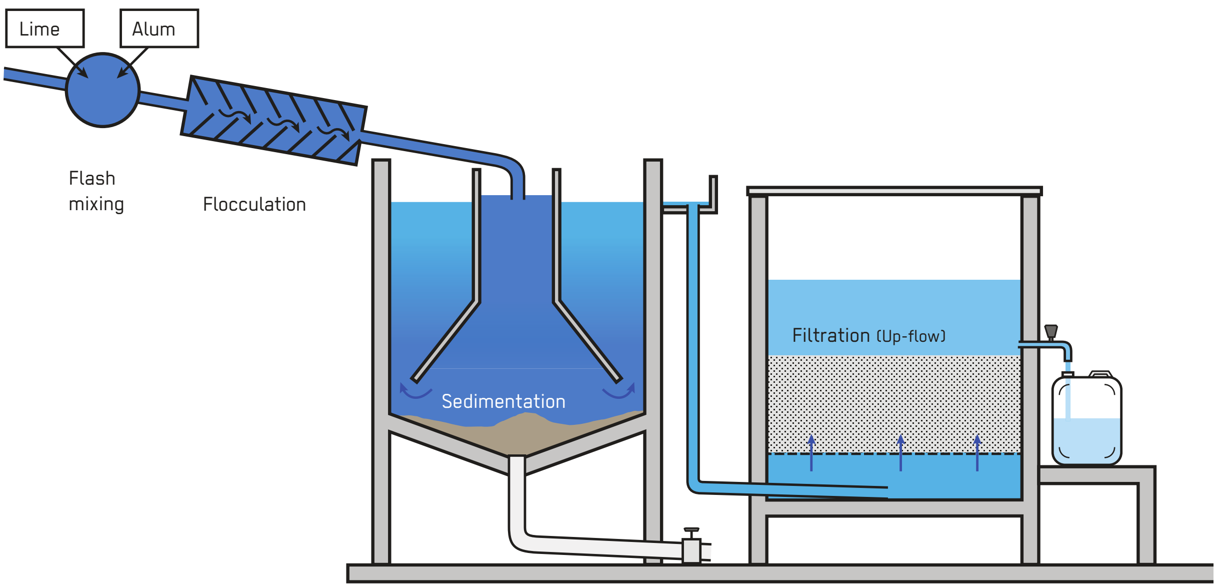
Fluoride Removal Technologies

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



Fluoride is a groundwater contaminant derived from minerals present in rocks and soils (commonly volcanic-derived sediments). At levels over 1.5 mg/L, it can directly impact human health so must be removed to ensure a safe water supply. Nonetheless, as the negative health impacts only occur over the long term and because they are time consuming to establish, Fluoride Removal processes are more suited to the stabilisation and recovery phases.

The health impact of ingesting fluoride from various sources, including drinking water, over a long period includes the mottling of teeth (occurs in childhood), joint pain followed by skeletal deformities, and non-skeletal issues (e.g. lethargy, a decrease in cognitive capacity). It can be removed by adsorption/ion exchange on calcium-phosphate- or aluminium-oxide-based filter materials or by precipitation and coagulation treatment processes. Removal is possible at varying scales from large drinking water supplies to the household level using Fluoride Removal Filters **(H.13)**.

Design Considerations: No single Fluoride Removal technology is suited to all contexts, with the choice of technology depending on the local situation. Factors particularly affecting this decision include the available financing, fluoride concentration and pH of the raw water, O & M requirements, availability of raw materials and the acceptance of the technology by the population. While a variety of advanced removal technologies exist (e.g. Reverse Osmosis **(T.15)**, electro-dialysis and distillation), methods in low-income countries commonly rely on coagulation/precipitation or adsorption/ion exchange processes. For coagulation and precipitation, added chemicals such as calcium and aluminium salts form precipitates that bind fluoride and can then be removed using conventional sedimentation and filtration. The most established method at a community scale, the Nalgonda technique, uses added aluminium sulphate and calcium hydroxide (lime). The chemical dose varies according to the groundwater fluoride concentration and needs to be calculated to avoid over- or under-dosing. The main advantages of

coagulation/precipitation are the moderate treatment costs and local availability of chemicals, though a daily supply of chemicals is required, and the sludge produced must be properly disposed of.
Adsorption/ion exchange passes the water through a layer of porous material ('contact bed') to remove fluoride through adsorption to the contact bed material. Appropriate contact bed materials include activated alumina or calcium–phosphate-based materials, such as synthetic hydroxyapatite and bone char. An important advantage of adsorption/ion exchange is that many filter materials can be regenerated once the uptake capacity is reached. Here, fluoride is removed by passing a basic (alkaline) solution over the filter bed followed by reactivation via an acidic solution before reuse, though the Fluoride Removal capacity of the filter media decreases with each regeneration cycle. Disadvantages of adsorption/ion exchange are that activated alumina is not always locally available or may be too expensive, while the quality of bone char can vary so considerably that the quality needs frequent monitoring and skill is needed in its production. Synthetic hydroxyapatite (HAP), chemically the same as bone char, generally has a higher uptake capacity with less fluctuation in quality. Other Fluoride Removal techniques include electrocoagulation (a mix of electrochemistry, coagulation and precipitation) and the Nakuru technique (a mix of precipitation and adsorption). Most techniques can remove over 90 % of fluoride, although a higher pH/alkalinity can make some techniques less effective (e.g. activated alumina and coagulation/precipitation are less effective at higher levels).

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

Applicability: Fluoride Removal is more suited to the stabilisation and recovery phases, as the negative health impact of fluoride results only from a prolonged use of the contaminated source. Higher levels of fluoride should be addressed, but in an acute emergency, the focus is primarily on providing sufficient quantities of drinkable water. Where coagulation **(T.4, T.5)** is used in an emergency setting, fluoride levels are reduced regardless.

Operation and Maintenance: Different O & M activities are needed for each system, but most have significant O & M requirements. For coagulation/precipitation, O & M includes the daily dosing of chemicals and sludge removal, and the plant often needs a power supply. For adsorption/ion exchange, O & M is less frequent, but when required, it involves regenerating the contact bed using alkalis and acids. These chemicals need to be stored and handled carefully, so this tends to be easier at a centralised level.

Health and Safety: Coagulation/precipitation produces daily sludge, and adsorption/ ion exchange saturates the filter material over time. Both can be an environmental hazard, and the waste needs to be disposed of safely (e.g. landfill away from drinking water sources). The regeneration of contact bed materials using alkalis and acids can be dangerous and requires the adequate training of operators as well as personal protective equipment (goggles, overalls, gloves, boots).

Costs: Some processes are more expensive than others. Cost is related to the actual materials used or re-used (e.g. chemicals or filter media), the infrastructure (e.g. treatment plant, stirrer or kiln) and the labour required to produce or regenerate materials (e.g. quite a lot needed for bone char production). For most processes, the cost is generally too high to be done at the household or community level without some form of external/ government funding, especially where fluoride levels are higher and regeneration cycles more frequent.

Social and Environmental Considerations: Bone char may not be acceptable in some areas due to religious or cultural reasons. For coagulation/precipitation, the high sulphates in treated water can make it unacceptable to users. Introducing fluoride treatment on a community scale requires the participation and involvement of all stakeholders from the outset. Where awareness is low, information and behavioural change interventions **(see X.16)** will be needed. The long-term effects of fluoride poisoning are not obvious, and users might be reluctant to accept this treatment it if it leads to higher costs. Regeneration solutions or saturated filter media pose environmental hazards and need to be disposed of safely away from sources of drinking water or land used in agriculture.

Strengths and Weaknesses:

- (+) Chemicals are readily available and inexpensive (Nalgonda technique)
- (+) Has high fluoride uptake capacity for some processes (e.g. activated alumina)
- (+) Can regenerate filter media for some processes
- (+) Requires only short contact time for some processes (e.g. bone char)

- (−) Some processes are less effective depending on pH (activated alumina)
- (−) Produces sludge that needs safe/managed disposal (Nalgonda technique)
- (−) Requires skilled operation for regeneration of media
- (−) Bone char production needs skill (e.g. kiln at correct temperature), as the quality may vary otherwise

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