

Disposal of Water Treatment Wastes Containing Arsenic - A Review

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ABSTRACT: *In poor nations, solid waste management is often unsustainable, depending on uncontrolled disposal in landfills. Because arsenic (As) is extremely mobile and has the potential to leak back into the environment, disposing of treatment leftovers produced by removing As from drinking water poses particular challenges. Surface and ground-waters. This study examines the disposal of As-containing water treatment pollutants. Stabilization/solidification (S/S) technologies, which are presently utilized to treat a variety of diseases, are given special attention. As-containing industrial wastes these have been evaluated to see whether they are suitable for treating Asthma. Contains effluent from water treatment Mixtures of Portland cement and lime are anticipated to be (at least in part) recycled. suitable for sorptive filter wastes, but may not be suitable for precipitative sludges, because Cement hydration may be slowed by ferric flocs, which are often employed to sorb As. Brine produced as a consequence of the regeneration of the use of activated alumina filters is expected to speed up the hydration of cement. Portland cement has the ability to immobilize soluble substances. Arsenites have been effectively utilized to stabilize As-rich sludge's, and it may also be useful for treating other types of sledges. sludges produced by precipitative removal systems As(III) is oxidized to As(V), and As(V) is formed. Calcium-arsenic compounds have a significant role in the immobilization of as in cements. Geopolymers are a kind of polymer that may be used to make alternative binder systems for the treatment of alumina and metal hydroxide-rich wastes and As wastes produced with activated alumina may have potential. Cemented surfaces provide a long-term stability. However, the fate of arsenic-bearing wastes is unclear, since they, like many cements, are sensitive to carbonation. As a consequence of these side effects, As may be re-released in the future.*

Keywords: *Arsenic, Water pollution, Stabilisation/Solidification, Portland, Cement Eaching.*

INTRODUCTION

GI illnesses were spread by surface water in Bangladesh and India throughout the 1970s, resulting in very high rates of morbidity and death. As a result, hundreds of tube wells were constructed as an alternate source of water. Providing water for drinking Arsenic (As) levels in the groundwater in these areas are often above 500 g As/l. The World Health Organization's recommended limit of 10 g As/l (World Health Organization, 2001) is considerably exceeded. Standard water testing methods did not originally monitor. As levels, and because of the cumulative nature of As's effects on human health, acute arsenicosis took many years to detect. Several million individuals had been exposed to As by this time, in what has been characterized as the world's greatest mass poisoning incident[1]. As a result, a variety of As removal methods have been developed for both home and municipal applications. Apart from the serious As issues in Bangladesh and India, it is clear that many other nations (both developed and developing) have found As concentrations in drinking water above the 10 g/l guideline value, indicating the present and worldwide character of the problem[2]. As a result, there has been a commensurate increase in research and development aimed at developing suitable treatment methods for removing As from polluted groundwater sources. While much progress has been made in the field of water treatment, the disposal of As-containing wastes produced during these procedures is a significant problem that has gotten little attention.

This paper's main goal is to look at the problems surrounding the disposal of As-containing water treatment pollutants.

Arsenic in aqueous solution

Arsenic, like other metalloids on the periodic table near to it, is redox sensitive and may produce oxyanions, much like many nonmetals. As a result, arsenic speciation is affected by the redox state and pH of the chemical environment. 3 (arsine gas, AsH₃), 1 (alkyl arsenic), 0 (zero-valent, elemental arsenic), +3 (arsenites) and +5 (arsenates) are the most stable redox states, and these latter two states dominate aqueous arsenic solutions. Both As(III) and As(V) species may bond with one or more hydrogen ions once dissolved, producing two deprotonation series that control As mobility or fixation. Above the solid line separating each redox pair in Fig. 1, the standard electrode potentials (E_o in volts versus SHE) are displayed[3].

The amount of successive deprotonation of aqueous arsenic species in oxidation states III and V with increasing pH may be estimated using the dissociation constants for the processes listed in Table 1[4].

Table 1: Deprotonation Of Arsenic Species In Solutions

Deprotonation series of the arsenates (AsV)	
$\text{As}(\text{OH})_5^0 \rightarrow \text{H}^+ + \text{AsO}(\text{OH})_2$	$\text{pK}_a = 9.32$
$\text{AsO}(\text{OH})_2^- \rightarrow \text{H}^+ + \text{AsO}_2(\text{OH})^{-2}$	$\text{pK}_a = 12.10$
$\text{AsO}_2(\text{OH})^{-2} \rightarrow \text{H}^+ + \text{AsO}_3^{-3}$	$\text{pK}_a = 13.41$
Similarly, for the arsenites (AsIII)	
$\text{As}(\text{OH})_3^0 \rightarrow \text{H}^+ + \text{AsO}_2(\text{OH})_2^-$	$\text{pK}_a = 2.2$
$\text{AsO}_2(\text{OH})_2^- \rightarrow \text{H}^+ + \text{AsO}_3(\text{OH})^{-2}$	$\text{pK}_a = 6.96$
$\text{AsO}_3(\text{OH})^{-2} \rightarrow \text{H}^+ + \text{AsO}_4^{-3}$	$\text{pK}_a = 11.5$

The abundance of each species may be estimated as a function of solution pH using these data. The ion-pairing model PHREEQC-I, version 2.13.2 (Parkhurst, 1995) and the Lawrence Livermore database that is provided with that code were used to compute Fig. 2 (AsV) and Fig. 3 (AsIII)[5]. The solutions selected to simulate an electrolyte buffer with a changing pH were HCl–NaCl–NaOH combinations with a total ionic strength of less than 0.2M. It is critical to have a thorough knowledge of the chemical environment when evaluating the mobility and fixation of arsenical pollutants. Solution chemistry has a significant impact on both the precipitation–dissolution and sorption–desorption processes that control arsenic fixation[6]. Under anoxic circumstances, such as in groundwater, the reduced trivalent form arsenite (AsIII) predominates, while the oxidized form arsenate (AsV) predominates in oxygenated or surface waters across the pH range usually encountered in water treatment. In oxygenated water, conversion of As(III) to As(V) is thermodynamically advantageous, although shift in oxidation states takes time and may take many days, weeks, or months, depending on the circumstances (Jiang, 2001). It's worth noting that many conventional leach tests aren't intended to assess the leaching of waste material over actual time periods, such as 24 hours. Many redox processes exhibit slow behavior, and studies of sampling waters show that disequilibrium situations may persist. Combining Figures 1–3 results in

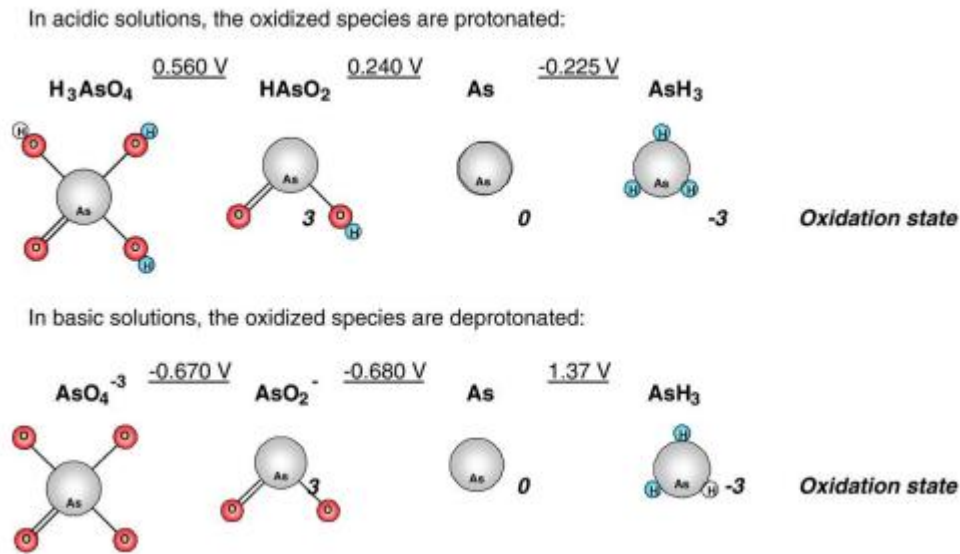


Figure 1: Schematic Speculation of Arsenic in Oxidation States 5, 3, 0 And -3 in Acidic and Basic Solutions.

As illustrated in Fig. 4, a Pourbaix diagram for arsenic in aqueous solution was calculated.

Ferric and aluminium hydroxides are able to remove dissolved As and other metal species from solution via sorption due to the surface charges they generate. Over a broad pH range, ferric precipitates are the most efficient in removing arsenates from solution. Iron and aluminum salts, such as ferric chloride $[\text{FeCl}_3]$ and aluminium sulphate $[\text{Al}_2(\text{SO}_4)_3]$, are widely used in traditional water treatment procedures to separate dissolved and colloidal pollutants, primarily via the precipitation of Fe or Al hydrolysis products[7].

Calcium is often utilized in water treatment procedures as well as several of the technologies described in this article in the form of lime (CaO), hydrated lime (Ca (OH)₂), and calcium carbonates. Dutr  and Vandecasteele (1995a) discovered that arsenates and arsenites chemically bind with hydrated lime to produce precipitates when studying the behavior of arsenic in leachate:

These Ca–As compounds have been studied extensively in the presence of cements by determined both experimentally and numerically the thermodynamic properties of Ca–As compounds. They demonstrated the utility of thermodynamic modeling in the arsenic–cement–pore

The experimentally measured concentrations and their numerical predictions were found to be in close agreement. The limiting solubility of CaAsO_2OH in cement pore solutions in the presence of CSH gel and portlandite (Ca(OH)₂) is estimated to be approximately $7\text{E}4\text{M}$. As demonstrated in Fig. 5, the minimum solubility of calcium arsenate as $\text{Ca}_3(\text{AsO}_4)_2$ is about double that of calcium arsenate as $\text{Ca}_3(\text{AsO}_4)_2$ [8].

Robins (1981) looked examined the solubility of comparable metal arsenates (Mg, Fe, Ca) in aqueous environments and presented a complete set of phase diagrams, as well as their susceptibility to carbonation. Bothe and Brown (1999) investigated the stabilization of arsenic in a variety of conditions that would normally produce $\text{Ca}_3(\text{AsO}_4)_2$, but found that

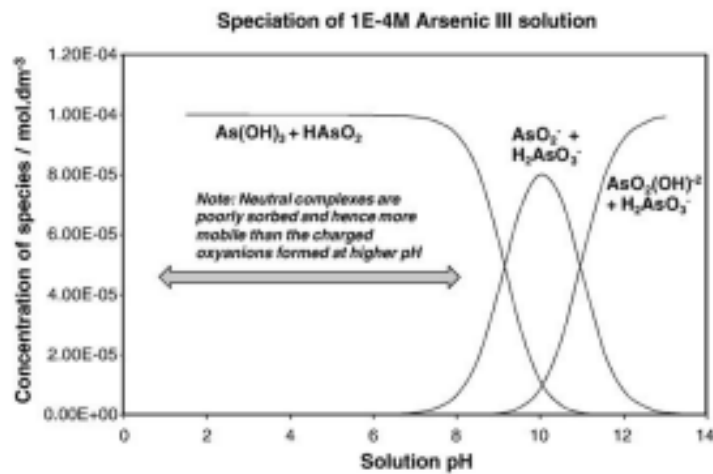


Figure 2: Aqueous Speciation of Arsenic III as A Function of pH

$\text{Ca}_4(\text{OH})_2(\text{AsO}_4)_2 \cdot 4\text{H}_2\text{O}$ and $\text{Ca}_3(\text{AsO}_4)_2 \cdot 3/2 \text{H}_2\text{O}$ dominated the solid phases. They expanded their research to include phosphorus and discovered that the combination $\text{Ca}_5(\text{AsO}_4)_3\text{OH}$ (arsenate apatite) is stable. They also looked into its partial solid solution with hydroxyapatite, which turned out to be limited, with arsenate apatite forming at the cost of $\text{Ca}_5(\text{PO}_4)_3\text{OH}$ [9].

CaHAsO_3 (s) is more soluble than arsenite, indicating that arsenates are simpler to immobilize than arsenites. Where the pH is acidic or near neutral, it is now widely recognized that As(V) is more strongly sorbed than As(III). Ferric iron hydroxides occur as colloids in oxidizing conditions with a pH higher than 4.09. They will sorb arsenic. In a reducing environment, circumstances that decrease As(V) to As(III) are anticipated to reduce Fe(III) to Fe(II), thus any precipitated ferric hydroxide will become soluble, releasing the arsenic previously sorbed. In reality, this implies that when groundwater becomes more reducing, arsenic adsorbed to ferric hydroxides in sediments will begin to be liberated. Arsenate is reduced to arsenite, and ferric iron is converted to ferrous iron, which is soluble in groundwater with a normal pH range. Although changes in source water composition below pH 8 had no effect on arsenate removal by ferric chloride or alum, the effectiveness of ferric chloride at pH 8–9 reduced if organic matter was present, indicating that arsenic may not be as forcefully sorbed in waste that is rich in organics. Organic colloids have been shown to mobilize sorbed species, although this is outside the scope of this study[10].

Although ionic sorption onto charged surfaces has been widely known, evidence on arsenic fixing onto metal oxides has been scarce. In their study on surface complexation of ferrous iron and carbonate on ferrihydrite and mobilization of As, we made considerable progress in bridging this knowledge gap. They used the double-layer model for surface complexation and calculated complexation constants for carbonate and ferrous iron on ferrihydrite, which allowed them to simulate competitive sorption. They found that sorption of carbonate, in particular at common soil and groundwater concentrations, substantially decreased the sorption capacity of arsenic on ferrihydrite, and based on their predictions, which were in excellent accord with experimental results. This is significant because the carbonation of cement-stabilized flocs may be susceptible not only to denaturing of any arsenic-bearing particles present, but also to competitive arsenic desorption by dissolved carbonate ions.

DISCUSSION

In nations like Bangladesh and India, the disposal of As-containing wastes produced during water treatment has relied on dubious and unsustainable techniques that have not been well studied. Methods like stabilization with cow dung are frequently used without regard for the toxicity of the by-products and how they should be handled.

Disposal options are restricted. Untreated as contaminated trash is often discarded or buried, and As has the potential to leak back into the ecosystem as a consequence. Despite the fact that studies have shown that as leaching from sludge is not usually substantial, the quality of the leaching tests employed is often questioned since they do not mimic actual field circumstances. Due to the restricted applications and markets for as, recycling is not a feasible alternative. Incineration and other high-temperature thermal treatment procedures volatilize As-containing compounds, resulting in hazardous aerosols or an As-containing sludge from cleaning emissions. The only long-term solution for As-containing water treatment sludge is to convert the As to the least mobile or stable form possible and then use a solidification/encapsulation technique to separate the stabilized material from the environment.

CONCLUSION

There has been little study on long-term S/S techniques for properly managing and disposing of waste produced by As removal systems. There is little evidence that the present waste management methods used in Bangladesh or India are successful. It is determined from this study of S/S methods for handling As wastes in poor nations that

- a) There has been little study on long-term S/S techniques for properly managing and disposing of waste produced by As removal systems. There is little evidence that the present waste management methods used in Bangladesh or India are successful. It is determined from this study of S/S methods for handling As wastes in poor nations that with increased leachability. Brine resulting from the regeneration of AA filters may accelerate cement hydration. Optimum moisture content and waste to binder ratios depend on the chemical properties of the waste. There is evidence that Portland cement can immobilise soluble arsenites.
- b) Precipitation and solidification has been successfully used to stabilise arsenic-rich sludges and may be suitable for treating sludges generated by precipitative removal units.
- c) Geopolymerisation works well with waste materials high in alumina and metal hydroxides, making it a viable treatment option for AA unit waste. Geopolymer treatment with easy operation and minimal operating costs has promise. Physical occlusion would immobilize these components rather than incorporating them into the geopolymer framework, and their long-term behavior is unknown.

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