# Low-Cost Technique of Arsenic Removal from Groundwater with Underlying Mechanism.

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## Research Article

### ABSTRACT

This research examines the potential of removing arsenic from water by Co precipitation with naturally occurring iron. This study examined the sensitivity of arsenic removal in response to manual mixing and prolonged settlement. It was observed that 24 h settlement could achieved about 88% arsenic from polluted water. It has also demonstrated that arsenic mixed with iron level (1.2 mg/l) Shaking in container and 3 days settlement could reduce the arsenic concentration from 0.10 mg/l to standard 0.05 mg/l. There was evidence that absorption may be the effective trapping mechanism when Fe/As weight ratio was $\geq$ 10.

## INTRODUCTION

Arsenic contamination of groundwater has been a major problem in floodplains affecting human health. In India groundwater is playing a pivotal role in fulfilling the demands of domestic, industrial and agriculture sectors. The rural drinking water supply is mainly dependent on groundwater. Arsenic in groundwater was detected following reports of many people suffering from skin diseases. Technology for arsenic removal from water already exists [6]. However, the socio-economic conditions which prevail in India, do not permit implement of high cost remediation. The task was to develop technology, which could be implemented at household level and at virtually zero cost.

Arsenic occurs in water as Arsenate and Arsenite depending on the pH and redox potential in natural waters [3]. The thermodynamically stable forms are As (V) in oxygenated surface water and As (III) in reducing groundwater. However, both forms can occur together in both environments due to the slow oxidation and reduction Kinetics [2]. It is already known from previous studies [1,2] that coagulation precipitation is a very effective and frequently applied technique in arsenic removal. In this technique, addition of coagulant facilitates the conversion of soluble arsenic species into insoluble products through co precipitation and adsorption. Adsorption of arsenic onto $Fe(OH)_3$ and $FeCl_3$ has been shown to be an effective method for removing arsenic [5]. Settlement is a well-known mechanism in the context of iron precipitation and iron removal. It was suggested that where arsenic removal depends on iron precipitation, the setting time must exert a major influence on the removal process. A study carried out by Shen [8] with just arsenic containing water showed that sedimentation could only remove 8.7% arsenic after 24 h settlement. Thus, arsenic removal through iron adsorption and settlement may be laid down as low- cost technique in underdeveloped countries to floodplains as maximum risk site for arsenic contamination in both surface and groundwater.

## MATERIALS AND METHODS

Laboratory distilled water was used for the preparation of the standard and sample waters. The Chemicals employed for the experiments were general purpose grade (GPR) and used without any purification. Solution of arsenic

trioxide (1 mg/ml) in 0.5 m/l HCl and FeCl$_3$ for Fe was taken. Alkalinity was maintained with 0.01 M/l NaNo$_3$ and 0.1 gm/l NaHCo$_3$. P$^H$ was provided by adding 0.1 M NaOH. All glassware was cleaned by soaking 10% HNO$_3$ and rinsed three times with pure water. Values of the parameters(Arsenic, pH and iron/arsenic ratio) were chosen to be range found in Bihar. Experiments were carried out with initial AS (III) concentration of 0.2 mg/l, Fe dosage of 4.0 mg/l and PH =7.5. Mixing is a stage to ensure aeration, induce flocculation as well as assuring dispersion of the chemicals. Both mechanical mixing and filtration was introduced for reference purposes. But, the prime focus of the study was to exploit sedimentation as a means of achieving solid– liquid separation following the arsenic–iron compound.

Mechanical mixing was applied to 1 litre samples water (0.01 M/l NaNO$_3$ and 0.1 g/l NaHCo$_3$) Containing 0.2 mg/1 As (III), 4.0 mg/1 Fe at p$^H$ 7.5. The sample in a 2 litre capacity Conical glass flask was mixed in an orbital shaker at a rapid rate (410 rpm) for 5 min, at a slow rate (100 rmp) for 25 min and allowed to settle. In manual mixing, samples were shaken vigorously for 15 sec to 5 min and then allowed to settle. After 2 hour settlement, two sets of supernatant were collected at depth of 20 mm from the top surface to both mechanical and manually mixed samples. One set of sample was analyzed for residual AS (III) concentration with filtration through 0.45 µm filter papers and another set was analyzed for the same conditions but without filtration. The effects of mixing condition and filtration on AS (III) removal differs with taken time. We observed that the removal efficiency is not depends upon mixing regime, whereas removal depends on mixing type and time for the unfiltered samples with enhancement of flocculation. It seems likely that the larger removal rates are associated with larger particle size.

The effect of settlement on AS (III) removal, tests were carried out following the procedure in manual mixing with 24 hour time. The collected supernatant was collected after 2, 4, 6 and 24 hour interval to analyze residual AS (III) concentration without filtration. We observed that shorter retting time is fairly sensitive but longer setting time is less sensitive to the initial stage of mixing.

## RESULT AND DISCUSSION

The experiments were conducted to illustrate about the interaction between AS (III) and Fe (III) with 1.0 litre sample water in a 2 litre capacity conical flask at Fe dosage of4mg/l,As(III) concentration range between 0.1–7.5 mg/l and PH 7.5.

**Figure 1: Effects of settlement on arsenic removal for manually mixed unfiltered samples at varying mixing time with initial AS (III) concentration of 0.2 mg /l, Fe 4.0 mg/l and pH 7.5**
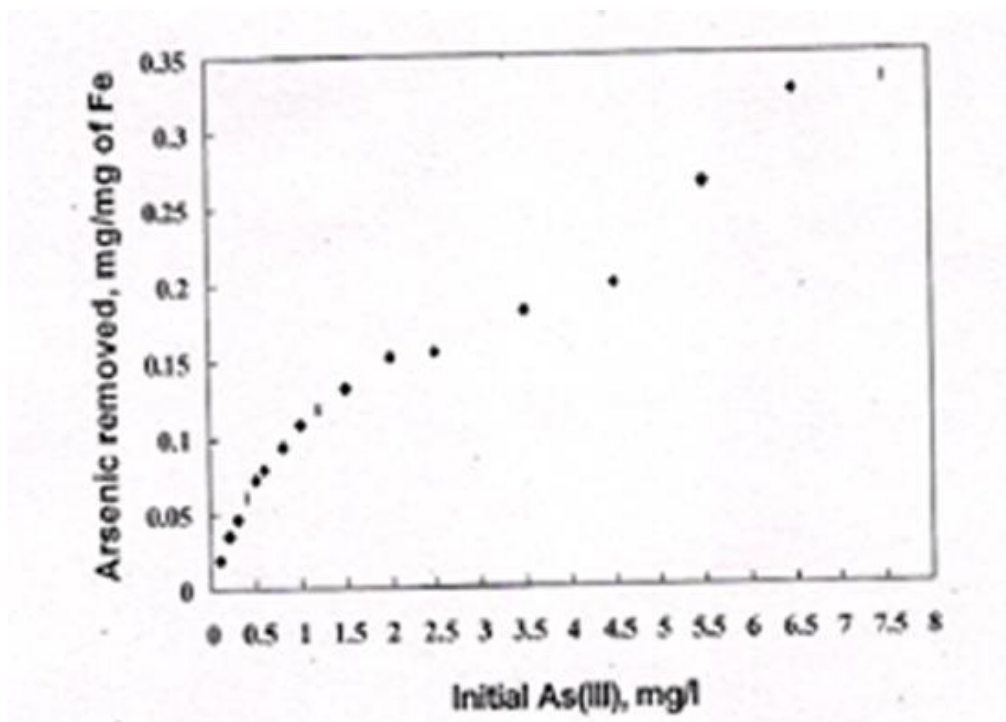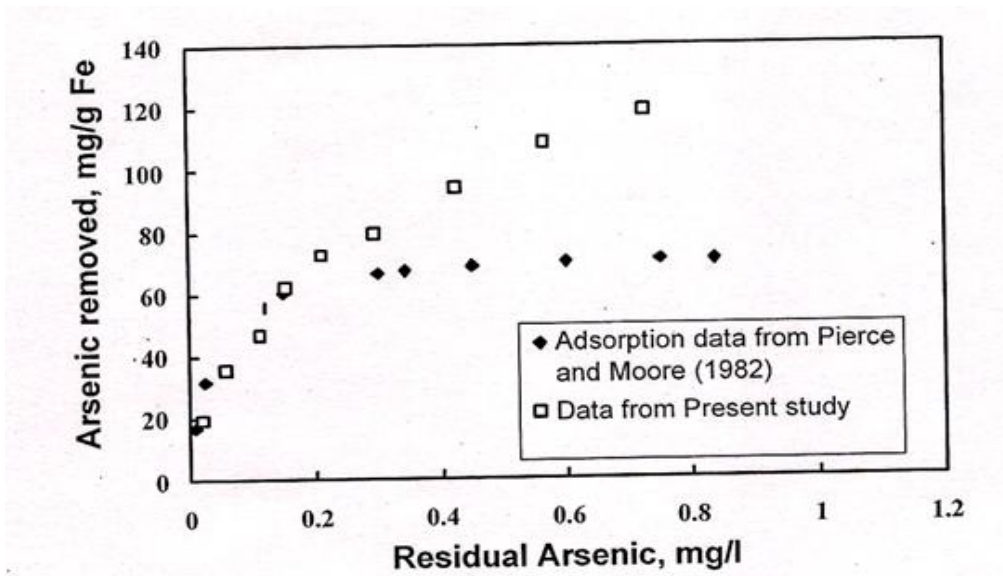
**Figure 2: Removal density of arsenic using KCl3 with 1 min. Manual mixing and 1 day settlement with initial AS(III)concentration over the range of 0.1–7.5 mg/l, Fe 4.0 mg/l and pH 7.5**

The flask was shaken manually for 1 min and then transferred to a 1 litre capacity cylinder (432 mm height) to settle for 1 day. The supernatant was collected from the mid–depth of cylinder and the residual arsenic was measured. The removal of AS (III) was determined from the difference between AS (III) added and the measured residual.

Results of this test showed that as Fe removal becomes less sensitive to initial AS (III) between 1.6–2.8, AS/Fe ratio in the range of 0.4–0.7 and 0.15 removal density. However, further increase of AS/Fe ratio lead to higher removals. In this type of test, the removal depends on a series of mechanisms (interaction between Fe and AS influenced by molecular diffusion, floe formation by shaking and solid liquid separation by sedimentation. Figures 3 and 4 shows combination of processes for arsenic removal in comparison of absorption data from Pierce and Moore [7] study with similar conditions.

**Figure 3: A comparison of arsenic removal density as a function of residual arsenic concentration by adsorption–coprecipitation and sedimentation with PCl3 at pH 7.5 and adsorption onto performed Fe(OH)3 at pH 7.0 for initial AS(III) concentration of 0.05–1.0 mg/l and contact time 24 h**
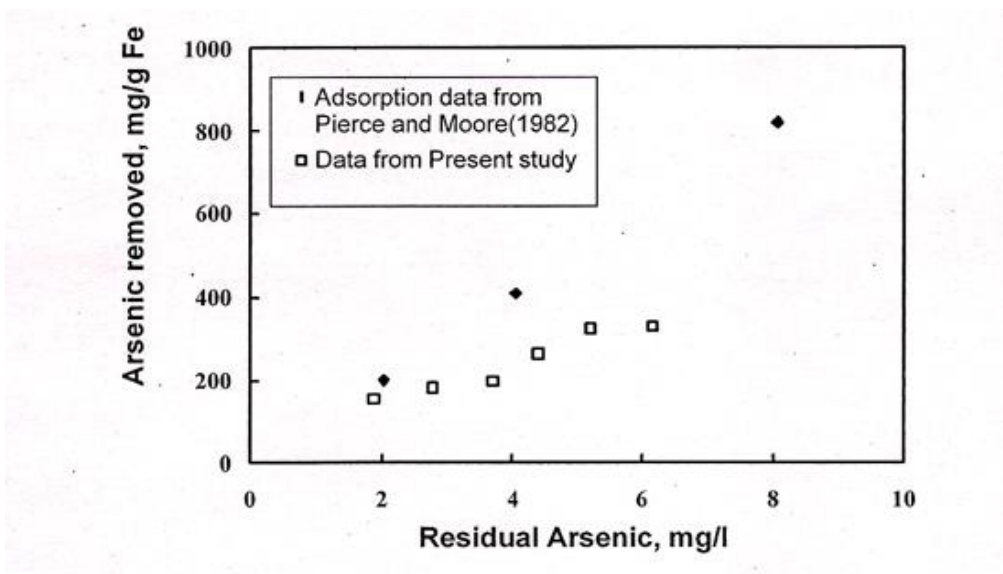
Figure 3 showed remarkable similarity between removal and absorption in the domain AS (mg)/Fe (g) < 60. Higher level of removal (about 130 mg AS (III)/g Fe) are achieved by the co precipitation sedimentation techniques.

Figure 4: A comparison of arsenic removal density as a function of residual arsenic concentration by adsorption-coprecipitation and sedimentation with FeCl3 at pH 7.5 and adsorption onto performed Fe(OH)3 at pH 7.0 for initial AS(III) concentration of 2.5-10 mg/l and contact time 24 h
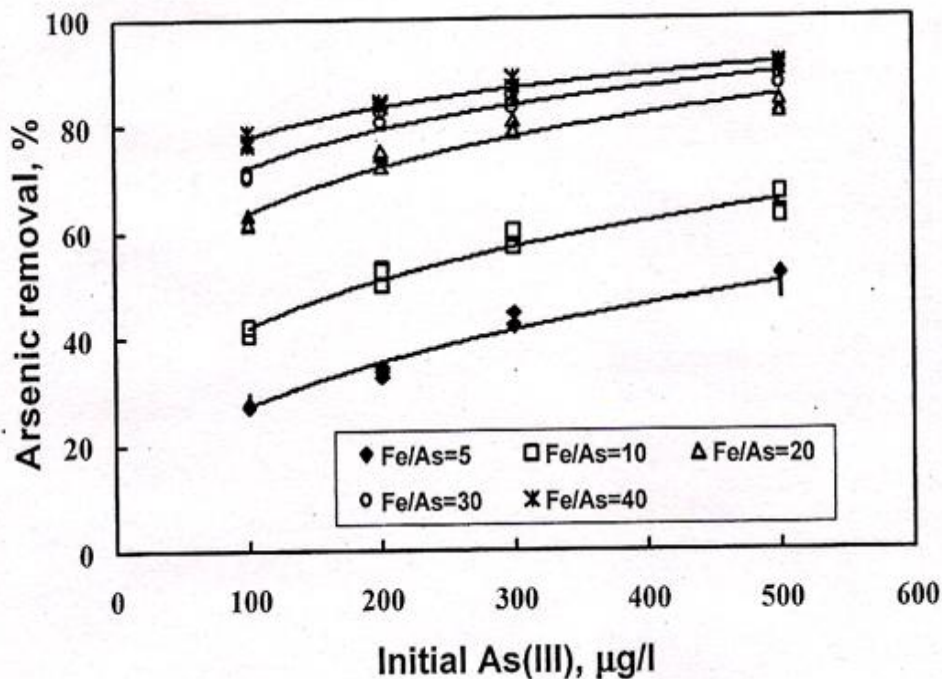


Figure 4 shows the comparison at higher initial AS(III) concentration and displays a very different form of behavior due to the differences in experimental procedure. Pierce's work was carried out with $Fe(OH)_3$ solution, While in present study neutralized acid solution containing both Fe and AS was applied. Further $p^H$ value of 7.5 was maintained to solve AS (III) $\geq$ 2.5 mg/l through large amount of 0.1 M NaOH.

## Implication of Iron concentration on Reducing the level of Arsenic

A series of tests was conducted with varying AS (III) concentration between 0.1 mg/l to 0.5 mg/l and Fe/AS ratio (by weight) ranging from 5 to 40 at $p^H$ 7.5. The samples was mixed for 1.0 min manually and transferred to a measuring glass cylinder to settle four days. After settlement, the supernatant was collected and the residual arsenic was measured.

The effect of Fe/AS ratio on the AS (III) removal is presented in Fig. 5. The trend shows that the AS (III) removal is strongly influenced by the Fe/AS ratio and is also sensitive to initial AS (III) concentration.

The data shown in figure 4 after experimental setting is calculated with the minimum amount of Fe required for reducing the arsenic level to the drinking standard (0.05 mg/l) for a given AS (III) concentration. The relationship between Fe and AS removal may be given as:

$$Fe = 66 \, AS \, 1.79$$

Where Fe and AS concentrations are in mg/l.

This equation is used to determine minimum Fe amount required for a given arsenic concentration at pH 7.5 after 3 days settlement to comply with the drinking standard for arsenic (0.05 mg/l).

## DISCUSSION

The Central finding in this study has been the demonstration that adsorption and co-precipitation with iron followed by settlement can remove significant amount of arsenic with limitation of sufficient iron and a settling time (>, 3 days). As such the method has considerable as a low-cost technique due to total absence of added chemicals a surprising mixing and sedimentation was capable of achieving higher rates of removal than mechanical mixing and filtration through a 0.45µm filter paper. At early time (< 6h) manual shaking influence the separation process arising from the enhancement of

the microflocs. But, simple increment in size are not responsible for settling because Gregory [4] showed that larger size of flocs tending to lower effective density. The experiences with settlement in this study differs from Shen [8] with application of iron as absorbent. This emphasis the advantage gained by co-pecipitation to enhance arsenic removal.

The comparison of removal mechanism in present study with others showed different preparation technique and settlement arised complications. The removal density did not reach a saturation point of the AS (III) to tested ranges (0.1 – 7.5 mg/l) as is somewhat consistent with maximum adsorption density at 0.4 mole AS/ mole Fe stated by Fergusan and Anderson [3]. Pierce and Moore [7] suggested that a multisite adsorption occurred in arsenic adsorption with $Fe(OH)_3$. The trends in Fig. 3 suggests that adsorption is responsible for the removal of arsenic up to the initial concentration of 0.4 mg/l. Our data is linked to a time dependent process and this aspect is also true of the Pierce and Moore [7] study wherein centrifugation after 24 h adsorption is used as the separation technique. According to Hering et al (1996), adsorption is a dominant mechanism in the arsenic removal by coagulation. But, some comparative studies of AS (V) adsorption on performed $Fe(OH)_3$ and co-precipitation showed that higher removal densities could be achieved by co-precipitation in comparison of adsorption at high AS – Fe ratios (Edwards , 1994).

Thus AS / Fe interaction offered sufficient promise for arsenic removal. The method is potentially very useful in spite of lack of understanding the underlying mechanisms. A necessary condition is the sufficiency of iron.

## CONCLUSIONS

Manual flocculation followed by sedimentation may be a promising method for arsenic removal from iron containing groundwater. The settlement period excess to 24 h achieved up to 88%. removal. For high level of iron ($<$, 1.2 mg/l in water), simple shaking of a container and allowing the arsenic iron complex to 3 days settlement could reduce the arsenic conc. from 0.10 mg/l to the 0.05 mg/l. The study suggests that adsorption may be the primary mechanism controlling the AS (III) removal when the Fe/AS weight ratio is $\geq$ 10. However this aspect requires further scrutiny.

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