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Arsenic in Drinking-Water: Health Disorders, Nutrition Factors and Elimination Processes

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Abstract: Arsenic is a ubiquitous and toxic element that can be found in rocks, water, soils and plants and even in air. As-contaminated water and endemic exposure with this pollutant emerged as a single catastrophe affecting the people in worldwide. Survey of ground water quality and environmental geology in Iran shows pollution of water in several regions with this pollutant is major problem. Several factors such as nutrition, arsenic concentration and its forms were effective in arsenic toxicities. Based on epidemiological studies underweight individuals with low body mass index (BMI) who live in low in-come societies were disproportionately more susceptible for arsenic toxicity. Because these situations have predominant in rural area and in Iran several villages have high concentration of As in their drinking-water, this paper provides an overview of As contamination of water, its health hazards and toxicities, relationship between nutrition states and arsenic toxicity and introducing elimination methods of this contaminant from drinking-water for selection of appropriate method for rural areas and in household applications.

Key words: Arsenic · Water pollution · Drinking-water · Health disorders · Nutrition

INTRODUCTION

For many years, several elements and compounds such as mercury (Hg), arsenic (As) and thrihalomethanes (THM$_s$) received special attentions from the scientific communities and health organizations. There were triggered by their toxicological relevancies, which became known to the broad public conclusively with the outbreaks of poisonings. The outbreak of Minamata disease is one of the most important poisoning that had been related to Hg in 1956. Nowadays, arsenic is one of the most important understudy topics of the public health organizations. This is a ubiquitous element in the environment that can be found in trace amounts in rocks, water, soils, plants and even in air. The problems related to As are mainly due to the endemic and epidemic-like health problems distributed among millions of people in several countries such as Bangladesh, India, Nepal [1], Pakistan, Mexico, Mongolia, Germany, Thailand, China, I.R.Iran, Chile, USA, Canada and Myanmar [2, 3].

In these countries, As-contaminated water and endemic exposure with this pollutant emerged as a single catastrophe affecting the people in these regions. Survey of ground water quality in Iran shows that drinking -water in some of rural area in kurdestan province, located in the west of Iran has high concentration of arsenic. The results of this study showed that concentration of total As in six village of Bijar city is higher than that of WHO guidelines value (10μgr/l) and in one of these village it's concentration is higher than the national standards of water quality for As (50μgr/l) [3, 4].

Survey of environmental geology in Iran shows that deposits and sediments in some part of central zone of eastern Alborz, located at 54° 33′-55° 15′ E and 36° 15′-36° 48′ N in north east of Iran have as high as 140ppm of arsenic. Analysis of water quality shows that, in this area surface and ground water had been affected by the high concentration of As and its contaminations. Bastam, Jafarkhan, Mojen and Nash are regions that As-concetration of water was higher than WHO guideline value and national standards of water quality for As [5].

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Also, considering the geochemistry's data in North West of Iran indicates that Zarshuran As-Au deposits that located at 36° 43′ 21° N and 47° 8′ 25° E, 42 km north of the town of Takab in the West Azarbaijan province has high concentration of As.

The Zarshuran deposits in many aspects, is very similar to the Carlin type sediment hosted gold deposits of western USA. About 30 sulfide minerals and sulfosalts have been identified at this region that includes pyrite (FeS_2), orpiment (As_2S_3), realgar (AsS), stibnite(Sb_2S_3), getchelite($AsSbS_3$), cinnabar(HgS) and barite, among which, orpiment is the main arsenic ore mineral in Zarshuran deposit. Analysis of chemical constituents of water in this region shows that some of samples have high concentration of As [6].

Based on the above mentioned literature, we can conclude that contamination of surface and ground water resources in Iran is possible and should be recognized as an important problem; thus, substitution of contaminated drinking-water resources or elimination of this pollutant from water and provision of healthy drinking-water is necessary. The aim of this paper is to provide an overview of As contamination of water, its health hazards and introducing elimination methods of this contaminant from water.

Arsenic in Environmental

Arsenic in Soil and Deposits: Various components of lithosphere have different concentration of arsenic. Upper crust, ultramafic rocks, stony meteorites have 1.5-2, 0.7 and 1.8 mg/kg of As respectively. Based on 2.13×10^9 ton of weight for earth's crust, As concentration in this part has been reported 1, 1.7 and 1.8 mg/kg, so that the total As amount in earth's crust is estimated 4.01×10^{16} kg, which is 20th most abundant element [7]. Based on Chilvers and Peterson (1978), the 1.74×10^6kg of the As can be stored on atmosphere. This mass is unevenly distributed between the north and south hemispheres. Larger land mass and the distribution of industrialized countries with high releasing profiles on the northern hemisphere lead to impair and unevenly distribution of As in earth's crust. Northern hemisphere has 1.48×10^6 kg of As but southern hemisphere has 0.26×10^6 kg of As.

Arsenic occurs in environmental in variable oxidation states (-3, 0, +3, +5). This element belong to metalloid group that shows many metallic properties and co-exist in nature with other metalloid and non metalloid elements like S, P, Fe, Cu, Ni, etc. as sulfide or oxide ores [2]. Orpiment (AsS_3) with 61% As in its chemical composition is the main As ore mineral. Realgar (AsS) is a less common but important ore mineral. Arsenical pyrite with 4.5 % As is another As-bearing mineral that can be found in environment [6]. Arsenic can not be destroyed but can be converted from one stage to another stages [2]

Arsenic in Aqueous Environments: The arsenic compounds introduced into water through natural and anthropogenic sources including dissolution of mineral ores [7], weathering of mine waste piles [6], seepage of leachate from hazardous or industrial waste sites, wood preservation by arsenic based compounds[8], geochemical reactions[9], hydrothermal activities[10], mining and processing of various ores like Cu, Au, Pb, Zn and Ni, use of arsenical herbicide and insecticides[2,9], waste incineration, combustion of fossil fuels(Oil and Coal) in power plants [1,11], glass wear production, semiconductor production [8], converting of electrical energy into coherent light, drying agent in cotton and wool processing and medication [1].

These activities contributed to the release of arsenic into the surface and ground water and via atmospheric emissions onto the soils. Arsenic is present in natural waters in both organic and inorganic forms. Although the presence of organoarsenic compounds, such as monomethylarsenate (MMA) and dimethylarsenate (DMA) with considerably high concentrations have been reported in natural waters of countries like Mexico and Taiwan, but the inorganic species are predominant in natural waters. Survey of lake and groundwater in some places in USA shows only 10-24% of methylated species detected in natural waters that related to agriculture consumption of MMA, DMA and phenylarsenic acid derivatives [12].

The organic species of arsenic are abundant in seafoods [8]. These species occur in natural waters as a result of organo-arsenical pesticide use, as well as through the biomethylation mechanisms of micro-organisms [13]. It has been established that the toxicity of arsenic depends on its specific chemical form. Although WHO reported that organic species of As are much less harmful to health and are readily eliminated by the body[11] but recent studies have demonstrated the carcinogenic ability of methylated arsenic compounds, especially DMA and MMA [12, 14].

The most common form of inorganic As in aqueous solutions is arsenat [As (V)] and arsenite [As (III)]. The toxicity of As(III) is much higher than that of As(V) Based on toxicological studies and dependent on experimental system in toxicity assessment system , the toxicity of

As(III) is 2.6-59 or 25-60 times higher than As(V) [3,11,15]. The methylated form of As (III), which is likely to produce during the methabolism of MMA and DMA, are equally or more toxic than As (III) in terms of cytotoxic effect [12].

The distribution of inorganic species (trivalent and pentavalent) and their various forms in aquatic environmental is mainly dependent on redox potential and pH conditions [16]. In aqueous oxide environments, such as those prevailing in surface water, the predominant species is As(V) [2,16,17] while As(III) is found in anaerobic and anoxic environments, like in well water or in ground water that reduced condition is predominant [18]. In the pH range of 4-10 due to the thermodynamical stability, the trivalent As species are neutral in charge, while the As(V) are negatively charged and present in the oxy-anionic forms such as $H_2AsO_4^-$ and $HasO_4^{-2}$ [16,18,19].

Based on this presumption, that As is a metalloid contaminant of water and this categories of pollutants are not degradable, environmental and health authorities should have taken a more stringent attitude towards the presence of arsenic in drinking-water resources [2,16]. Although people may be exposed to arsenic in many ways like wood preservative facilities and glass factory, burning of cigarette tobacco [8] but survey of origins of contaminants show that, water is one of the most important media through which arsenic enters into the human body worldwide [2,8]. Based on WHO reports, absorption of As through the skin is minimal and thus hand-washing, bathing and laundry with water containing As do not pose human health risks but, drinking of As contaminated water pose the greatest threat to public health [11].

Standards in Drinking-water: WHO's norms for drinking-water quality go back to 1958 in which the international standards for drinking-water established 0.2mg/l as an allowable concentration for arsenic. In 1963, the standard was revaluated/improved and reduced to 0.05mg/l. In 1984 this was maintained as WHO guideline value and many countries have kept this as the national standards or as an interim target [11]. More than 100 million people worldwide have been estimated to be chronically exposed to drinking-water containing high concentration of arsenic[20] so, the arsenic toxicity and the necessity to protect human health and the environment should led to more stringent regulations.

Considering the lethal impact of arsenic on human health, WHO in 1993 and National Health and Medical Research Committee, Australia, in 1996 had recommended maximum contaminant level (MCL) of arsenic in drinking-water as 10 and 7μg/l, respectively. The European commission in 2003 has also reduced the MCL of As from 50 to 10μg/l [17]. Japan and Canada has reduced the MCL for arsenic in drinking-water to 10 and 25 ppb, respectively. As of February 2002, the USEPA has lowered the MCL of arsenic in drinking-water system from 50 to 10μg/l and set a required compliance date of January 23, 2006 [21]. The MCL of 10 μg/l results in an excess lifetime cancer risk of 6×10^{-4}. If the guideline were made strictly on a health basis, it would be set at 0.17μg/l in order to reduce the cancer risk to 10^{-5} [2] because epidemiological studies show that the relative risk of cancer in communities with a level of 10ppb arsenic in drinking-water is 1.9 [8].

Although the toxicity and carcinogenic effects of arsenic has been established, the MCL of this pollutant in countries like China, India, Iran, etc. is also 50μg/l [2-4]. Based on toxicological studies this standard in these countries needs reevaluation. The reason that the guideline cannot reach to this low level (0.17μg/l) and must be kept around 10μg/l is related to problems of testing methods or measurement limitations that is not so sophisticated enough to detect lower concentrations than 10μg/l [22]. On the other hand, accurate measurement of arsenic at levels relevant to human health requires laboratory analysis, using sophisticated and expensive techniques and facilities as well as trained staff that are not easily available or affordable in many countries. So, this was assigned as a provisional guideline value [11].

This review shows that fundamentals of MCL_s are availability for measurement methods with appropriate detection limits and in particular development and enhancing of measurement methods is one of the most important requirements that should be recognized in drinking-water quality control.

Health Effects of Arsenic

Toxicity and Attributed Diseases: It is estimated that 25-57 million people in Bangladesh have suffered from chronic exposure to arsenic and after decades of exposure the exposed population is at an elevated risk of arsenic-induced health problems. Toxicological studies show that the toxicity level of arsenic compounds decreased in the following order: arsin> inorganic arsenic (III)> organic arsenic (III)> inorganic arsenic (V)> organic arsenic (V)> arsenium compounds and elemental arsenic.

These levels of toxicity shows that the mod of poisoning depends on the chemical form of As. Arsenate is a molecular analog of phosphate that inhibits oxidative phosphorylation thereby short-circuiting life's main energy-generation system. Arsenite is even more broadly toxic due to binding to sulfhydryl groups impairing the functional of many proteins. It also affects respiration by binding to the vicinal thiols in pyruvate dehydrogenase and 2-oxoglutarate dehydrogenase [2]. Arsenic may also exert its toxicity through the generation of reactive oxygen species [23].

It is proved that arsenic poisoning occurs by consumption of drinking- water that contains high concentration of this pollutant [2]. Based on several researches the presence of As in water supplies has been linked to arsenical dermatitis, skin cancer, neurological disorders, enlargement of liver [24,2], cardiovascular and endocrine disorders [25], internal cancers [24,2], stillbirth [26], gastrointestinal disease [27], deficits of cognitive function and reducing of birth weight [20], lung, kidney , skin, colon and urinary tract cancers [28, 8]. There is evidence for associations with cancers of kidney and possibly prostate.

In addition, high level of drinking-water have been linked to cutaneous effects (hyper/hypopigmentaion, palmer-plantar hyperkeratosis and leucomelanosis), liver cirrhosis, vascular effects and Rynaud's syndrome, diabetes mellitus and peripheral neuropathy [8] as well as chronic cough, shortness of breath and chest sound [29]. Also, ingestion of high concentration of As by pregnant women may cause adverse reproductive and developmental effects and increase rates of stillbirths, spontaneous abortions, low-birth weight deliveries and neonatal and postneonatal mortality [30]. Based on Chen and *et el.* research that has been carried out in Bangladesh the overall lifetime excess mortality risks (per 100,000 person) from the three cancers (liver, bladder and lung) that attributed to arsenic contamination of drinking-water in combination were 198.3 for males and 53.8 for females, with an average across gender lifetime risk of 126.1 [31].

Table 1: Relationship between As concentration in tap water and cancer risk

Arsenic concentration (ppb)	Approximate total cancer risk
0.5	1 in 10,000
1	1 in 5000
3	1 in 1667
4	1 in 1250
5	1 in 1000
10	1 in 500
20	1 in 250
25	1 in 200
50	1 in 100

Based on data from epidemiological studies, it was estimated that the risk of dying from lifetime daily consumption of water containing 50μg/l of inorganic arsenic (the current standards of several countries) could be of the order of one in hundred [32]. Table 1 shows the relationship between various concentration of arsenic in tap water and cancer risk. This estimation values has been carried out by National Academy of Science in 1999 and based on consumption of 2L drinking-water per day [2].

Lifestyle and Arsenic Poisoning: Nutrition is one the most important lifestyle factors that may play important roles in modulation (retardation) of arsenic toxicity. Table 2 summarizes relationship between micronutrient/nutritional factors and arsenic toxicity. National Research Council (NRC), USA, reported that the nutritional status has the potential to modulate arsenic toxicity.

However, it was unlikely that nutrition has a substantial role in the etiology of arsenic-related cancers, because several different geographical, demographical and overall health factors are relatively effective in outcome of arsenic-related diseases. Survey of skin lesion in Bangladesh and west Bengal showed that underweight individuals were disproportionately more susceptible for this problem. As shown in Table 2 survey of Taiwanese diet shows similarly that undernourishment and low B-carotene levels were related with increased prevalence of arsenic-related skin lesion.

Table 2: Relationship between micronutrient/nutritional factors and arsenic toxicity [2].

Nutritional factor	Effect	Source of information
Â-carotene deficiency	Increased toxicity	Epidemiological studies
Selenium deficiency	Increased toxicity	Epidemiological studies
Cholineandmethionine deficiency	Increased toxicity	Animal studies
Antioxidant(Vitamin C and E) superannuation	Decreased toxicity	Animal studies
Folic acid superannuation	Decreased toxicity	Animal studies

Although several studies show contradictory results between nutrition and arsenic attributed skin lesions but new comprehensive studies based on biochemical pathways have been approved this phenomena. Methylation and excreting via urine are pathways that involved in detoxification process of arsenic.

The biochemical rate of methyation dependent on availability of S-adenosylmethionine (SAM). Several dietary factors such as methionine, choline and folate are components that can preserve methyl group for SAM. This role of methionine dietary approved in animal bioassay, which deficiency of this micronutrient lead to decreasing of urinary arsenic excretion and increasing of tissue retention of arsenic. Low-protein diets have similar effects and lead to deleterious effects. Based on this findings, it seems arsenic toxicity is greater among people with poor diets.

Epidemiological studies show that consumption of higher protein, cysteine and methionine lead to higher excretion of arsenic in urine. These results are likely to be explained by the roles of these nutrients in arsenic methylation and increasing of urine excretion of dimethylarsenic acid as an arsenic metabolite [33]. Also, higher consumption of dietary riboflavin, pyridoxine, vitamins A, C and E, folic acid and antioxidants can significantly reduce the skin lesions related to arsenic contaminated water [34]. Several studies correlated the arsenic attributed skin lesions to body mass index (BMI) and reported that this problem in low BMI population is higher than people with high BMI.

Accordingly low BMI reflects poor nutritional status and low intake of micronutrients such as antioxidants, folates and dietary proteins which are necessary for metylation and detoxification of arsenic which directly or indirectly influence the arsenic toxicity [25]. Although, appropriate state of nutrition with uptake of micronutrients enhances the excretion and bio-detoxification of arsenic; but, proper lifestyle with a good nutritional status may not be present in rural area or low income societies which suffer from As-contaminated water. So, removal of arsenic from drinking-water resources is necessary and is one of the best alternatives for protection of people and public health promotion in polluted regions.

Removal Techniques: Based on the recommended and established standards by EPA, WHO and EU, the effective As-removal processes are emerging issue and needed to meet the standards for drinking-water and the requirements for the discharge of industrial effluents [10,17]. Removal of arsenic from water can take place by several techniques and scale sizes.

Although, most of documented experiences have been performed with large municipal treatment plants, but some of these technologies can be applied at community or household level [35]. With respect to treatment and quality of drinking-water, the selected (respected) process/techniques should be simple, effective and selective for the target contaminant (As) and not eliminate the major ions [10]. Several processes are available for removing of arsenic from drinking-water resources, including enhanced coagulation, membrane systems [21], ion exchange, adsorption onto activated alumina and other oxyhydroxides [7], lime softening, electrodialysis [36], adsorption by metal oxides [21], zero valent iron [37], adsorption in modified/impregnated activated carbon [2], photocatalyst-adsorbent system[12], water treatment residuals [38], natural and synthetic zeolites such as clinoptililite, chabazaite, 13X, etc. [24], phytoremediation and biological treatment with living microbes/bio-filtration [2, 17].

Survey of these processes shows the remediation of water can take place with some conventional as well as advanced techniques which can be classified as physico-chemical and biological processes. The most common physico-chemical processes include adsorption, ion exchange, coagulation-precipitation, membrane processes and electro dialysis [2, 7, 39]. Some of arsenic removal processes like ion exchange, activated alumina, reverse osmosis, modified coagulation-precipitation had been categorized as the best available technology by the USAEPA [2].

Coagulation-precipitation: This technique is one of the most established and reliable processes in which, removal of arsenic take place by transformation of soluble arsenic in to insoluble forms which precipitated or adsorbed on the floc surfaces and co-precipitated with precipitating species. Several of coagulant compounds like alum, iron, Fe/Mn, lime, manganese sulfate, ammonium sulfate and copper sulfate can be used for this propose.

Although co-precipitation with ferric chloride is an effective and economical technique and iron hydroxide formed from the ferric salts have a high adsorption capacity for As (V) [40] and coagulation with iron compounds is more efficient than alum coagulation, but based on enhancing effects of phosphate on mobility of As (V) it may be told that presence of elevated concentration of phosphate and silicate may dramatically

Table 3: Advantages and disadvantages of arsenic adsorbents

Adsorbent	Advantages	Disadvantages	Reference
Activated alumina	Commercially available, is a best available technology, high surface area (200-300m2/g), excellent efficiency (>95%).	Less effective for As (III), efficiency decreased as pH increased, affected by competing ions, arsenic leakage probable, difficult and less regeneration, clogging and fouling of bed.	[7,35,39,42]
Iron coated materials and bone char	Appropriate for poor part of the world, very high efficiency (~99.5%)	Pre-oxidation is usually required for efficient removal, adversely affected by silicate, sulfate, carbonate and NOM.	[7,13,41,43,44,45,46]
Ion exchange resins	Is an attractive technology, high exchange capacity, high efficiency (>95%), insensitive to pH, relatively independent of pH and influent concentration,long effective lifetime of resins,	High cost, applicable in small, medium scale and point- of- entry, competing ions is effective, breakthrough occurs earlier.	[35, 39,43]
Zero valent iron	High efficiency (>99%), high concentration of SO4-2 (>600mg/l) has enhancing effects, simultaneous removal of As(III) and As(V) without preoxidation	Iron concentration is unacceptably highly, As (V) removal is higher than As (III), efficiency affected pH and DO concentration,humic materials have inhibiting effects	[35,37,43]
Zeolites	Applicable in large scale, greatest capacity, effective in wide range of pH (2-12), large surface area, strong affinity for As (III) and As (V).	May lead to Al realizing, have not meet the MCLs of As, Al: Si ratio is effective on capacity, may need for structure modifications, the capacity decreases with increasing of pH,	[24,35]

decrease the arsenic removal by co-precipitation treatment [41]. Experimental results of Meng *et al.* (2000) demonstrated that presence of silicate has adverse effects on the removal of As (V) and As (III) [41]. Meng *et al.* (2001) reported phosphate and silicate were the major anions affecting the removal of As (V) by co-precipitation with ferric chloride; so, a high concentration of coagulant that should lead to high Fe/As ratio had to be used to achieve substantial arsenic removal.

These researchers reported single presence of silicate and phosphate has moderate and drastic effects on arsenic removal respectively but, simultaneous presence of these anions has further decreasing effects on the process. The interferential effects of these anions are attributed to the competition of these anions via As (V) for sorption on ferrichydroxide sites [40]. Although the presence of some anions have inhibiting effects for the coagulation of arsenic by iron compounds but high affinity of As(V) for iron hydroxide precipitates lead to low leaching of arsenic from process's sludge.

This advantage of co-precipitation with iron-compounds shows, if these sludge is properly disposed in soil may not have much drawbacks on environment. However, leaching of arsenic is most probable if the condition changed to anoxic that lead to reduction of ferric hydroxides to ferrous iron and As (V) to As (III) [40] that has high mobility in environment [19]. As a result, although co-precipitation processes were been proven and reliable but, the efficiency of processes highly influenced by origin water characteristics like anions, organic compounds and pH. Also, production of large volume of high arsenic contaminated sludge, use of chemicals, it's handling /housekeeping, interference of anions, need for secondary treatment unit like direct filtration through sand beds or micro-filtration [13] and high cost to installation and operation are the most disadvantages that may limited application of these processes [2].

Adsorption: In water treatment, adsorption process has been shown to be highly efficient for removal of colors, odors, organic and inorganic pollutants. Many types of adsorbents have been used for the removal of arsenic from water which can be classified in three main groups: based on aluminum compounds (activated alumina, gibbsite), based on lanthanum compounds (lanthanum oxide) and based on iron compounds. Iron compounds which are preferred group of substances for arsenic adsorption being hematite, goethite iron oxide-coated materials and granular ferric hydroxide (GFH) [7].

Table 3 summarizes some advantages and disadvantages of several arsenic adsorbents. As shown, arsenic removal by adsorption is mainly affected by pH, pretreatment of adsorbents and presence of ions and organic compounds in origin water. For example during adsorption with activated red mud, obtained removal efficiency of As (III) and As (V) to occur between pH ranges of 5.8-7.5 and 1.8-3.5 respectively.

The pretreatment of activated carbon with Cu (II) lead to 30% increase in arsenic removal. Activation of zeolite also showed significant improvement in arsenic removal. Finally, the presence of competitive anionic compounds or natural organic matters (NOM) can lead to sharply decreasing of arsenic removal [43].

CONCLUSION

Geochemistry's data and water quality show arsenic is presence in drinking-water resources many of countries and more than 100 million people of worldwide have been estimated to be chronically exposed to drinking-water containing high concentration of arsenic.

Since, As-contaminated water and endemic exposure with this pollutant emerged as a single catastrophe affecting the people in these regions and based on toxicological studies, this pollutant was categorized as a priority pollutant by the corresponding organizations; WHO, EU and EPA revaluated and improved their water qualities guidelines for arsenic. Although this MCL of arsenic is not completely safe and need more reimprovement but, corresponding organizations announced that measurement problems from point of reliable/ valid instruments and sophisticated staff resulted the current MCL (10μg/l) to be assigned as a provisional guideline value. Based on this review investment, research and development for localizing of the single and reliable/valid methods for detection of arsenic is required.

Also, due to concerns about arsenic toxicity and corresponding organizations approaches in improvement of arsenic MCL in water, it is noteworthy that although several factors such as overall healthy, lifestyle factors like appropriate state of nutrition (micronutrient uptake), socio-economic and education of people for improvement of knowledge and attitude for health promotion are important for the control and limiting of arsenic exposure/toxicity but, investment for research and development of localized arsenic removal techniques from water is the most important alternative and is the best way for protection of people that should be recognized as priority barrier for protection of arsenic entrance to human body.

Survey of arsenic removal processes shows in most of the available techniques the presence of other anions has inhibitory effects, so that eliminates the efficiency and applicability of the process. At the same time, fundamentals of several techniques which are based on the formation of an insoluble compound produced arsenical sludges which have several problems from point of handling and disposal. Also, leaching / releasing of adsorbed arsenic may take place due to change of environmental condition [7], requiring implementing of toxicity characteristic leaching procedure(TCLP) test based on the USAEPA for identification of leaching potential from adsorbents that have been used for arsenic removal [47].

Due to these problems, a better understanding of these treatment processes is essential for development and selection of effective/best methods for removing of arsenic in order to produce high quality drinking-water with respect to integrated management of health, safety and environmental fundamentals goals.

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