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A. R. SANKHYAN

*Anthropological Survey of India,
27, Jawaharlal Nehru Road,
Kolkata 700 016, India
e-mail: sankhyan51@rediffmail.com*

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Reducing arsenic concentration in groundwater

Arsenic is found in various rock types^{1–5}. It is dissociated in the groundwater by water–rock interaction in particular, by hydrogeological processes such as weathering return and biological acting. Anthropogenic activities may also cause enrichment of arsenic in groundwater^{6–8}. Arsenic-enriched groundwater has been found in various parts of India, including West Bengal, Orissa and Andhra Pradesh. Studies were carried out regarding the occurrence, source, speciation^{9–16} and also the effect of arsenic if consumed in drinking water¹⁷.

Not much attention was given to the removal/reduction of arsenic from groundwater. However, studies showed that attempts were made for reducing arsenic concentration, without much success^{18–20}. In this study, an attempt has been made to reduce arsenic concentration in the groundwater using economical, easily available, natural inorganic compounds. For this, Column Chromatographic Separation Technique (CCST) has been experimented and tested with a large number of inorganic chemical absorbents along with various complex derivatives. The water (10 $\mu\text{S}/\text{cm}$) with variable solute constituents and their concentration was run with specific time conditions. A large number of chromatographic separated fractions were collected. These fractions were quantitatively analysed for arsenic concentration, and also for pH and EC. Data showed that arsenic concentration could be reduced by the application of various type of adsorbents and coagulants. Activated alumina (Al_2O_3) was used in this study as an adsorbent. It is an inorganic porous compound, prepared by dehydration of $\text{Al}(\text{OH})_3$ in the

temperature range 300–600°C. The effective size of Al_2O_3 is 0.4 to 0.6 mm. Another adsorbent used was a coagulant-type of inorganic compound, namely calcium carbonate (CaCO_3). Fine clay (calcium/sodium montmorillonites) and calcium oxy-chloride were also used. Laboratory investigation was carried out in three different stages and in each stage the type of adsorbent, adsorbent quantity and concentration of aqueous medium were altered. The Column Chromatographic

fractions were collected and analysed quantitatively for arsenic, EC and pH. Arsenic was analysed using selective ion electrodes, namely E-As-201, E-As-040 (Wissenschaftlich–Technische–Werkstätten GMBH (WTW), 2000).

The purpose of this work was to develop an approachable and economical technique for reducing the concentration of arsenic in groundwater.

CCST is used for reducing arsenic concentration in groundwater. For adsorption,

Table 1. Chemical components and aqueous ionic species used in the experimental study

	Montmorillonite	Al_2O_3	CaCO_3	CaOCl_2	pH	EC	Arsenic
Stage 1	500	50	25	25	7.3	1050	200
Stage 2	500	50	25	25	7.8	1500	400
Stage 3	500	50	25	25	8.2	1800	800

Weight in g; pH: $-\log \text{H}^+$ at 25°C, EC, Electrical conductance in $\mu\text{S}/\text{cm}$ at 25°C; Arsenic in $\mu\text{g}/\text{cm}$.

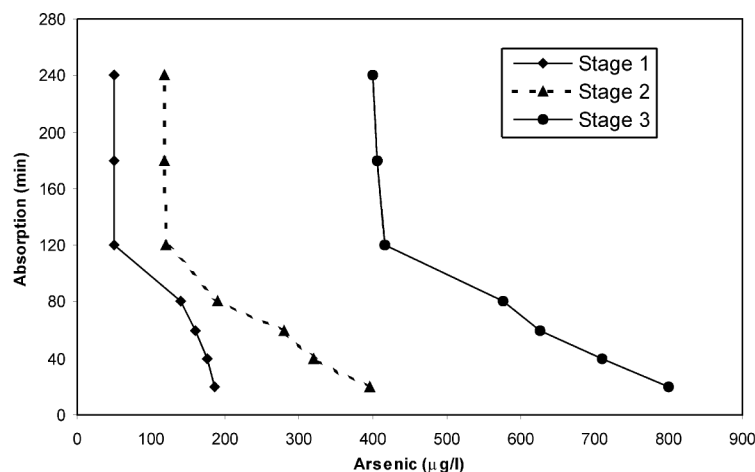


Figure 1. Rate of reducing arsenic concentration.

coagulation, filtration and fractionation, focus was given more to naturally occurring chemical compounds, which must be economically viable, easily available, and quick in desired chemical process. Calcium/sodium montmorillonite, aluminium oxide, calcium carbonate and calcium oxy-chloride are useful absorbents and coagulants for the preparation of columns and for fractionations. Experiments showed reduction of arsenic concentration with the help of the above-mentioned compounds with respect to chemical kinetics. Water with different arsenic concentrations (200, 400 and 800 µg/l) was prepared and applied in the columns. Our study showed that arsenic behaviour in groundwater tends to vary with pH and EC of the aqueous medium. With lower arsenic concentration (< 400 µg/l), the ratio of initial number of moles of arsenic available, and surface area may be less. Because of this, the fractional absorption trend may become independent of initial concentration. At higher concentration of arsenic (> 400 µg/l), the available pore of absorption becomes less and hence partial removal of arsenic becomes dependent upon the initial concentration^{1,13,16}. The role of pH and EC on arsenic dissolution process is well discussed in various publications^{6,16}.

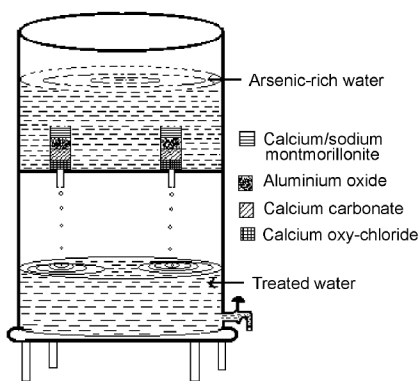


Figure 2. Symmetric diagram for reducing arsenic in groundwater.

Table 2. Arsenic concentration of the fractionations with time

Time (min)	Stage 1	Stage 2	Stage 3
20	185	395	800
40	175	320	710
60	160	280	625
80	140	190	575
120	50	120	415
180	50	118	405
240	50	118	400

As described above, laboratory experiments were carried out for reducing arsenic concentration in water. Selected compounds used in fractionation during CCST and their quantities are shown in Table 1. The experiment was performed in the following three stages. Stage 1: Chromatographic column prepared using 500 g clay (calcium/sodium montmorillonite) + 50 g Al₂O₃ (activated alumina) + 25 g CaCO₃ (fine powdered limestone) and 50 g calcium oxy-chloride. The aqueous medium maintained the standard levels of pH: 7.3; EC: 1050 µS/cm, and arsenic: 200 µg/l (arsenic was spiked (200 µg/l) and chemical concentration was measured along with pH and EC). The column and interaction solute fractions were collected in fixed intervals of 20, 40, 60, 80, 120, 180 and 240 min and were analysed quantitatively for arsenic concentration (the normal permissible limit of arsenic in drinking water is 50 µg/l)²¹. In stages 2 and 3, the chemical concentration of aqueous media and compounds used in the columns was varied (Table 1). The chemical analysis of fractions (Table 2) indicated that the compounds used in this study absorbed arsenic. The rate of absorption vs arsenic in the above-mentioned three stages has been plotted in Figure 1, which shows the difference in the rate of absorption and reduction of arsenic in the above-mentioned three stages. Furthermore, EC and pH of water are also useful chemical parameters in this process²¹. Our technique is best suited under the following criteria: arsenic is < 200 µg/l, neutral to mildly alkaline pH and low EC (< 1050 µS/cm).

Based on this study a very simple and symmetric diagram has been designed and presented for reducing arsenic concentration in groundwater (Figure 2).

Thus calcium and sodium montmorillonite, activated alumina, calcium carbonate and calcium oxy-chloride are effective coagulants and absorbents for reducing arsenic concentration. These compounds are naturally occurring, economically viable, easily available and safe to use.

The proposed technique for reducing arsenic concentration is best suited in water of low-to-moderate arsenic (< 200 µg/l), neutral to mildly alkaline pH, and low-to-moderate EC (< 1050 µS/cm).

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V. K. SAXENA*
N. C. MONDAL
V. S. SINGH

National Geophysical Research Institute,
Uppal Road,
Hyderabad 500 007, India
*For correspondence.
e-mail: vks_9020010@yahoo.co.in