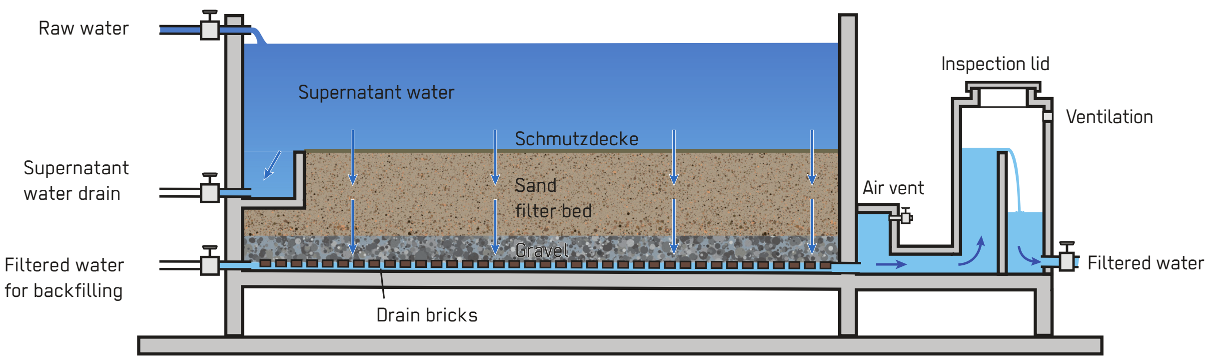
Slow Sand Filtration

Response Phase	Application Level	Management Level	Objectives / Key Features
Acute Response * Stabilisation ** Recovery	** Household ** Neighbourhood ** City	Household * Shared ** Public	Pathogen removal, fine sand filtration as part of final treatment process
Local Availability	**Technical Complexity**	**Maturity Level**	
*** High	*** High	*** High	



Slow Sand Filters remove suspended solids and pathogens from water with varying levels of turbidity (or 'muddiness') using fine sand as the filtration medium. They are used as a final treatment step and are most applicable in the stabilisation and recovery phases of an emergency.

Slow Sand Filters consist of a tank containing the filter media with a gravel support at the bottom, an underdrain to collect the filtered water, a flow control and a filter drainage system. They are unique in their ability to greatly reduce pathogens in the water through a combination of naturally occurring physical and microbiological processes within the filter bed (including sedimentation, straining, adsorption, adhesion, competition for food and predation). As such, Slow Sand Filters can be one of the most effective one-step treatment methods available and can be applied across scales, from large treatment plants to households.

Design Considerations: A raw water turbidity of up to 10 NTU is recommended for Slow Sand Filtration, with occasional peaks of up to 50 NTU tolerated. For higher turbidity, a pre-treatment such as Roughing Filtration **(T.1)** or (Assisted) Sedimentation **(T.4)** is needed. Slow Sand Filters can reduce turbidity to under 1 NTU and can also significantly reduce pathogenic organisms (> 95 % reduction in bacteria and viruses and > 99 % reduction in Giardia and Cryptosporidium). They improve colour and taste while reducing other organic and inorganic toxicants by at least 50 % (e.g. cyanobacterial toxins, mercury, polyaromatic hydrocarbons, iron, manganese, chromium, cadmium and arsenic). The effectiveness of these filters depends on the sand size, sand bed depth, temperature and hardness of the water (more turbidity removal with harder water). Sand size is a critical design parameter, with an effective grain size ranging from 0.15–0.35 mm (higher efficiency with smaller grains) and a uniformity coefficient of between 1.5–3 (meaning it is not too uniform or too diverse). When the sand size is correct, solids are strained out

within the top few centimetres only, but when the sand is coarser, solids will penetrate deeper such that maintenance procedures will not properly restore flow.
Slow Sand Filters must be kept saturated because they serve as the habitat for the organisms responsible for the biological filtration process. This diverse microbial community (known as the 'Schmutzdecke') forms during the first few weeks to months of operation, depending on the raw water quality. For larger-scale filters where water is flowing 24 hours a day to bring oxygen and food to the biological layer, the sand depth varies from 0.6–1.2 m, while the water height above the filter bed is usually between 1.0–1.5 m (Household Biosand Filters **(H.5)** have a different water level). The filtration rate should be slow—between 0.1–0.4 m/h (compaction of m^3/m^2/hour) to support the biological activity and allow adequate contact time for other physical processes. An underdrain system allows clear water to flow out, above which several graded gravel layers prevent sand from leaving the filter while improving flow velocity. Flow is always down and driven by gravity, and it will decline over time as the filter clogs. For larger filters, a constant flow is usually achieved by controlling water leaving the filter using valves or float controls to account for the increase in resistance within the filter bed. The filter must be designed so that incoming water does not disturb the Schmutzdecke. Once flow reduces below that which is needed, cleaning is required.

Materials: Materials include the filter compartment(s), water inflow and outflow system with control mechanism, underdrain system, filter media and equipment for washing and storing sand.

Applicability: Slow Sand Filters are not suited to the acute response, as it takes time for the biological activity to mature within the filter. They can be considered for the stabilisation and recovery phases as part of a wider treatment process, where time is available for plant design and construction. Household Biosand Filters **(H.5)** could also be considered in the recovery phase (initially as a pilot project to ascertain acceptance) for ongoing sustainable water treatment for dispersed populations. In cold climates, special measures may be needed to avoid freezing. The performance of biological processes also reduces in cold climates. In hot climates, some types of algae might proliferate on the surface of the open filters leading to clogging. This sometimes means the filters must be covered, though some types of algal growth combined with exposure to UV light in open filters might support biological processes.

Operation and Maintenance: Main O&M tasks relate to general plant maintenance, flow control and manual cleaning. Cleaning is done by draining the filter so that the water level is around 10 cm below the sand surface before manually scraping off the top layer. The quicker the cleaning process, the quicker the re-ripening period (placing geotextile over the sand surface has been found to speed up cleaning). Scrapings can then be washed and stored. Additional sand is only added when the filter bed reaches a minimum depth (0.6 m), which happens every few years. As it takes at least a few days for microorganisms to recover (and longer after sand replacement), it is normal to install multiple filter units in parallel so that water can still be treated while maintenance is ongoing.

Health and Safety: Slow Sand Filtration is considered a final treatment step and may be used as a single-step treatment process for drinking water, depending on the raw water quality. The effectiveness of pathogen removal depends on the filter design and operating conditions. In acute emergencies, however, the standard protocol is to always disinfect the water via Chlorination **(T.6)** to provide residual protection.

Costs: Filter capital costs vary around 100 USD/m^3/day capacity (similar to Rapid Sand Filters, **T.2**). Ongoing costs for O&M are around 3 USD/m^3/day capacity, which is lower than Rapid Sand Filters, as the intervals between maintenance tasks are longer. Slow Sand Filters require large areas, often up to 10 times greater than for Rapid Sand Filters and over 50 times greater than for membrane systems like Microfiltration **(T.3)** or Ultrafiltration **(T.10)**. The price and availability of land will influence the capital costs considerably.

Social and Environmental Considerations: Slow Sand Filters are very well accepted. Because it is known that clean water can be drawn from holes dug next to a dirty river, the concept of Sand Filtration is easily understood. Slow Sand Filters do not change or improve the taste of water.

Strengths and Weaknesses:
- (+) Does not require the use of chemicals and needs no additional water for backwashing
- (+) Can be constructed with local resources
- (+) Requires no pump or power supply
- (+) Has low life cycle costs (especially low operational costs)

- (−) Needs proper design, operation and monitoring for best pathogen removal rates
- (−) Reduced treatment efficiency against viruses and at low temperatures
- (−) Requires time for recovery after cleaning
- (−) Comparatively low flow rates

→ **References and further reading material for this technology can be found on page 218**