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REMOVING ARSENIC BY FOOD-PROCESSING WASTE (*ZIZYPHUS JUJUBA* SEEDS) AND STUDY ON ITS ADSORPTIVE PROPERTIES

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Abstract

Research was carried out to remove arsenic from synthetic AMD, raising the pH of the solution and using waste material for food processing by adsorbing arsenic to recover impurities. Arsenite can be quickly converted into arsenate, the more thermodynamically stable. Attention was paid to biomaterials, which are by-products or agricultural waste. *Zizyphus* seeds were used for this purpose as cheaper and often available food waste materials, due to the potential sorption capacity of arsenic. In order to clean the soils in contaminated towns and mining districts, establish its adsorption potential and enable food production in these areas, collective soil samples were taken from a depth of 0 – 40 cm from the area of 5 cities and 10 sub-regions of Anguran, province Zanjan in Iran. In the trials, the amount of As(III) and/or arsenate(V) in the soil was evaluated. Their content was tested using ICP-MS. The adsorption process was significantly dependent on adsorbent concentrations and also time. The efficiency and the complicated mechanism of the uptake of Arsenic ions onto the soils depend on the concentration of cellular surface of the Jujube seed powder and also the time of being interaction. 10 % of Jujube seed attained maximum removal all Arsenic ions in this study. Significant differences in decreasing toxic metal were observed among the time of 48 hours and 1 week in all concentrations of bio-adsorbent. The maximum adsorption of toxic metals varied between 80 and 90 % depending on the contact time, stirring action and concentrations of studied bio-adsorbent *Ziziphus jujuba* seeds. With higher biomass doses the removal efficiency of As was higher even at the same time of being contact. Authors suggest more studies on the mechanism in the next projects and utilizing other dead bio-masses.

Keywords: *Zizyphus jujube*; arsenic; bio-adsorption; food waste.

1. Problem statement and analysis of the recent researches and publications.

Large scale industrialization is mainly responsible for heavy metal concentration in the environment and is becoming is a threat not only to the physical well-being of man but also in future may endanger his existence due to increasing violence in the society. Because of the narrow concentration difference, reliable knowledge of the metal content in various matrices is mandatory. Knowledge of the chemical state of the trace metals in natural waters or biological fluids is important for understanding their reactivity, transport and toxicity. It has been reported that the roots of various hydrophobically grown terrestrial plants like Indian mustard, Sunflower and various grasses can be used to remove toxic metals from aqueous solution [1]. Inorganic ion exchanges like titanium oxide, manganese dioxide and anmmnonium molybdophosphate are used for treatment of liquid effluents bearing activation and fission radionuclides along with uranium. The bioremediation is one of the suggested ways of controlling the amount likely to be present in the soil solution, which is affected through uptake by easily growing plants [2]. Accumulation of chemical substances at the surface of a solid is called adsorption. The process of removal of an adsorbed substance from the surface is known as desorption. The substance adsorbed on the surface of another substance is called an adsorbate. A substance which adsorbs another substance on its surface is called an adsorbent. Adsorption is one of the most convenient techniques for the removal of heavy metals from wastewater. Due to regeneration of adsorbent, minimization of chemical and or biological sludge, high efficiency, possibility of metal recovery some studies focused [3]. The flexibility and simplicity of design, the process is suitable even when the metal ions are present in concentration as low as 1 mg dm^{-3} [4], insensitivity to toxic pollutants, low cost, easy to operate adsorption has been found to be superior technique as compared to the other methods for the removal of heavy metals from the wastewater. In publication [4] first presented the use of activated carbon for the adsorption of heavy metals [5]. The attachment of atoms or molecules of adsorbate on the surface of solids and liquids may be through two types of forces, physical or chemical. Depending upon the types of forces involved in adsorption, it may be divided into two types, physical adsorption or physisorption and chemical adsorption or chemisorption [6]. In physical adsorption the forces of attraction between the particles of the adsorbate and the adsorbent are weak Van der Waals' forces. Physical adsorption is relatively weak because Van der Waals' forces are weak. In chemical adsorption

the forces of attraction between the adsorbate and the adsorbent are chemical bonds. It is slow process.

Adsorbents for metal removal: Literature survey indicates that there are several chemical, biological and waste vegetable matters or substances that have been used by several researchers as adsorbents for the removal of heavy metals from the wastewater. But to make the adsorption process economic adsorbent should be readily available, inexpensive and environmentally friendly. So most of the researchers have been used adsorbent having low cost and which were abundant in nature or the materials which required little processing or was byproduct or waste material from another industry or which has lost its economic or further processing values. Such adsorbents are seaweed, orange peel, peanut skins, bamboo-pulp, dyed sawdust, algae, clay, zeolite, sawdust, flays, maize or corn cob, modified cotton and wool, tea waste, dyed jute, groundnut shells [6, 7], coffee, green tea, date tree leaves, jambool, potato husk, Ashoka leaf powder, Syzygium cumini, Jute, sun hemp, apple pomace, almond husk, Prosopis spicegera, ratrani leaf powder, jute stick, cashew nut shells, Cassia siamea, Coconut husk, feathers, hairs, bagasse etc. [7].

Agricultural waste materials particularly those containing cellulose shows potential metal biosorption capacity. The basic components of the agricultural waste materials biomass include hemicellulose, lignin, extractives, lipids, proteins, simple sugars, water hydrocarbons, starch containing variety of functional groups that facilitates metal [8, 9]. Conventional and unconventional by-products from the food processing industry have been frequently included in livestock diets [10]. In recent years, because of economic considerations and waste technology, by-products are receiving increased attention by livestock producers and animal nutritionists [11]. Remediation techniques for as contaminated soils can be classified into physical, chemical and biological methods. Physical methods include soil excavation/replacement and thermal desorption; chemical methods include chemical leaching/washing, chemical fixation/ stabilization, electro kinetics and vitrification; while biological methods include phytoremediation and bioremediation [12]. Though there are many technologies for remediation of arsenic contaminated soils and groundwater, most are impracticable in the field due to financial implications. The physical methods tend to be disruptive to the ecosystem while the chemical methods may adversely affect soil fertility due to removal of basic cations [13].

Of 1.4 million worldwide contaminated sites 41 % are in the USA and US EPA has recognized that arsenic (As) concentration in Australia was greater than 10000 mg kg^{-1} [14]. Arsenic has been found at high levels (10000 – 20000 mg kg^{-1}) in some contaminated areas and that results in unacceptable levels of risk to human health from the incidental ingestion of soil [15]. Arsenic (As) is both acutely and chronically toxic, which has led both the World Health Organization (WHO), and the National Health and Medical Research

Council (NHMRC) in Australia to recommend that arsenic concentrations in drinking water should not exceed 0.01 mg dm^{-1} [16, 17]. It is also a well-known carcinogen that has been linked to skin, bladder, lung and kidney cancers [18]. Natural sources include geothermal activity, e.g., California, USA [19, 20] and microbially – induced reductive dissolution of iron oxyhydroxide minerals in aquifers, e.g. Bangladesh [21, 22]. In comparison, anthropogenic mobilisation of arsenic is typically related to acid and metalliferous drainage (AMD) in mining-affected areas [17], especially mines that produce copper, gold, base metals and coal [23]. Mine drainage and mine waste are both commonly identified sources of arsenic; however, an underexplored source of arsenic is disused processing equipment and the remaining building infrastructure at derelict mine sites [24]. In populations exposed to arsenic emitted to the environment by the copper industry, the toxic and carcinogenic effects of arsenic should be monitored.

2. Statement of the problem and its solution.
2.1. Materials and methods.

Jujube seeds were purchased from Tehran herbal markets and from confectionaries where they had been produced as waste products from processing food. The jujube seeds were selected manually and packed in air tight, moisture proof zip lock aluminum foil pouches. Packed samples were stored under ambient conditions before being used for further experimental purpose cleaned with deionized water, then dried at 110 °C, and ground to particles that were smaller than 2 mm by Laboratory Jaw Crusher Pulverized 1.

Soil sampling. Anguran Rural District, Anguran District, Mahneshan County, Zanjan Province, Iran in North West of Iran is located at 36°34′ N 47°38′ E with average height of 1620 m [25, 26]. The annual precipitation in this area is about 295 mm and annual average air temperature is 10 °C. There is a discharge site of waste and tailing soil on the south side of the city near the zinc industrial complex with almost one km^2 area. More than three million tons of waste soil is daily discharged in this site without any environmental concerns. Agriculture is the principal occupation, and crops include rice, corn (maize), oilseeds, fruits, and potatoes. Poultry, cattle, and sheep are raised. Moreover there is a site with almost the same area on the east side of town within 16 km distance near to Zanjan lead and zinc factory allocated to the discharge of waste soils. Location of industrial complexes around the city is shown in figure 1.

Collective soil samples were taken from a depth of 0 – 40 cm from the area of 5 cities and 10 sub-regions of Anguran, province Zanjan in Iran. The soil samples were filled in several plastic bags and carried to a laboratory at the Islamic Azad University, Nutrition and Food Sciences Research Center, Tehran Medical Sciences, Tehran, Iran. The heavy metal contaminated soil samples, so collected were safely transported in clean self-sealing quart-size polyethylene freezer bag to the Tehran laboratory.

Figure 1 – Zanjan map and studied area indicating sampling points [26, 27].

The contaminated soils were put in 110 vases of $27 \times 13 \times 16$ cm size and kept in the same conditions. Varying masses of the biosorbent 1 %, upto 10 % (weight/weight) of *Zizyphus jujuba* seeds powder were added to 100 vases and 10 vases considered as control group with no any adsorbent. All soil samples in vases were watered by 10 mL de-ionized water every 24 hours and treated in the similar and same conditions such as light, temperature and physical conditions. All necessary precautions were taken to avoid any possible contamination of the sample as per the AOAC guidelines [28–33]. Investigation on removal total Arsenic ions in 24 hours till 2 weeks and agitated in a magnetic stirrer for 1week and 2 weeks at a speed of 400 rpm at room temperature. The content of each vase was filtered and analyzed using ICP-MS.

Soil samples were mixed, homogenized and separated into 3 parts, 1/3 of each samples were air-dried and pass through a 2 mm sieve in order to determine p and k content, pH and electrical conductivity and particle-size distribution. The other 1/3 was passed through a 2 mm sieve without drying and 1/3 of it used to determine heavy metals concentration by ICP-MS.

Total Arsenic Determination. Digestion Total digestion of the samples was conducted by measuring out 0.5 g dry weight of sample into 50 ml polypropylene centrifuge tubes and adding 2.5 ml of nitric acid (65 % Merck MSDS) and 4 ml of Hydrogen peroxide 30 % MSDS (material safety data sheet), followed by microwave digestion using a CEM Mars5 Microwave system (Inductively Coupled Plasma – Mass Spectrometry, Analysis Arsenic content was measured using an Agilent 7500c ICP-MS with hydrogen as collision/reaction gas. Extraction samples were extracted in 1 % nitric acid and 1 % (vol/vol) hydrogen peroxide suprapur using a CEM Mars5 microwave system. The supernatant was used for determination of extractable arsenic and as speciation. This oxidizes arsenite to arsenate, improving chromatographic resolution as arsenate elutes at some distance to MMA and DMA, where arsenite elutes adjacent to MMA and DMA. Analysis Arsenic species were separated on a Hamilton PRP X 100 anion exchange column using

phosphate buffer. Internal standard Indium (0.01 mg kg^{-1}) in 1 % (vol/vol) nitric acid was added during the analysis via a t-piece as an internal standard. Standards Solutions (0.1 mL) containing known amounts of DMA (10 to 100 μg/kg) was subjected to LC-ICP-MS under the same conditions as the supernatants. Peak areas from these measurements were used to construct a calibration curve. Single species standards DMA, MMA and as (V) were used for identification of species by retention time. Calibration standard solutions containing the five as species at different concentrations (1 ppb, 5 ppb, 10 ppb, 50 ppb, 100 ppb and 200 ppb) were prepared and analyzed. The chromatogram for the 10 ppb calibration standard (5 μL injection) shows the five as species are well separated in 4 minutes. The supernatants (0.1 mL) were used as they were and injected onto the column. Peak areas were used for quantification of As-species. Total As determination every 10 days and samples were digested in duplicate and measured. Each analytical batch contained procedural blanks, spiked samples (for recovery estimate purposes) and CRM. Data were accepted if the spike recovery was between 80 and 120 %. Replicate values for a given sample must have a relative standard deviation of less than 20 %. The reference material results for each batch should be within the certified range. The limit of detection is defined. All analyzes, in all assay terms, were performed in five replications.

Statistical Method. One-parametric Kruskal–Wallis/Mann–Whitney U tests were applied to compare differences between objects. Non-parametric multiple comparison test (Dunn's test) was performed to determine statistical significance of results at $p < 0.05$. The GLM procedure was used for analysis of different bio-adsorbent concentration treatments with means separated by Duncan's multiple range test at $p < 0.05$. The CORR procedure was used for correlation analysis with means separated at $p < 0.05$.

2.2. Results.

The mean content of Arsenic in contaminated soils collected from Zanjan Province after 24, 48, 72 hours and 1 and 2 weeks in accompany of 1 %, 2 % and 3 % *Zizyphus jujuba* seeds powder are shown in table 1 and

figures 2 – 5. Once the adsorbent becomes exhausted, the metals must be recovered and the adsorbent regenerated. Desorption and adsorbent regeneration are a critical consideration and contributor to process costs and metal(s) recovery in a concentrated form.

The efficiency and the complicated mechanism of the uptake of Arsenic ions onto the soils rely on the concentration of cellular surface of the Jujube seed powder and also the time of being interaction. This is because the biosorption is a surface phenomenon.

Table 1 – The removing total Arsenic in higher bio-adsorbent concentrations in specified times

Total Arsenic content in presence of Jujube seed powder (w/w%) in studied soil samples	24 h	48 h	72 h	1 week	1 week (stirred)	2 week	2 week (stirred)
5 %	0.4891[a]	0.4017[a]	0.3982[b]	0.2001[c]	0.1205[d]	0.0467[e]	0.007[f]
6 %	0.3337[a]	0.2978[a]	0.2543[b]	0.1989[c]	0.0989[d]	0.0412[e]	0.005[f]
7 %	0.3009[a]	0.2056[b]	0.2004[b]	0.1564[c]	0.0675[d]	0.0365[e]	0.003[f]
8 %	0.2561[a]	0.1987[b]	0.1673[b]	0.1003[c]	0.0542[d]	0.0307[e]	0.001[f]
9 %	0.1111[a]	0.0903[b]	0.0872[b]	0.0801[c]	0.0342[d]	0.0261[e]	0.001[f]
10 %	0.0867[a]	0.0444[b]	0.0329[c]	0.0423[d]	ND	ND	ND
Control Group	1.109	1.109	1.109	1.109	1.109	1.109	1.109

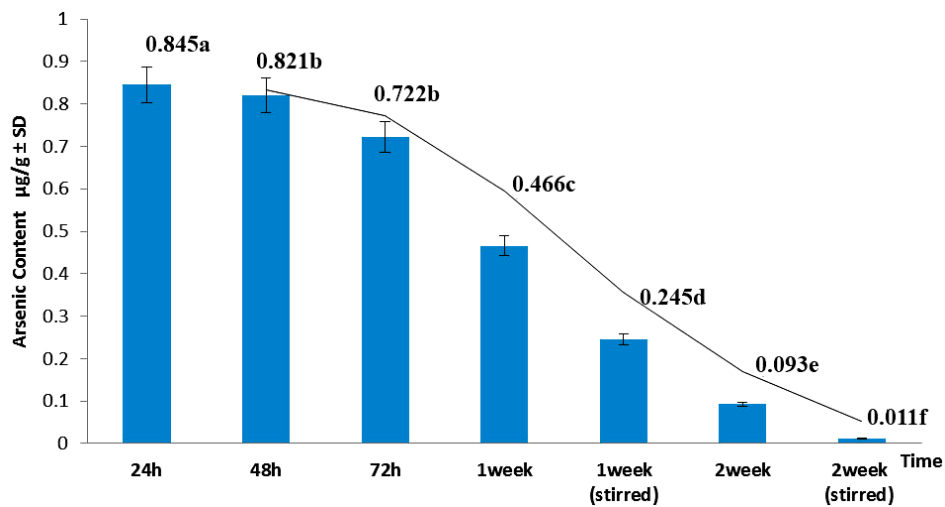ND – Not Detectable; Different letters indicate significant differences at $p < 0.05$

Figure 2 – Effect of contact time on the removal of total Arsenic, adsorbent dose of jujube seed powder is 0.1 mg/100 ml, temperature is 25 ± 1 ℃, pH = 4.5, and the study followed in 6 specified time: 24 h, 48 h, 72 h, 1 week and 2 weeks (by stirred action: agitation speed is 400 rpm and without it).
Further increase in contact time more than 2 weeks did not show significant increase in bio-adsorption ($p > 0.05$)
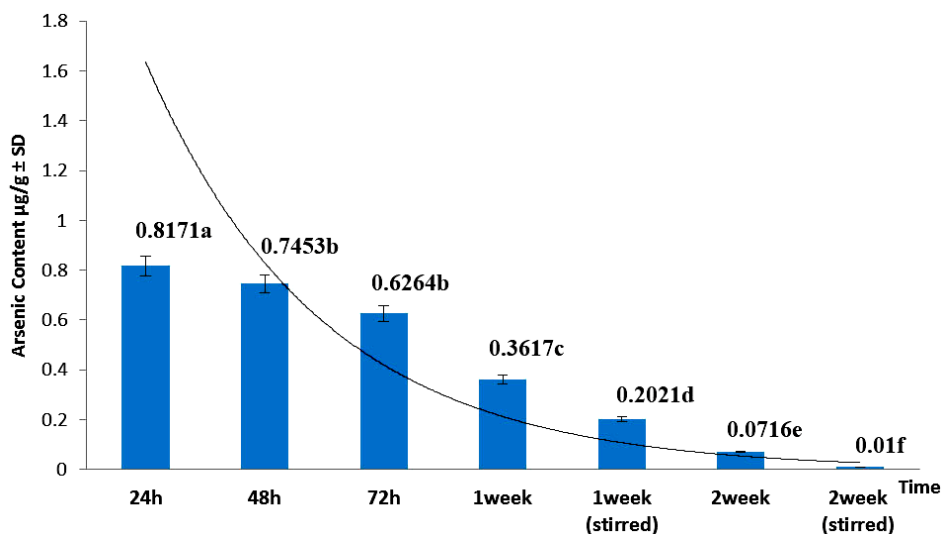

Figure 3 – Effect of contact time on the removal of total Arsenic, adsorbent dose of jujube seed powder is 0.2 mg/100 ml, temperature is 25 ± 1 ℃, pH = 4.5, and the study followed in 6 specified time: 24 h, 48 h, 72 h, 1 week and 2 weeks (by stirred action: agitation speed is 400 rpm and without it)

Figure 4 – Effect of contact time on the removal of total Arsenic, adsorbent dose of jujube seed powder
is 0.3 mg/100 ml, temperature is 25 ± 1 ℃, pH = 4.5, and the study followed in 6 specified time: 24 h, 48 h, 72 h,
1 week and 2 weeks (by stirred action: agitation speed is 400 rpm and without it)
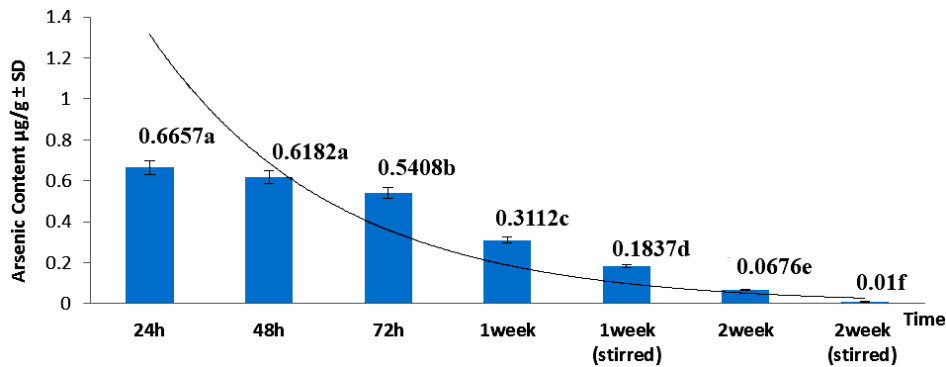
The mechanism of metal binding as documented by various reviews involves the interaction and exchange of metal ions followed by complex formation with the metal ions on the reactive chemical sites on the surface of the food waste/agricultural and also microbial cell followed by ion. The results of current study from figure 2 revealed that the factor of contact time: after 48 hours, 1 and 2 weeks and other factor of stirring have significant effect ($p < 0.05$) on removal of Arsenic content from contaminated soil samples even in low level and content of food waste sample. Further increase in contact time more than 2 weeks show insignificant increase in bio-adsorption ($p > 0.05$).

The studied different percentage of Jujube seed powder as a biosorbent, irrespective of their source has demonstrated good Arsenic removal efficiencies. The food waste biosorbent in different percentages 3 % up to 4 % have been either stirred or developed in the laboratory conditions in figures 3 and 4 revealed that after very short time (48 hours) have the high and significant potential to removal Arsenic from contaminated soil samples ($p < 0.05$).

The study of the adsorption kinetics of a sorption process is very crucial as it demonstrate the rate of adsorbate up taking sites, which in turn obviously determinates the residence time of the solute uptake at the solid-solution interface or the sorption reaction. This factor is very major characteristic in defining the efficiency of sorption. The data obtained from figure 5 focused on the study of adsorption dynamics which could be necessary to understand the variables that affect the sorption of Jujube seed. Due to complicated mechanism comparing data from different percentages of adsorbent and different times reveals the most important thing when searching for an appropriate sorption mechanism, therefore, need to choose a mathematical model which not only fits the data with satisfactory accuracy but also complies with a reasonable sorption mechanism.

The results from figure 5 showed that the best results obtained by 0.4 % of jujube seeds powder after 2 weeks (by stirring factor) and in more time after that show in significant increase in Arsenic removal. In table 1 the results of removing total Arsenic in higher concentration of bio-adsorbent is demonstrated.
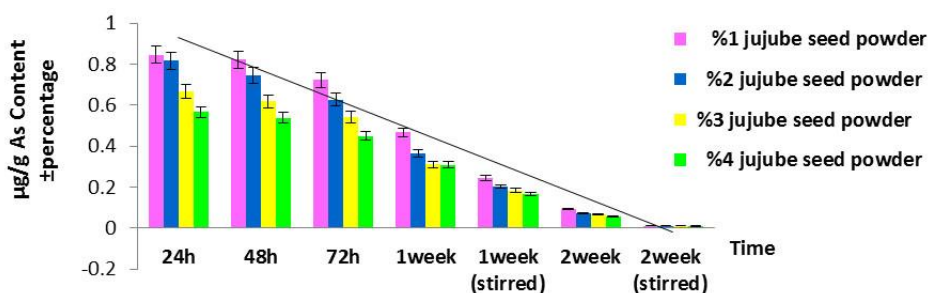

Figure 5 – Effect of adsorptive properties based on concentration of adsorbent on the removal of total Arsenic,
adsorbent dose of jujube seed powder is 0.1, 0.2, 0.3 and 0.4 mg/100 ml, temperature is 25 ± 1 ℃, pH = 4.5, and the
study followed in 6 specified time: 24 h, 48 h, 72 h, 1 week and 2 weeks
(by stirred action: agitation speed = 400 rpm and without it)

The data from table 1 shows that increased adsorbent loading increased the total Arsenic ions percentage removal. 10 % of Jujube seed attained maximum removal all Arsenic ions in this study, decreasing Arsenic content accelerate with increasing dosage due mainly to an increase in the number of available exchangeable active sites for metal ion sorption is rational and other studies confirm this assume.

Significant differences in decreasing toxic metal were observed among the time of 48 hours and 1 week in all concentrations of bio-adsorbent. The correlations between arsenic removal and time were found to be strongly positively correlated in all concentrations of Jujube seed powder with the stirring function ($r = 0.69$, $p < 0.0001$). The bio-adsorbents concentration among 0.5 up to 0.9 % were not only very strongly positively

correlated with each other (r = 0.58 to 0.90, p < 0.0001), but also were very strongly correlated to the stirring function after 1 week (r = 0.71 to 0.72, p < 0.0001).

2.3. Discussion.

Arsenic occurs naturally in a wide range of minerals which, together with the common use of arsenic in pigments, insecticides and herbicides, is the main source of arsenic in nature [2]. In the publication [34] and others point out that waste from mining operations removed on the plain or water reservoir, polluting waste can spread throughout the area and can cause environmental pollution. If, in addition, these wastes containing arsenic compounds are not adequately handled, this creates agriculture for human and animal health. Especially in tropical regions, high levels of chemical weathering and biochemical activities will contribute to the acceleration of the mobilization of potentially toxic elements. One of the harmful consequences of arsenic for human life is that drinking water contains these elements more than the threshold value; with symptoms of chronic intoxication in the human body in the form of intestinal irritation, nerve and cell damage [34]. Arsenic from water, sediments, soil and rocks can concentrate in organisms that are harmful to health [35–40]. The soluble arsenic compounds can be easily absorbed either orally or by inhalation, and the extent of the absorption depends on the solubility of the compound. Dissolution of minerals and leaching of arsenic from the soil also poses a potential threat to the quality of groundwater. Many aquatic organisms can accumulate arsenic, and many catalyze the oxidation of arsenate, to white arsenate, also promoting the formation of methylases through a biometric reaction, which is of great importance due to very toxic products. In addition, this process transfers arsenic from sediments back to the water column in water systems, increasing the mobility of arsenic in the environment. Bio-transformation of arsenic can cause high volatility of compounds such as arsin (AsH_3), HA dimethylarsine ($CH_3)^2$ and trimethylarsine $As(CH_3)_3$. Among the arsenic compounds, in a special environment, is arsenine, which is 10 times more toxic than arsenate and 70 times more toxic than methylated species and can cause the greatest environmental threats [34]. Therefore, the research undertaken on the disposal of these compounds is particularly valuable for the natural environment, especially for human and animal health.

The use of arsenic compounds to remove impurities in own studies gave the expected effect of changing the pH of the soil to 4.6. Previously, similar research was conducted by Ziarati and Alaedini [25] on the phytoremediation technique using Amaranthus species for the purification of soil contaminated with heavy metals. Because the forms of oxidation in the treated soil were significantly smaller than the untreated soil samples after 20 days, removal of As(V) gave more than other forms of As(III). There is no similar research in the literature on this subject.

Desorption and adsorbent regeneration are a critical consideration and contributor to process costs and metal(s) recovery in a concentrated form. A successful desorption process must restore the sorbent close to its initial properties for effective reuse. Desorption can be improved by gaining insight into the metal sorption mechanism. In most of the arsenic sorption studies discussed earlier, desorption/regeneration was not discussed. Very few desorption studies were found in literature. Furthermore, once arsenic is recovered in the concentrated form, the problem of how to dispose of this concentrated arsenic product must be addressed. This is a difficult task. Few attempts have been made in the literature toad dress the handling of concentrated arsenic wastes. Various disposal options and their advantages and disadvantages were reviewed in publications [5, 35, 36, 39, 41]. The methods frequently used for other metals and organics include combustion or recovery and purification for resale. These options, according to [41], it is not possible to perform in the case of arsenic, for technical reasons and the mechanism of metal sorption.

One of the most important factors in adsorption process is the Bio-adsorbent dose, which affect significantly on influence specific uptake of all toxic heavy metals such as Nickel, Cadmium and Cobalt from waste water effluent and in current research Arsenic as the most toxic metal and major issue in the world. Arsenic is one of the most important heavy metals causing disquiet from both ecological and individual health standpoints [36]. Generally, for low bio-adsorbent dose, there is an enhanced Arsenic adsorption such as other studies, which is the direct relation between dose of adsorbent by adsorption potential especially in low concentration and after increasing the dose of seed jujube powered increasing bio-adsorbent dose (figure 2 and 3) there were no significantly differences in potential of adsorbent. The current research indicated that adding food-processing waste such as jujube seed powder could reduce the volume of total biomass and keep total Arsenic mainly as safe form. Metal biosorption is the removal of metal ions by inactive, nonliving biomass due to highly attractive forces present between the two. Particularly, it is due to the presence of certain functional groups, such as amine, carboxyl, hydroxyl, phosphate, sulfhydryl etc., on the cell wall of the biomass [42]. The process involves a solid phase (biomass) and a liquid phase containing metal ions (solution of metal ions/waste-water). Metal ions are attracted and bound to the biomass by a complex process that comprises of several mechanisms like adsorption on the surface and pores, ion-exchange, surface precipitation, complexation and chelation and entrapment in capillaries and spaces of polysaccharide network, due to the concentration causing diffusion through the cell wall and membrane. To study the mechanism, it is necessary to have the exact information about the cell wall structure of the biomass as well as the solution chemistry [43, 44]. Therefore, the research undertaken on the disposal of these compounds is particularly valuable for the natural environment, especially for human and animal health.

Conclusion and recommendations.

The maximum adsorption of toxic metals varied between 80 and 90 % depending on the contact time, stirring action and concentrations of studied bio-adsorbent *Ziziphus jujuba* seeds. With higher biomass

doses the removal efficiency of As was higher even at the same time of being contact. The current study presents the results of using different forms of *Ziziphus jujuba* seeds powder waste as low-cost bio-sorbents, highlighting effects of contact time, pH, the dose and size of the adsorbent particles, initial metal concentrations and the effects of pre-treatment on the adsorption efficiency of Arsenic. The mechanism of Arsenic removal/increasing is very complicated and opposed to a much more complex phenomenon of bioaccumulation, which highly depend on active metabolic passage , bio-sorption by dead biomass of jujube seeds due to some molecules and/or their active groups) is passive and stand essentially on the «affinity» between the (bio-)sorbent/adsorbent and sorbate. Like surface capacity adsorption is a consequence of adsorbates. Nowadays according to the vast and huge of contaminants more research is inquired to explore new and low-cost biosorbents from environment. Profound insight is really needed on approach of metal removal as well as its efficient recovery them as usable forms. Authors suggest more studies on the mechanism in the next projects and utilizing other dead bio-masses.

Conflicts of Interest.

It is declared that the authors neither have any financial gain nor conflict of interests regarding this paper.

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ВИДАЛЕННЯ МИШ'ЯКУ ХАРЧОВИМИ ВІДХОДАМИ (НАСІННЯ *ZIZYPHUS JUJUBA*) ТА ДОСЛІДЖЕННЯ ЇХНІЇ АДСОРБЦІЙНИХ ВЛАСТИВОСТЕЙ

Проведено дослідження з використання харчових відходів для адсорбції миш'яку. Арсеніт може бути швидко перетворений у термодинамічно стабільний арсенат. Увага була приділена біоматеріалам, які є побічними продуктами або сільськогосподарськими відходами. Насіння *Zizyphus jujuba* використовували для цієї мети як найбільш дешеві і часто доступні харчові відходи через наявність потенційної сорбційної здатності миш'яку. Для очищення ґрунтів у забруднених містах і гірничовидобувних районах, встановлення їхньої адсорбційного потенціалу й забезпечення виробництва харчі в цих районах були взяті проби ґрунту на глибині 0 – 40 см з території 5 міст і 10 субрегіонів Anguran, провінції Zanjan в Ірані. У дослідженнях оцінювали кількість As(III) і/або арсенату (V) в ґрунті. Їх зміст було перевірено з використанням ICP-MS. Процес адсорбції в значній мірі залежав від концентрації адсорбенту, а також від часу. Ефективність і складний механізм поглинання іонів миш'яку на ґрунтах залежить від концентрації клітинної поверхні порошку насіння *Zizyphus jujuba*, а також від часу взаємодії. У цьому дослідженні 10 % насіння *Zizyphus jujuba* досяг максимального видалення всіх іонів миш'яку. Значні відмінності в зниженні вмісту токсичних металів спостерігалися протягом 48 годин і 1 тижня при всіх концентраціях біоадсорбента. Максимальна адсорбція токсичних металів варіювалася від 80 до 90 % залежно від часу контакту, застосування перемішування й концентрацій досліджуваних біоадсорбентів насіння *Ziziphus jujuba*. При більш високих дозах біомаси ефективність видалення As була вище.

Ключові слова: *Zizyphus jujube*; миш'як; біо-адсорбція; харчові відходи.

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ИЗВЛЕЧЕНИЕ МЫШЬЯКА ПИЩЕВЫМИ ОТХОДАМИ (СЕМЕНА *ZIZYPHUS JUJUBA*) И ИЗУЧЕНИЕ ИХ АДСОРБЦИОННЫХ СВОЙСТВ

Проведено исследование по использованию пищевых отходов для адсорбции мышьяка. Арсенит может быть быстро превращен в термодинамически стабильный арсенат. Внимание было уделено биоматериалам, которые являются побочными продуктами или сельскохозяйственными отходами. Семена *Zizyphus jujuba* использовали для этой цели как наиболее дешевые и часто доступные пищевые отходы из-за наличия потенциальной сорбционной способности мышьяка. Для очистки почв в загрязненных городах и горнодобывающих районах, установления ее адсорбционного потенциала и обеспечения производства продовольствия в этих районах были взяты пробы почвы на глубине 0 – 40 см с территории 5 городов и 10 субрегионов Anguran, провинции Zanjan в Иране. В исследованиях оценивали количество As(III) и/или арсената (V) в почве. Их содержание было проверено с использованием ICP-MS. Процесс адсорбции в значительной степени зависел от концентрации адсорбента, а также от времени. Эффективность и сложный механизм поглощения ионов мышьяка на почвах зависит от концентрации клеточной поверхности порошка семян *Zizyphus jujuba*, а также от времени взаимодействия. В этом исследовании 10 % семян *Zizyphus jujuba* достиг максимального удаления всех ионов мышьяка. Значительные различия в снижении содержания токсичных металлов наблюдались в течение 48 часов и 1 недели при всех концентрациях биоадсорбента. Максимальная адсорбция токсичных металлов варьировалась от 80 до 90 % в зависимости от времени контакта, применения перемешивания и концентраций исследуемых биоадсорбентов семян *Ziziphus jujuba*. При более высоких дозах биомассы эффективность удаления As была выше.

Ключевые слова: *Zizyphus jujube*; мышьяк; био-адсорбция; пищевые отходы.