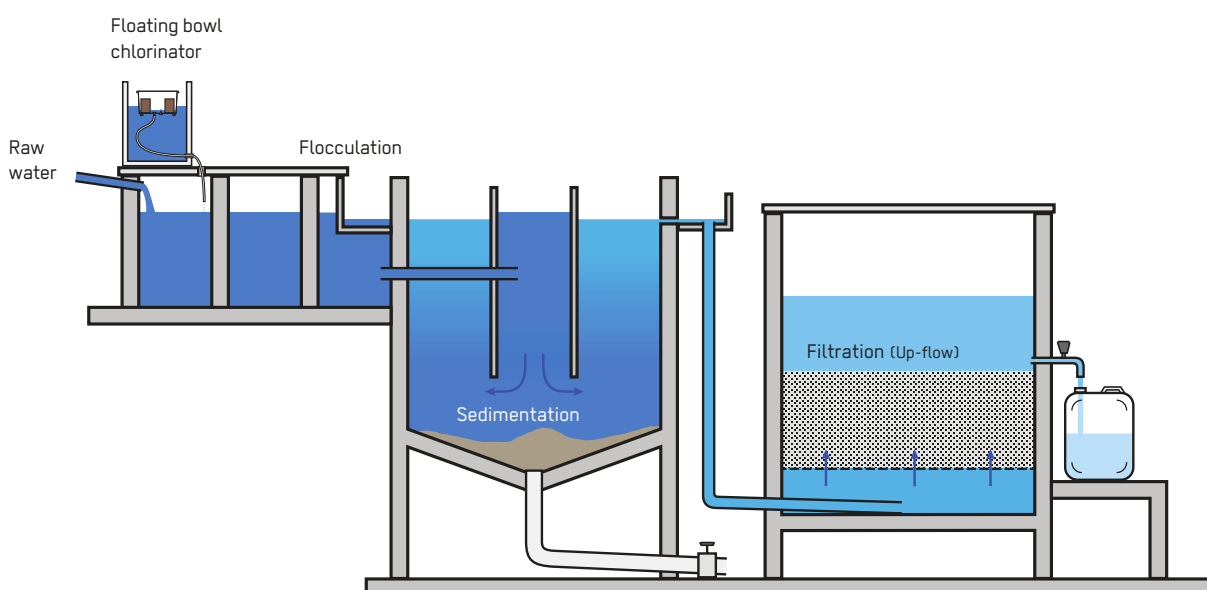


Arsenic Removal Technologies

Response Phase	Application Level	Management Level	Objectives / Key Features
Acute Response ** Stabilisation ** Recovery	** Household ** Neighbourhood ** City	** Household ** Shared ** Public	Removal of arsenic
Local Availability	Technical Complexity	Maturity Level	
** Medium	*** High	*** High	



Arsenic is a groundwater contaminant derived from naturally occurring minerals present in rocks and soils (commonly in young alluvial sediments) as well as from industrial activities (e.g. mining). When present at levels over 10 µg/L, arsenic can directly impact human health and should be addressed as soon as possible at any phase of an emergency. Arsenic can be removed from groundwater by precipitation, adsorption, ion exchange or Reverse Osmosis (T.15).

The health impacts of ingesting arsenic over a prolonged period include changes to skin pigmentation, organ damage, anaemia, metabolic disorders, increased risk of various cancers and skin diseases, and other symptoms (e.g. bronchitis, vascular disease, depression). Short-term effects include increased risks of heart attack, diarrhoea and nausea. These health impacts can continue even after the arsenic is removed from the water. Soluble arsenic found in natural waters usually occurs as trivalent arsenite, As(III) (present under anaerobic conditions and lower pH),

or pentavalent arsenate, As(V) (present in aerobic conditions and at pH values above 7). It can be removed by precipitation, adsorption and ion exchange processes varying in scale from large drinking water supplies to the household level (see H.14).

Design Considerations: As(III) is the common form of arsenic found in anaerobic groundwater conditions and is more difficult to remove than As(V), which is strongly adsorbed onto various solids such as iron (hydr-)oxides. While some treatment processes can partially remove As(III), sufficient removal requires a preliminary conversion of As(III) to As(V) using a pre-oxidation step that is followed by a second process for As(V) removal. Pre-oxidation can be effectively achieved through the addition of chemicals (e.g. chlorine or potassium permanganate) or by filtering the water through a bed of manganese (IV) oxides. Once oxidised to As(V), there are different processes that can remove it, such as coagulation and co-precipitation, adsorption and ion exchange.

For coagulation and co-precipitation, chemicals such as iron and aluminium salts are added to form iron and aluminium (hydr-)oxide precipitates that adsorb As(V). Once these particles settle, they can be removed using conventional sedimentation and filtration steps. To be effective, the type of coagulant must be suited to the raw water pH, and dosing/mixing conditions should be optimised (see T.4, T.5). Co-precipitation can also occur without a coagulant when there is enough naturally occurring iron in the water. Here, aerating the water creates insoluble iron (hydr-)oxides that in turn adsorb arsenic. This has worked well in some areas along with household level Biosand Filters (H.5). The efficiency depends on the natural concentration of iron in the water and the presence of competing ions.

As(V) can also be removed through adsorption and ion exchange, in which water passes through a layer of porous material ('contact bed') that removes arsenic through an exchange of ions that allows its adsorption to the contact bed material. Appropriate contact bed materials include synthetic ion-exchange resins, activated alumina, activated carbon and iron-based solids (granular ferric hydroxide or iron-coated sand). The effectiveness of the contact material differs, where some are not affected by pH or the concentration of arsenic (e.g. ion-exchange resins, iron-based solids) though others are (e.g. activated alumina). Some materials also preferentially adsorb competing ions instead of arsenic (e.g. sulphate with ion-exchange resins). Additionally, some materials are easily regenerated with less dangerous chemicals (e.g. ion-exchange resins), while others may require strong acids and alkalis (e.g. activated alumina) and some cannot be regenerated (e.g. iron-based solids). Given the right conditions, though, these techniques can remove over 90% of arsenic. Other techniques exist that are more (e.g. electrocoagulation) or less (e.g. membrane-based methods like Nanofiltration/ Reverse Osmosis, T.15) effective.

Materials: The required materials depend on the chosen removal process and can include the physical treatment infrastructure, filter media and various chemicals. Some of these may not be available locally.

Applicability: Arsenic is a more serious health threat than fluoride, with some health effects occurring after only short-term ingestion. Therefore, it is recommended to begin Arsenic Removal as soon as possible in an emergency. Regardless, when coagulation is used in an emergency setting, arsenic levels would also reduce.

Operation and Maintenance: Different O&M activities are needed for each system, but most have significant O&M requirements. For coagulation/precipitation processes, O&M includes daily dosing of chemicals and sludge removal, and the plant often needs a power supply. For ion-exchange resins, O&M is less frequent and is a fairly easy process involving regenerating the contact bed, which is

typically done using a concentrated salt (NaCl) solution. For activated alumina, regenerating the contact bed is done using a strong alkali followed by a strong acid.

Health and Safety: Establishing the presence of arsenic in water sources may prove difficult. Consulting health data and health centres on the number of cases of arsenicosis might be useful. The Groundwater Assessment Platform (GAP) provides information on high-risk areas. Water quality monitoring using arsenic test kits is recommended if the GAP or health information indicates an elevated risk. Arsenic-rich waste is produced by most of the Arsenic Removal processes and has to be disposed of properly (e.g. landfill away from drinking water sources). Contact bed regeneration using alkalis and acids can be dangerous and requires adequate training for operators as well as personal protective equipment (goggles, overall, gloves, boots) and adequate storage.

Costs: Indicative cost per litre for bulk treatment varies from around 8–120 USD/m³, with the cheapest being coagulation and co-precipitation. Cost depends on the type of process and scale and is related to the actual materials used or re-used (e.g. chemicals or filter media), the infrastructure (e.g. the treatment plant, stirrer or kiln) and the labour required to produce or regenerate materials.

Social and Environmental Considerations: For coagulation/precipitation, high concentrations of sulphates in treated water may make it unacceptable to users. The introduction of arsenic treatment at a community scale needs to be participatory from the outset and involve all stakeholders. Information and behavioural change interventions (see X.16) will be needed to increase the awareness of the population in areas where this is not the case. The long-term effects of arsenic poisoning are not obvious, and users may be reluctant to agree to treatment if it leads to higher costs. Regeneration solutions or saturated filter media pose an environmental hazard and need to be disposed of safely away from sources of drinking water or land used in agriculture.

Strengths and Weaknesses:

- ⊕ Uses readily available and inexpensive chemicals (coagulation and precipitation)
- ⊕ Has high arsenic uptake capacity for most processes
- ⊕ Filter material can be regenerated for some processes (ion-exchange resins, activated alumina)
- ⊖ Requires pre-oxidation for most processes
- ⊖ Can be less effective depending on pH (activated alumina) or competing ions in the water (ion exchange)
- ⊖ Produces toxic waste that needs proper, safe disposal
- ⊖ Requires skilled operation for media regeneration

→ **References and further reading material for this technology can be found on page 219**