Acceptability
- **Taste, smell and colour**: Some people do not like the taste or smell of chlorinated water; does not change the colour
- **Ease of use**: Follow manufacturer’s instructions for specific products

Direct Cost
- **Initial purchase cost**: Relatively low
- **Operating cost**: On-going cost to buy chlorine products; flocculant/disinfectant is high cost

Solar Disinfection (SODIS)

- Combines solar radiation and temperature to kill pathogens
- Disinfects small quantities of water with low turbidity
- Transparent, non-coloured 1−2 litre plastic bottles
  - Made from polyethylene terephthalate (PET)
- Exposed to direct sunlight for a minimum 6 hours
Solar Disinfection (SODIS)

Effectiveness
- Microbiological quality: Highly effective in killing and inactivating all pathogens
- Turbidity: does not remove turbidity
- Quantity: 1–2 litres/bottle
- Applicability to local water: Should only be used with clear water; may need to sediment and filter water before using SODIS
- Safe storage: water should be kept in bottles until actually consumed

Appropriateness
- Local availability: Plastic bottles are available in most places
- Time: 6 hours on a sunny day; up to 2 days when cloudy; cannot use when raining
- Operation and maintenance: Simple
- Lifespan: Bottles need to be replaced if they have a lot of scratches

Acceptability
- Taste, smell, colour: Waiting time required while water cools; does not change smell or colour
- Ease of use: Easy

Direct Cost
- Initial purchase cost: Cost of bottles
- Operating cost: Bottles must be replaced after about 6 months
Solar Pasteurization

• Process of disinfecting water by heat or radiation
• Achieves the same effect as boiling, but at lower temperatures (usually 75° C), over a longer period of time
• Simple method of pasteurizing water is to put blackened containers of water in a solar cooker
• Thermometer or indicator is needed
Solar Pasteurization

Effectiveness
- Microbiological quality: Very effective for all pathogen types
- Turbidity: does not remove turbidity
- Quantity: Depends on size of container being used
- Applicability to local water: Can be used with any water source
- Safe storage: must be provided to prevent recontamination

Appropriateness
- Local availability: Can be constructed with local materials
- Time: up to 4 hours to reach optimal temperatures, weather dependant
- Operation and maintenance: Need to use a rotation system to ensure availability of treated water; system should be cleaned regularly
- Lifespan: depends on system

Acceptability
- Taste, smell, colour: No change from source water. time for cooling required
- Ease of use: Solar pasteurization boxes can also be used as solar cookers for cooking meals; boiling is sometime preferred because it provides a way to see when the water has reached a high enough temperature without needing a thermometer

Direct Cost
- Initial purchase cost: US$20–US$25
- Operating cost: None

Solar Distillation

- Process of evaporating water into vapour, and then capturing and cooling the vapour so it condenses back into a liquid
- Any contaminants in the water are left behind when the water is evaporated
- One of the few options for treating saline/brackish water
- Many different designs for solar distillation units (also known as stills)
Solar Distillation

Effectiveness
- **Microbiological quality**: Very effective in removing pathogens and other contaminants
- **Turbidity**: does not remove turbidity
- **Quantity**: Depends on the size of still
- **Applicability to local water**: Can be used with any water source

Appropriateness
- **Local availability**: Can be purchased from a manufacturer or built with local materials
- **Time**: 6 hours on a sunny day; will not work when raining
- **Operation and maintenance**: Simple; some stills are self-cleaning
- **Lifespan**: 5–10 years depending on the still and the construction quality

Acceptability
- **Taste, smell, colour**: Some people believe that distilled water tastes flat
- **Ease of use**: Easy

Direct Cost
- **Initial purchase cost**: US$10-400/m² (box still), US$32 (cone still)
- **Operating cost**: None
Safe Storage Container Design

- **efficient**: tight-fitting lid prevents loss of water by spillage and keeps out dirt and germs.
- **clean**: has a built-in cap which never gets lost and helps to keep water safe and clean.
- **convenient**: they stack inside each other, which means they are easy and cheap to transport.
- **durable**: moulded from plastic that doesn’t deteriorate in sunlight. Oxfam buckets last longer than other containers.
- **easy to use**: includes a tap (which can be removed for stacking) to dispense water more hygienically.
- **cost-effective**: All for just: £2.55!

(Credit: Oxfam)

Safe Handling Practices

- Using a separate container for untreated water.
- Frequently cleaning out the storage container.
- Storing water off the ground in a shady place in the home.
- Storing water away from small children and animals.
- Pouring water from the container instead of scooping.
- Drinking treated water as soon as possible, preferably the same day.

(Flooding in Laos (Credit: CAWST))