

Granular Ferric Hydroxide for Elimination of Arsenic from Drinking Water

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INTRODUCTION

Arsenic is a naturally occurring element that is tasteless and odorless. As a compound of underground rock and soil, arsenic works its way into groundwater and enters food chains through either drinking water or eating plants and cereals that have absorbed the mineral. Daily consumption of water with greater than 0.01 mg/L of arsenic, less than 0.2 % of the fatal dose, can lead to problems with the skin and circulatory and nervous systems. If arsenic builds up to higher toxic levels, open lesions, organ damages (such as deafness), neural disorders and organ cancer, often fatal, can result.

Groundwater is the preferred source of drinking water in rural areas, particularly in developing countries, because treatment of the same, including disinfection, is often not required and its extraction system can be placed near consumers. The groundwater of vast areas in the Ganges Delta – in West Bengal and Bangladesh – is highly contaminated by arsenic. Of all the 18 districts of West Bengal together having 341 blocks, 10 districts with 69 blocks have already been identified as severe arsenic contaminated areas, which include many places around Calcutta, such as Barasat, Habra etc. in North 24-Parganas. The problem of arsenic contamination of groundwater is more serious in Bangladesh, where the groundwater in 59 of the 64 districts is contaminated with arsenic and about two-third of the population is exposed to “the biggest mass – poisoning case the world has ever known” (Washington Post). The water from deep wells in these areas may not be initially contaminated by arsenic, but there is every reason to fear that in course of time the contaminated groundwater from upper level may ultimately affect the water of the lower level too.

The most common valence states of arsenic in geogenic raw water sources are As(V) or arsenate and As(III) or arsenite. In the pH range of 4 to 10, the prevalent As(III) species are neutral in charge, while the As(V) compounds are negatively charged. The removal efficiency for As(III) is poor compared to that for As(V) by any of the of the conventional technologies for elimination of arsenic from water. For effective removal of arsenic form water a complete oxidation of As(III) to As(V) is required. [1]

CONVENTIONAL ARSENIC REMOVAL SYSTEMS

Some important works on evaluating treatment methods for removal of arsenic have been carried out recently. However, all these studies indicate that only As(V) can be removed from water effectively . If As(III) is present in source water, oxidation of the same is essential.

- Removal of arsenic by coagulation with ferric salts, followed by filtration (co-precipitation), is the best known technique. This technique allows doses of ferric salts below 10 mg/L and achieves residual arsenic concentrations below 10 **mg**/L. [2]
- Lime softening for reducing carbonate hardness is also an efficient process for removal of As(V) .
- Further, the conventional Iron-Manganese removal processes can be utilized for removal of arsenic from groundwater containing naturally occurring iron and/or manganese. Iron coagulation/filtration and iron addition with direct filtration methods can significantly reduce arsenic while removing the iron and manganese from the source water. But the biggest problem with the systems is the safe separation of the precipitate and the disposal of the contaminated coagulant sludge. The coagulation technique is not appropriate for small water facilities, because of high cost and need for well-trained operators.
- Ion exchange can remove As(V) from water. However, high levels of TDS, selenium , sulfate, fluoride and nitrate contained in water can affect the life of resin. Disposal of highly concentrated spent regenerant is a serious problem. As (III) is hardly removable by ion exchange method.

- Reverse osmosis and nano-filtration may deliver satisfactory removal efficiencies, but water rejection is very high in these technologies and the discharge of reject water is also a concern.
- Adsorption of arsenic on Activated Alumina in fixed bed is a simpler but less effective technology. [3] The presence of phosphate, sulfate, fluoride and chloride in raw water may reduce the adsorption capacity of Activated Alumina substantially. Chemical handling requirements to make this technique attractive may make the process too complex. The highly concentrated spent regenerant may create disposal problem. Activated Alumina cannot be effectively applied for removal of As(III).

ADSORPTION OF ARSENIC WITH GRANULAR FERRIC HYDROXIDE (ADSORPAS®)

The requirements for an acceptable technique for removal of arsenic from drinking water are:

- high efficiency
- safe technology to ensure the maintaining of the maximum contaminant level,
- simple operation
- minimum residual mass.

Fixed bed Granular Ferric Hydroxide (AdsorpAs®) reactors satisfy all these requirements. This technology combines the high arsenic removal efficiency of the coagulation–precipitation process with the advantage of simple operation of the fixed bed adsorption technology.

Granular Ferric Hydroxide – A High Performance Adsorbent

Granular Ferric Hydroxide (AdsorpAs®) is an adsorbent, developed at the Technical University of Berlin, Germany, Department of Water Quality Control, especially for selective removal of arsenic from natural water. Studies on the adsorption of both arsenic forms on amorphous ferric hydroxide had determined that such a material should have 5 to 10 times higher efficiency than Activated Alumina [4]. Also in the coagulation- filtration process ferric salts show better removal efficiency than alum at equal dosage. So it is expected that a granular activated ferric oxide or ferric hydroxide should have higher capacity for the adsorption of arsenic from water than Activated Alumina in a fixed bed system.

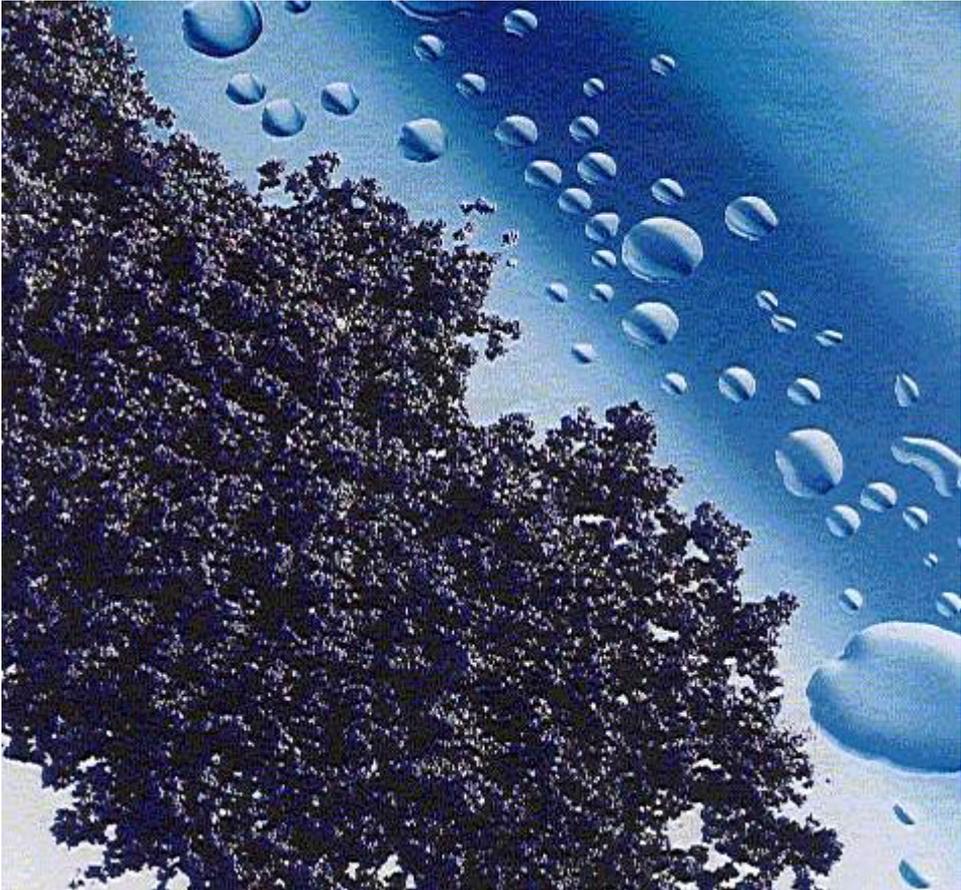


Figure 1 : Granular Ferric hydroxide (AdsorpAs®)

Granular Ferric Hydroxide (AdsorpAs®) is poorly crystallized $\hat{\alpha}$ - FeOOH manufactured from a ferric chloride solution by neutralization and precipitation with sodium hydroxide. As no drying procedure is included in its preparation, all the pores are completely filled with water, leading to a high density of available adsorption sites and thus to a high adsorption capacity [5]. The main application of AdsorpAs® is the adsorptive removal of arsenate, arsenite and phosphate from natural water as well as wastewater. It can, however, be applied also for the removal of various other dissolved substances in water, e.g. fluoride, molybdenum, selenium, antimony etc.

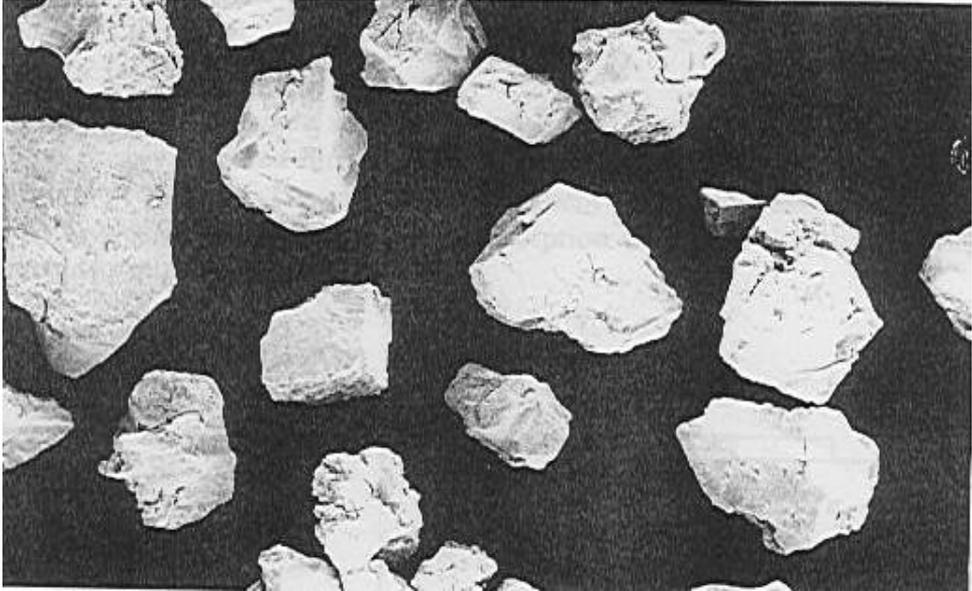


Figure 2 : AdsorpAs® - synthetically manufactured Iron Hydroxide having a porosity of about 75% and specific surface of 250 – 300 m² /g.

Material Properties

Chemical composition:

Active substance	Fe(OH) ₃ and (α-FeOOH)	:	52-57 %
Water content		:	43-48 %

Adsorption Density:

AsO ₄ ³⁻ - Arsenic	:	typical 28 g/dm ³ adsorber bed,	45g/kg dry weight
Phosphorus	:	typical 10g/dm ³ adsorber bed,	16g/kg dry weight

Physical data

Grain size	:	0.2- 2.0 mm
Density of grains	:	1.59 kg/dm ³
Bulk density	:	1.22 – 1.29 kg/dm ³
Porosity of grains	:	72 –77 %
Specific surface	:	250 – 300 m ² /dm ³
Bulk porosity	:	22b – 28 %

Application

As shown in figure 3, the arsenate adsorption density on Granular Ferric Hydroxide is almost similar to that on freshly prepared ferric hydroxide. Granulation does not lead to a considerable decrease in adsorption capacity. The granulated adsorbent can be successfully applied in the pH range between 5.5 to 9. However, the arsenate adsorption decreases slightly with pH, which is typical for anion adsorption.

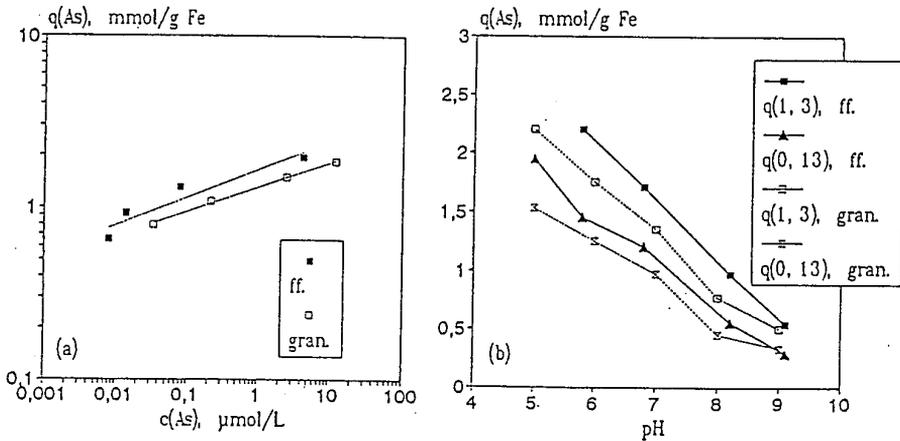


Figure. 3 : Arsenate adsorption density $q(\text{As})$ on AdsorpAs® (gran) and on freshly prepared ferric hydroxide (ff) in the pH range 5 – 9.

Granular Ferric Hydroxide can remove huge amount of arsenic from ground water. Various tests conducted with the adsorbents in operation have shown a high treatment capacity of the adsorbent between 40 000 to 60 000 bed volumes, until the permissible limit for arsenic of 10 **mg/L** was exceeded. The typical residual mass is in the range of 5 – 25 **g/m³** of treated water.

Figure 4 shows the result of the studies carried out with natural groundwater by a plant installed in the southern part of Lower Saxony, Germany. The raw water had a pH of 7.8 and an arsenic concentration of 21 **mg/L**. The maximum contaminant level (MCL) of 10 **mg/L** of the effluent was reached only after 60000 bed volumes were treated.

Several arsenic elimination plants with Granular Ferric Hydroxide in fixed bed reactors are being successfully operated in Germany and Great Britain to remove the toxicant from groundwater contaminated from geogenic as well from anthropogenic sources.

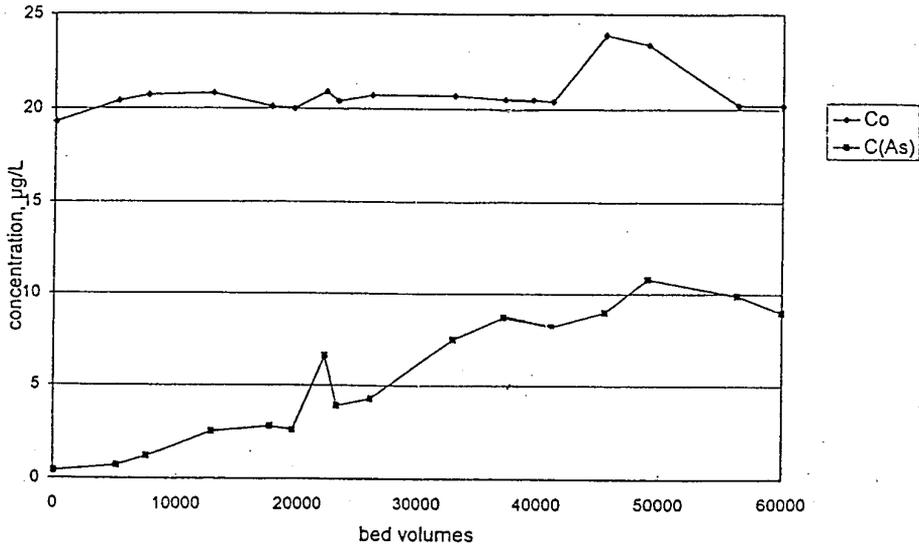


Figure. 4 : Arsenic concentration in groundwater (pH 7.8) before and after treatment with AdsorpAs® at a water facility in Lower Saxony.

At the initiative of the Central Ground Water Board (CGWB), Govt. of India [1], Public Health Engineering Department (PHED), Govt. of West Bengal [2], and State Water Investigation Directorate (SWID), Govt. of West Bengal [3] a number of tests had been carried out with a model Granular Ferric Hydroxide reactor at their laboratories and at different arsenic contaminated sites, e.g., Habra, Barasat, Ashoke Nagar, Baruipur etc. in West Bengal. The analysis report of all these tests reveal that input water containing any amount of arsenic (5 mg/lit at CGWB laboratory) could be freed from the toxicant by Granular ferric Hydroxide to a level much below the permissible limit of 0.01 mg/L.

Process

Granular Ferric Hydroxide reactors are fixed bed adsorbers operating like conventional filters with a downward water flow. The technique aims at the combination of the high arsenic removal efficiency of the coagulation-filtration process with the simple operation of the fixed bed adsorption. This technology is not only economical but also the most effective system as far as the efficiency in eliminating arsenic from groundwater is concerned. It can be used for small-scale application in rural areas with hand tubewells, as well as for large-scale application in towns with community waterworks.

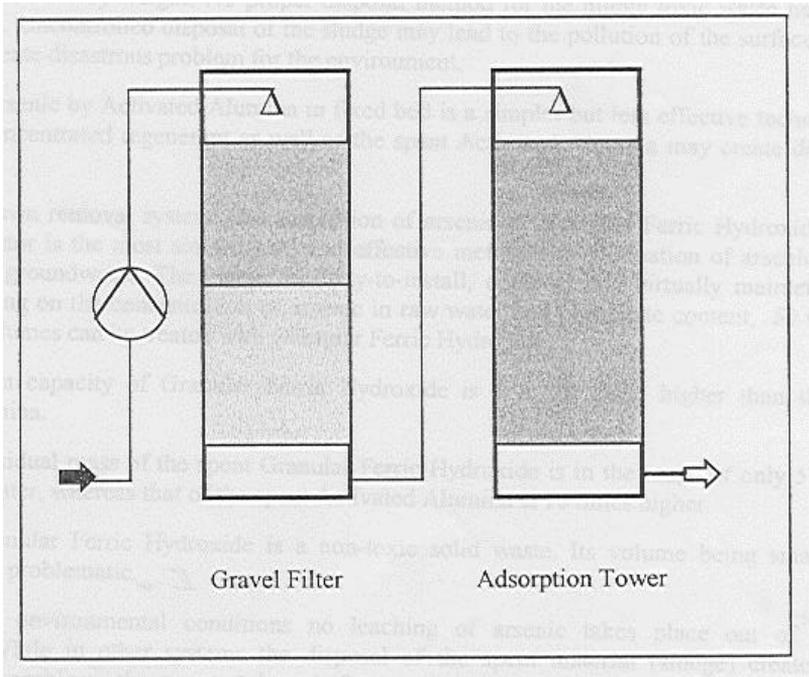


Figure. 5 : Arsenic Removal Plant

The configuration is easy to install, as it consists only of a iron removal-cum- gravel filter followed by an adsorption tower filled with AdsorpAs® . The feed water passes through the first filter to be freed from iron and suspended particles contained in groundwater. It then passes through the adsorption tower, where the arsenic content in water will be brought down by adsorpAs® to a level below 10 **mg/L**. Contaminated water containing arsenite (III) and arsenate (V) while passes through AdsorpAs® bind on the surface of ferric hydroxide building inner-sphere complexes. This is a specific adsorption process, also known as chemisorption.

There is no need to man the system round the clock, as is the case with the precipitation and flocculation methods. It cuts considerably down on operation and personnel costs. For a trouble-free operation of the plant, it is equipped with a back-washing system for the filter.

As the technology involves fixed-bed adsorption, the adsorbent is better utilized; the amount of solid residue at the end of the adsorption process is small and needs no further dehydration. The spent adsorpAs® is a non-toxic and non-hazardous solid waste. Its volume being small, its disposal is less problematic.

CONCLUSIONS

The occurrence of geogenic As(III) and As(V) in groundwater is a serious problem in certain regions, particularly in Bangladesh and West Bengal. As stated above, different treatment technologies are available at present, which may offer solutions to this menace. Among them arsenic removal by co-precipitation technique is the best known system, but it is also one of the most unsafe systems for arsenic separation. In arsenic affected areas where the contents of naturally occurring iron and /or manganese in groundwater is high, one may be tempted to remove arsenic together with iron and manganese by using the co-precipitation technique. The precipitation (Iron-Manganese removal) process produces sludge with considerable arsenic content of up to 10% by weight. No proper disposal method for the highly toxic waste has been developed yet. Uncontrolled disposal of the sludge may lead to the pollution of the surface water system and create disastrous problem for the environment.

Removal of arsenic by Activated Alumina in fixed bed is a simpler but less effective technology. The highly concentrated regenerant as well as the spent Activated Alumina may create disposal problem. Of all the known removal systems the adsorption of arsenic by Granular Ferric Hydroxide in a fixed bed reactor is the most simple, safe and effective method for elimination of arsenic from contaminated groundwater. The plants are easy-to-install, compact and virtually maintenance-free. Depending on the concentration of arsenic in raw water and phosphate content, 50 000 to 70 000 bed volumes can be treated with Granular Ferric Hydroxide. The adsorption capacity of Granular Ferric Hydroxide is 5 to 10 times higher than that of activated Alumina. The typical residual mass of the spent Granular Ferric Hydroxide is in the range of only 5 to 25 g/m³ treated water, whereas that of the spent Activated Alumina is 10 times higher.

The spent Granular Ferric Hydroxide is a non-toxic solid waste. Its volume being small, its disposal is less problematic. Under normal environment conditions no leaching of arsenic takes place out of spent AdsorpAs®. While in other systems the disposal of the spent material (sludge) creates big environment problem, the spent AdsorpAs® can be advantageously utilized as an useful component for manufacturing bricks. AdsorpAs® is the safest and the most effective system for removal of arsenic of arsenic from groundwater.

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