

Ways of Arsenic Compounds Getting into Natural Waters

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Abstract: Different factors often make the surface and ground water sources unfit for drinking purpose. Arsenic is often found in natural waters and makes it unsuitable for consumption without special treatment. Arsenic is released into water bodies as a result of human activity and natural processes. There are the following natural ways of arsenic release into ground water and atmosphere: volcanic activity, forest fires and leaching from arsenic rocks and minerals. The use of arsenic pesticides, processing of sulphide ore production, arsenic dyes and pigments production, producing of arsenic are encountered among anthropogenic sources. The terrible influence of long-acting arsenic compounds on the body (cancer, endocrine and neurological disorders, etc.) make dearsenication the necessary stage of the drinking water treatment.

The problem of arsenic compoundspresence in natural waters is the challenge not only for underdeveloped countries where water treatment is performed using outdated methods, but also for many developed countries which require more economically and environmentally effective methods of water purification from arsenic compounds.

Key words: arsenic, volcanic activity, arsenic rocks and minerals, pesticides, sulphide ore production

1. Introduction

Water is one of the most important resources of our planet, because for their existence all organisms require water without harmful impurities. But various factors often make the surface and ground water sources unfit for drinking purpose therefore it is necessary to clean it.

Arsenic belongs to chemical elements, which are often found in natural waters and make it unsuitable for consumption without special treatment.

Arsenic occures in water sources of many countries (Argentina, Bangladesh, India, Mexico, Mongolia, Thailand, Taiwan, etc.), where the concentration of As in aqueous phase is ranging from 100 to more than 2000 μ g/l, which highly exceeds the maximum allowable concentration of arsenic equal to 10 μ g/l [1].

The amount of people affected by the toxic effects of compounds of arsenic varies considerably depending

on the country, resulting from different mineral composition of rocks, geochemical and biological conditions, density and population. However, according to Малецкий З., Митченко Т., Макарова Н. (2012) and Smedley P. L. (2002) [2, 3], in 2002, 137 million people in 70 countries underwent negative effects of arsenic compounds in drinking water.

Arsenic is released into water bodies as a result of human activity and natural processes.

There are the following anthropogenic ways of arsenic release into ground water and atmosphere: the use of arsenic pesticides, processing of sulphide ore production, arsenic dyes and pigments production, producing of arsenic semiconductors and others.

Volcanic activity, forest fires and leaching from arsenic rocks and minerals are encountered among natural sources [1, 4-5].

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The main part of arsenic is in the earth's crust in the dispersed state. It is present in the form of impurities in the sulfide ore and non-metallic formations, including iron, copper, mercury, lead [6].

Arsenic naturally occurs in over 200 mineral forms, of which approximately 60% are arsenates, 20% sulphides and sulphosalts and the remaining 20% arsenide, arsenites, oxides, silicates and elemental arsenic [6-7].

The natural concentration of arsenic in soil usually varies from 0.1 to 40 mg/kg with an average concentration about 5.6 mg/kg [1, 8].In artesian and ground water arsenic impurities mainly come as a result of the dissolution of arsenic minerals, including realgar (AsS), orpiment (As₂S₃), arsenopyrite (FeAsS), klaudetite (As₂O₃), arsenolite (As₄O₆), scorodite (FeAsO₄· H_2O), alhgodonite (Cu₆As), domeykite (Cu₃As), lolingite (FeAs₂), nickeline (NiAs), rammelsbergite (NiAs₂), safflorite ((Co,Fe)As₂), scutterudite ((Co,Ni)As₃), sperrylite (PtAs₂), erythrite $(Co_3(AsO_4)_2 \cdot 8H_2O)$ olivenite $(Cu_2AsO_4(OH)),$ mimetesite ($Pb_5(AsO_4)_3Cl$), armangite ($Mn_3(AsO_3)_2$) $(Ni_3(AsO_4)_2 \cdot 8H_2O)$ annabergite metazeinerite $(Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O)$, dyuftite $(CuPb(AsO_4)(OH))$, austyinite $(ZnCa(AsO_4)(OH)),$ tilasite $(MgCa(AsO_4)(F,OH))$, adamite $(Zn_2(AsO_4)(OH))$, beudantite ($PbFe_3(AsO_4)(SO_4)(OH)_6$) etc. [1, 9].

The most common arsenic mineral is arsenopyrite (FeAsS).

Arsenopyrite (FeAsS) is arsenic ore. Arsenopyrite deposits are known in Russia, Sweden, England, Mexico, Bolivia, Japan and other countries.

Realgar (AsS) occurs in hydrothermal deposits with orpiment. Distribution: Jahimov (Czech Republic), Carpathians — Baia Sprie and Sekerymb (Romania), Allchar (Macedonia) Puccoli (Italy), Valais (Switzerland), Utah, Nevada, Yellowstone National Park (USA), Luhumi (Georgia), Harz (Germany) and others. Orpiment (As₂S₃) is arsenic ore. Large deposits of orpiment are known in Kurdistan (Iran), Haydarkan (Kyrgyzstan) and others [9].

Lolingite (FeAs₂) occurs in hydrothermal and contact-metasomatic deposits. Findings of it are in Erensfridersdorfi and Andreasberg (Germany), Fossam (Norway), Brush Creek (Colorado, USA), Alexander (North. Carolina, USA) and others.

Scorodite (FeAsO₄·H₂O) occurs in zones of oxidation of deposits rich in arsenopyrite and around hot springs. It is often formed on arsenopyrite and lolingite as metasomatic formation. Findings: Loling (Australia), Creuse (France), Rhineland-Palatinate, Schneeberg, Saxony (Germany), Carinthia (Austria), Laura (Greece), Cornwall (UK), Burchmulla near Tashkent (Uzbekistan), Transbaikalia (Russia), Antonio Pereira (Brazil), Tsumeb (Namibia) and others.

Adamite (Zn₂(AsO₄)(OH)) occurs in zones of oxidation of lead-zinc sulphide deposits which contain arsenides: Novo-Pochekuevsk (Eastern Transbaikalia), Karamazar (Tajikistan), Tsumeb (Namibia) and others.

Tilasite (MgCa(AsO₄)(F,OH)) is found in manganese ores in Jakobsberg (Sweden) and Kaylidonhri (India) and others [9].

Dyuftite (CuPb(AsO₄)(OH)) is found in the oxidation areas of deposits in Tsumeb (Namibia) and others.

Austyinite (ZnCa(AsO₄)(OH)) is found in the oxidation area of deposits in Holdhill (Utah, USA) and in low-temperature hydrothermal deposit Lilly (province Sica-Sica, Bolivia).

Mimetesite ($Pb_5(AsO_4)_3Cl$) is found in the oxidation zone of lead ores. It is known in Baden, Hesse, Saxony (Germany) Pribram (Czech Republic), Nerchinsk (Russia), Puy de Dôme (France). In addition, it is in England, Sweden, Namibia, USA.

Erythrite $(Co_3(AsO_4)_2 \cdot 8H_2O)$ is formed in the oxidation zone from arsenides and sulphoarsenides of cobalt. Erythrite is the search feature of cobalt ore. It is found in deposits such as Dashkasan (Azerbaijan),

Ak-Dzhylha (Alay Mountains, Central Asia) and others [9].

Olivenite (Cu₂AsO₄(OH)) is found in mines "Schone Aussicht" (Dernbach, Germany), Alston-Moore (Cumberland, UK) and Saint Day (Cornwall, UK), Cinovec and Belovec (Czech Republic), Nizhny Tagil (Urals, Russia), Khaidarkan (Kyrgyzstan), Tintic (Utah, USA), Chuquicamata (Chile), Tsumeb (Namibia), South Africa.

Nickeline (NiAs) occurs in hydrothermal cobalt-nickel-silver and uranium- bismuth deposits with sulphide and arsenide of nickel and cobalt and with native bismuth and silver. It is known in deposits in the Ore Mountains (Germany, Czech Republic) and Cobalt (Ontario, Canada), Schladming (Styria, Austria), Khovu-Aksy (Tuva), Berikul (Western Siberia, Russia). It is nickel ore [9].

Arsenic sulfides (realgar and orpiment) are dissolved in alkali and carbonate solutions forming tiosalts (salts of tioacids H_3AsS_3 H_3AsS_4). Arsenic tiosalts are soluble in water. Arsenides (lolingite, arsenopyrite, nickeline, etc.) are resistant to acids intermetallic compounds. After weathering and oxidation lolingite (FeAs₂) turns into scorodite (FeAsO₄·H₂O) and other water arsenates of iron [10].

Arsenic can be a part of some rock-forming minerals. Its content in magnetite is ranging from 2.7 to 16.4 mg/kg, in amphibole, pyroxene and feldspar it is an average of 1 mg/kg or less. In quartz and agate it is contained 0.5-1.3 mg/kg. This is because the ionic radii of trivalent and pentavalent arsenic (0.48 and 0.56 Å, respectively) are close to the ionic radius of silicon (0.43 Å) and isomorphic substitution of silicon by arsenic in silicon-oxygen tetrahedrons is possible. Arsenic can replace Si⁴⁺ and Al³⁺ in feldspar, and in magnetite probably arsenic replaces Fe³⁺. Crystalline schists contain 2-18 mg/kg of arsenic, shales: 5-15 mg/kg, limestones: 1.2 mg/kg, sandstones: less than 1 mg/kg [10].

The content of arsenic in rocks is strongly influenced by the formation conditions. Therefore, the content of arsenic in similar rocks is different for various geological areas. The content of arsenic in rocks of contemporary or recent volcanism can be up to 20 mg/kg. In sedimentary rocks, if during diagenesis or autogenesis were formed, arsenic minerals concentration of arsenic can reach 60 mg/kg.

The content of arsenic in the parent rocks usually correlates with its initial content in the rocks, but the process of weathering result in the relative scattering and re-distribution of arsenic between different mineral components [10].

Fig. 1 shows the scheme of one of the most common theories of arsenic compounds getting into natural waters.



Fig. 1 Scheme of arsenic compounds getting into natural waters [4].

In Ukraine arsenic is also found in many places. Arsenopyrite occurs in Nagolniy ridge in Donbas, Kryvorizhzhya, Chyvchyn mountains in Transcarpathia. Arsenopyrite, orpiment and realgar usually occur in sulfide ores of metals such as copper, lead, silver and gold [1].

In the Ukrainian Carpathians arsenic minerals are also found, among them arsenides (nickeline, lolingite etc.), realgar and orpiment, arsenates (scorodite, beudantite etc.) are encountered.

Arsenic minerals are often present in golden mines, such as Bobrykivske (Luhansk region). In this mine scorodite and beudantite are found entailing the variation of arsenic content in the ore from 0.1 to more than 0.5% [1].

In Yuriyivsk gold mine (Middle Dnieper)arsenic is found in the form of arsenopyrite, and in Klyntsivsk gold mine (Kirovohrad area) — arsenopyrite and lolingite.

Some arsenic compounds get into water as a result of the dissolution of minerals, and other as a result of the interaction with different substances in the water and minerals [1].

The problem of arsenic compoundspresence in natural waters is the challenge not only

forunderdeveloped countries where water treatment is performed using outdated methods, but also for many developed countries which require more economically and environmentally effective methods of water purification from arsenic compounds. Among the six surveyed water sources in Rome only in four of them arsenic content satisfies the norm (5-8 μ g/l), while arsenic excess occurs in the other two sources (26 and 31 μ g/l respectively) [1].

Studies of the samples from different sources of drinking water reveal the actuality of this problem in Ukraine, namely 70% of the analyzed samples of natural waters were characterized by arsenic content higher than 10 μ g/l. In 17 samples of groundwater arsenic concentrations were in the range 20-83 μ g/l, in 19 samples of groundwater were 20-100 μ g/l and in 5 samples of surface water were 10-85 μ g/l [1, 2].

As a result of volcanic activity a lot of arsenic substances get into the atmosphere and then into water bodies. So Zhupanovsky volcanic ashes contain 119 g As/t [11]. Microelement composition of volcanic ash of Zhupanovsky (Russia) and Colima (Mexico) is shown at the Fig. 2.



Fig. 2 Microelement composition of volcanic ash of Zhupanovsky (Russia) and Colima (Mexico) [11].

According to [12] after the eruption of volcanoes in Kamchatka (Russia) in February 2013 snow fallen on the set lava surface contained a large amount of arsenic (178 μ g As/L in melt water at 2.12 μ g As/g fresh lava), due to intense gassing with the formation of plume which interacted with snow. Snow performed the role of the collector, concentrated available in a gas phase components.

Minerals such as realgar (AsS) can also be the product of volcanic activity. They are formed on the walls of the craters, in the cavities of porous lava, as the product of sublimation.

Hydrogeochemical features of hot springs on the slopes and craters of active volcanoes depend from a number of exogenous and endogenous factors affecting on magmatic fluids which are separated from the melt. Primarily, the qualitative and quantitative content of chemical elements and physico-chemical characteristics of thermal solutions are affected by the dilution degree of fluid by source groundwater. This ratio can significantly move to one side or another according to the meteorological and hydrological conditions on the volcano and the geostructural features of migration routes of fluids to the surface. An equally important factor in the formation of volcanic thermas is the chemical composition of enclosing volcanic strata on which solutions circulate, leaching a variety of rock-forming and impurity elements. However, other things being equal, the presence of geochemical barriers on the way upward solutions can significantly change the composition of surface water. Separation on condensate and separate on secondary boiling borders greatly complicates the process of formation of solutions contents and can radically change hydrogeochemical parameters of thermal springs. [13]

Arsenic compounds are quite agile and easily get in condensate and remove with steam phase.

Hydrothermal waters have a high content of arsenic (from 900 to $3560 \mu g/L$) as a result of falling into water

bodies significantly increase the concentration of arsenic in natural waters [8].

Plants growing up in soils with high arsenic content, easily absorb it from the soil and accumulate it in the vegetative biomass. Moreover, according to [14], the content of arsenic in the root part is much larger than in the overground part of plants.

For plants one of the main indicators of of accumulation of elements is the biological absorption coefficient (BAC). It is the ratio of the concentration of the element in the ash of plants to its concentration in the upper soil horizons [14].

Fig. 3 shows the value of the biological absorption coefficient of arsenic for some species of plants growing up in the lower stream of the Irtysh River (Russia) at the average content of arsenic in the soil of 2.7 mg/kg.

During forest fires as a result of burning of containing arsenic biomass a significant amount of arsenic gets with smoke into the air, and then into surface waters.

3. Anthropogenic Ways of Arsenic Compounds Getting into Natural Waters

There are the following anthropogenic ways of arsenic release into ground water and atmosphere: the use of arsenic pesticides, processing of sulphide ore



Fig. 3 Biological absorption coefficient of arsenic: 1 – Plantago media L., 2 – Ínula británnica L., 3 – Carex vesicaria L., 4 – Mentha arvensis L., 5 – Equisetum arvense L., 6 – Cirsium arvense L., 7 – Artemisia absinthium L., 8 – Trifolium pratense L., 9 – Vicia villosa Roth., 10 – Lathyrus tuberosus L, 11 – Lathyrus pratensis L. [14].

production, arsenic dyes and pigments production, producing of arsenic semiconductors and others [1].

Wastewaters of many plants contain large amounts of arsenic. According to [15] sewage of the plant on the smelting of copper (India) contain 1628 mg As/L. And for sewage of LEDs production (China) is characteristic the content of arsenic of 500-2000 mg/L [16].

There is a high arsenic content in mine waters of some deposits. So for deposits of lead and zinc ores arsenic content can reach 800 μ g/L, for antimony ore deposits: 80 μ g/L, for mercury ore: 60 μ g/L, for gold ore: 300 μ g/L. In wastewaters of tin gravity enrichment plants arsenic content can reach 500 μ g/L, for effluents copper-tungsten flotation enrichment plants values can be up to 1350 μ g/L [17].

If using ineffective methods of wastewater treatment, pollutants including arsenic get into the water.

Until 1960s, arsenic salts were widely used as insecticides and seed-impregnates. As insecticides were used lead arsenate, calcium arsenate, copper acetarsenite, arsenate acid, sodium methanarsenate, cacodylic acid. During 1970s, about 80% of the consumption of arsenic were for agriculture purpose [6, 18].

The first wood preservative was Fluor-Chrome-Arsenic-Phenol (FCAP). This wood preservative was used as early 1918 in USA. Arsenic salts (zinc arsenate, chrome arsenate, etc.) were widely used as wood preservatives and dryers [6].

Arsenic acid (H_3AsO_4) is used extensively as a cotton desiccant for many years. More then 2000 tonnes of arsenic acid were used as desiccants on 495,000 ha of U.S. cotton in 1964 [6].

Washed by rain from agricultural crops arsenic compounds get into the ground, and then into groundwater and water bodies.

Now in civilized countries arsenic pesticides are no longer used, but in underdeveloped countries there are still cases of its application.

4. Characterization of Arsenic Compounds in Natural Waters

The main forms of arsenic in groundwater and surface waters are inorganic compounds of As (V) and As (III). The inorganic arsenic compounds which are stable in oxygenated waters are arsenate (As (V)) acid and anions derived from its dissociation (H₃AsO₄, H₂AsO₄⁻, HAsO₄²⁻andAsO₄³⁻). Arsenite (As (III)) acid and its anions (H₃AsO₃, H₂AsO₃⁻, HAsO₃²⁻andAsO₃³⁻) generally exist only under anaerobic conditions [8].

Generally compounds of As (V) are more characteristic for surface waters, whereas the compound of As (III) are more common for underground anoxic waters. Thus redox potential (Eh) and pH affect the form of arsenic compounds. Fig. 4 shows Eh-pH diagram for aqueous arsenic species in the system As-O₂-H₂O at 25°C and 1 bar total pressure. Under oxidising conditions H₂AsO₄⁻ prevails at low pH (less than about 6.9), while at higher pH, HAsO₄²⁻ becomes dominant. H₃AsO₄ and AsO₄³⁻ predominate only in extremely acidic and alkaline conditions, respectively. Under reducing conditions at pH less than 9.2 arsenic compound with zero charge, H₃AsO₃, prevails [4, 5].



Often arsenic in natural waters is present in the form of insoluble compounds, resulting in the bottom layers of water arsenic content is higher.

Toxicity and mobility of arsenic compounds depends on its oxidation state (compounds of As(III) are more toxic than compounds of As(V)), but the behavior of arsenic compounds greatly depends on the biological condition of natural waters.

Besides geochemical factors microorganisms also affect the state of arsenic compounds in natural waters. It can methylate inorganic arsenic compounds, oxidate As(III) to As(V), reducte As(V). Bacteria and fungi can reducte inorganic compounds of As(V) to the volatile methylarsines. Marine algae convert arsenates into non-volatile methylated arsenic compounds such as methylarsenic acid (CH₃AsO(OH)₂) and dimetylarsenic acid ((CH₃)₂AsO(OH)) in seawater. Water plants synthesize complex fat soluble arsenic compounds [8, 19].

The structures of most often found in natural waters arsenic compounds are shown at the Fig. 5.

Organic arsenic compounds are more common for surface waters than for groundwaters. In the samples oflake water methylarsenic compounds are often more



Fig. 5 The structures of most often found in natural waters arsenic compounds.

than 59% of the total content of arsenic [8]. But concentration of organic arsenic compounds is not constant and varies depending on the season.

Although organic arsenic compounds are less harmful than inorganic, but because of its toxicity it requires removal.

5. Methods of Arsenic Compounds Removal

Arsenic compounds are very dangerous due to its toxicity, but the greatest threat to human health are inorganic compounds of arsenic entering the human body with drinking water [25]. Prolonged usage of arsenic drinking water leads to negative health effects causing carcinogenic effects (cancer of the blood, lungs, skin, sinuses, liver, etc.) and non-carcinogenic effects (immunological, neurological and endocrine disorders and genotoxic effect) [8, 25].

As some effects of arsenic on organism are irreversible, the basic health measure is to prevent the occurrence of these contaminants in drinking water [2, 25], that's why the removal of arsenic compounds is very important.

Arsenic removing can be performed by various methods, including precipitation (coagulation/filtration, lime softening etc.), adsorption, ion exchange, membrane processes (microfiltration, ultrafiltration, nanofiltration, reverse osmosis) and others [1].

Coagulation is one of the most commonly used methods for arsenic compounds removing from natural waters. This method consists of adsorption of arsenic compounds on flakes, formed by coagulation. Aluminum coagulants usage gives significant effect only in the combination with oxidant (e.g., chlorine) which converts existing in water As(III)compounds to As(V) at pH7 and below [1, 20-22]. Whereas in the case of salts of Fe(III) as coagulants, additional oxidant dosage is not necessary, because the Fe(III) acts as an oxidant for As(III). The main disadvantages of coagulation treatment are: the need for continuous chemicals dosing, bulky equipment, the problem of produced sludge disposal [1]. It's well known that lime softening of water removes compounds that cause water hardness, transformating it into sediment, but arsenic compounds can also be removed by this method. Although it is necessary to apply oxidant dosing for effective arsenic removing [1, 20-22]. According to [1, 21], at pH 10.8 or higher 95% of arsenic may be removedfrom water, whereas at pH 8.5 only 30% arsenic is eliminated. This method should be used only if water softening is necessary. The main disadvantages of it are the same as for the treatment by coagulation.

A variety of sorbents can be used for the adsorption of arsenic compounds. Sorption efficiency depends on the type of sorbent, temperature, water pH, etc. Activated carbon is one of the most commonly used adsorbents for arsenic compounds removal from water [1, 20, 23, 25]. According to [1, 23], activated carbon doped by iron oxide shows significantly better results than non-doped carbon. Oxides and hydroxides of iron are other common adsorbents for the removal of arsenic compounds from natural waters that show good results and do not require additional dosing oxidants [1, 23]. Promising sorbents include anionite Dowex SBR-P with matrix doped by Sn(IV) and Fe(III) oxides [1, 2]. This sorbent shows better absorption of arsenic compounds than industrial sorbents. Doped oxide sorbent simultaneously works as an anionite, sorbent and oxidizing agent. Active alumina, zeolites, various plant materials can also be used for the adsorption of arsenic compounds from natural waters, but these methods require additional oxidants to convert As(III) to As(V).

The usage of of sodium hypochlorite or Fe(III) compounds is the most appropriate for oxidation of As(III) to As(V) in the process of water treatment.

It is necessary to mention such new sorbents for arsenic compounds removal in the processes of water treatment and water purification as iron oxide doped by Ce(IV), kaolin-humic complex, activated red mud, iron-manganese oxide, porous rubber with zirconium oxide and others, but these sorbentsare not enough investigated [21, 22, 24, 25].

The main disadvantage of this method is the need for sorbents regeneration and the problem of used water utilization [1].

In natural waters As(V) is often available in the form of anions which makes it possible to remove arsenic compounds from water by using anion exchangers, but removal of As(III) by ion exchange is usually not possible. However as forms of arsenic compounds are highly dependent on pH, the ion exchange efficiency in this case is also highly dependent on pH. The main disadvantages of this method are the need of ion exchange resins regeneration and the problem of used water and regeneration solutions disposal [1].

The use of membrane processes for arsenic compounds removing from natural waters is economically more advantageous than reagent treatment methods, but efficiency is significantly reduced in the case of a high content of compounds of As(III) in water, as the use of membrane process essentials deeper water treatment from As(V)compounds than from As(III) [1, 23]. In the absence of As(III)compounds reverse osmosis allows to achieve high removal levels in the case of fixed cost of chemical reagents.

It is possible to use other techniques for arsenic compounds removing, in addition to chemical and physicochemical methods, such as biological treatment, photocatalytic method electrocoagulation etc., but these methods have their own disadvantages.

According to [20, 25], such as plants and Pteris vittata and Pteris cretica can reduce the concentration of arsenic in water from 200 to 2.8 μ g/L and from 20 to 0.4 μ g/L in 24 hours. Water hyacinth and some algae also show high arsenic removal rates [20, 25] but these species are thermophilic (these plants naturally exist in tropical and equatorial zones). It makes their usage impossible in Ukraine.

Photochemical removal of arsenic compounds from natural waters is also possible, for example, using Fenton reaction [20, 25]. After dosing Fe(III) compounds arsenic changes its oxidation state from +3 to +5 and is sorbed on formed iron hydroxide flakes.

Another possible way of photocatalytic conversion of As(III) and As(V) to elemental arsenic is the use of such heterogeneous catalyst as TiO_2 [20, 25]. The main disadvantages of photochemical removal of arsenic from natural waters are rigorous requirements for turbidity (high content of suspended solids prevents the passage of light rays) and preventing influence of metal ions with variable valence in water (they can participate in redox reactions instead arsenic compounds).

Another possible method of arsenic compounds removal is electrocoagulation. According to Літинська M. I. et al. (2016) and Y. Weng et al. (2005) [25, 26], electrocoagulation unit with iron electrodes at pH 8.30 removes more than 99% of the arsenic, but at lower pH process occurs worse and at pH 2.86 process is not happening. The main disadvantages are the sensitivity of electrocoagulation method to pH, the possibility of secondary pollution of water by iron compounds, high power consumption.

Because As can be slightly removed by standard methods, the development of new methods of arsenic compounds elimination from natural water is highly actual. Combination of traditional methods such as adsorption/membrane filtration, oxidants dosing /membrane filtration is quite promising in the context of arsenic compounds removing from natural waters but there is no information concerning systematic studies of this subject in Ukraine [1, 25].

6. Conclusions

Arsenic is released into water bodies as a result of human activity and natural processes. Among natural ways there are volcanic activity, forest fires and leaching from arsenic rocks and minerals.

As a result of volcanic activity a lot of arsenic substances get into the atmosphere and then into water bodies. Hydrothermal waters have a high content of arsenic as a result of falling into water bodies significantly increase the concentration of arsenic in natural waters.

Plants growing up in soils with high arsenic content, easily absorb it from the soil and accumulate it in the vegetative biomass. During forest fires as a result of burning of containing arsenic biomass a significant amount of arsenic gets with smoke into the air, and then into surface waters.

In artesian and ground water arsenic impurities mainly come as a result of the dissolution of arsenic minerals.

The use of arsenic pesticides, processing of sulphide ore production, arsenic dyes and pigments production, producing of arsenicare encountered among anthropogenic sources.

The main forms of arsenic in groundwater and surface waters are inorganic compounds of As(V) (aerobic conditions) and As(III) (anaerobic conditions). Organic arsenic compounds are more common for surface waters than for groundwaters.

The terrible influence of long-acting arsenic compounds on the body (cancer, endocrine and neurological disorders, etc.) make dearsenication the necessary stage of the drinking water treatment.

Arsenic removing can be performed by various methods, including precipitation (coagulation/filtration, lime softening etc.), adsorption, ion exchange, membrane processes (microfiltration, ultrafiltration, nanofiltration, reverse osmosis) and others. One of the most commonly used methods for arsenic compounds removing from natural waters is coagulation. Combination of traditional methods such as adsorption/membrane filtration. oxidants dosing/membrane filtration is quite promising in the context of arsenic compounds removing from natural waters but there is no information concerning systematic studies of this subject in Ukraine.

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