

# Removal of Arsenic Through the Process of Biosorption

Shweta Tiwari<sup>1,2</sup> and Deepak K. Sinha<sup>1\*</sup>

<sup>1</sup>*Institute of Biological Sciences, SAGE University, Indore 452 020, M.P., India*

<sup>2</sup>*Amruta Herbals Pvt. Ltd., Indore 452 015, M.P., India*

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## ABSTRACT

Increase in human population and its need for its lifestyle improvisation leads to nature at risk. One of the natural source on which all live forms depends is water. Water pollution due to non-essential heavy metals is very common. Non-essential heavy metals are very toxic and are threats to human life and other life forms also. Arsenic is one of the non-essential heavy metal which is toxic as well as carcinogenic. Problem due to arsenic pollution is continuously increasing in Asian countries. Arsenic pollution in drinking water along with in paddy fields is global problem all around the world. In almost all regions of West Bengal, India concentration of arsenic in rice continuously increases. Arsenic toxicity is very serious for humans and causes various diseases. Hence, it is necessary to remove arsenic from aqueous solutions to protect human life from its toxic effect. This paper focuses on removal of arsenic using low cost adsorbents through process of biosorption. For removal of arsenic in this study a mixed biosorbent is prepared by mixing roots of Shatavari and Erandmool, leaves of Sadabahar, fruit of Nimbu and panchang of Brahmi. For removal of arsenic ultraviolet spectroscopy method is used here based on the principle of that arsenic when treated with acidified potassium iodate to liberate iodine. The Liberated iodine bleaches the violet colour of azure B which is measured at 644 nm. Results obtained show that maximum percentage of arsenic removal was obtained at 0.5 and 1.0 g of adsorbent dose at 3 mg/l and 5 mg/l of initial arsenic concentration in 3 hour contact time, pH of solution 7 and 8 and 40 rpm agitation speed. Maximum percentage removal obtained at pH 7 by 0.5 g adsorbent dose at 5 mg/l arsenic solution was 82 %. Adsorption isotherm model which supports arsenic removal was Freundlich model whose  $r^2$  value obtained was 0.99 and value of  $n$  is 1.78 and  $K_f$  is 2.53.

*Key words* : Arsenic, Biosorption, Mixed biosorbent, Freundlich, Paddy fields.

## Introduction

Man has very much revolutionized his life and in thirst of success has exploited every natural source around him and unbalanced the ecosystems. Human beings started facing problems of its exploitation in the form of global warming and pollution.

On earth's surface water nearly covers 70% surface and this most precious natural source is now continuously bearing piles of various chemical species, biological species, heavy metals and their ele-

ments, organic elements and radionuclides etc. This contamination or load in water increases due to increase in population on earth. Water is necessary for the sustenance of each creation of life, production of food, daily household works, industrial work, for drinking purpose, economic development and for common well being (Singh, 2015; Shah, 2016).

## Heavy metals

Metals are highly poisonous, non-degradable therefore they are heavily accumulated to toxic levels on

earth (Arief *et al.*, 2008). Metals with high density, atomic weight and atomic number are termed as heavy metals or can be termed as those whose density is higher than water. Heavy metals of three types of much concern which include poisonous heavy metals, precious metals and radionuclides (Macek and Mackova, 2011). Poisonous heavy metals are toxic to human beings even at low concentration and also they are non-biodegradable therefore they are persistence in nature which leads to both ecological and health problems (Stratton, 1987; Gadd, 1992).

Heavy metals have specific gravity more than 5.0 (density 5.0g/cm<sup>3</sup>) and poisonous heavy metals which on exposure have poisonous effects on human beings are 23 in number. These 23 poisonous heavy metals are Sb, As, Bi, Cd, Ce, Cr, Cu, Co, Fe, Pb, Mn, Hg, Ni, Pt, Ag, Te, Tl, Sn, Zn, U, V, Ga and Au.

These heavy metals can be categorized as essential and non-essential heavy metals (Shamim, 2018). Essential heavy metals are those which are required in little amount in body for some biological functions in humans like oxidation and reduction reactions but their higher concentration is harmful for human beings (Iyenger, 1998; Shamim, 2018). These are required by plants also for proper functioning. Their insufficiency in human body leads to various diseases or syndromes.

Non-essential heavy metals have no role in our body they only cause toxic effects and harm to humans and environment also (Koller and Saleh, 2018). These non-essential heavy metals are lethal and cause death like mercury and some of them are carcinogenesis like arsenic (Ahalya *et al.*, 2003). These heavy metals are completely banned from food consumption.

Poisoning due to heavy metals depends on oxidation state of metal ions and also the level, routes of exposure of metal ions. Damage of DNA, enzymes, proteins, lipids occurs due to free radical production originated by intracellular homeostasis interruptions. Heavy metals metabolism and excretions rest on various antioxidants like ascorbate, glutathione etc. These antioxidants are related with free radical quenching by preventing peroxidase, catalase, superoxide dismutase activity (Jan *et al.*, 2015).

One of the non-essential heavy metals is arsenic which is harmful to humans and causes various diseases to humans. Arsenic pollution continuously increases on earth through drinking water and most importantly paddy fields. This paper focuses on re-

moval of arsenic through process of biosorption.

### Arsenic

Increasing Arsenic concentrations in drinking water is the main problem and is the biggest point of concern all over the world in several countries like India, Argentina, China, Brazil, Korea, Japan, Greece, Mexico, Mongolia, Nepal, New Zealand, Poland, Vietnam, USA. Recent studies show that food crops especially rice is the main exposure of arsenic in human body. In Asian countries where arsenic is present in low concentration in drinking water humans are affected by eating rice because rice plants have special ability to absorb arsenic from soil. Presence of arsenic in rice is now a major point of concern.

### Discovery of Arsenic

German chemist Albertus Magnus in 1250 discovered Arsenic first by heating arsenic trisulfide orpiment with soap (Winter, 1998). The name Arsenic originates from Greek Word 'Arsenicon' which means Orpiment (Narayanan and Dhamodharan, 2014; Sultana *et al.*, 2015). It is a semi-metal element (Emsley, 2001). Nature of arsenic is odourless and tasteless. Arsenic is a naturally occurring metal which is metallic and non-metallic in nature. In periodic table it lies on group number 5 and a member of nitrogen family having atomic number 33 (Daniel *et al.*, 1994). From natural deposits in earth or from agricultural and industrial practices arsenic enters in drinking water and also paddy fields (<http://www.epa.gov/safewater/arsenic/index.html>). As we know heavy metals are non-degradable, i.e. they cannot be destroyed. Likewise arsenic cannot be destroyed but can be converted into various types. This metal forms insoluble compounds by combining with Fe and also linked with ores of lead, copper, gold etc. The permissible limit set by WHO or US EPA for arsenic in drinking water is 10µg/l.

### Presence of Arsenic in environment and its sources

Arsenic is a metalloid and present in average concentration of 2 mg/kg on earth's surface. It is widely distributed on earth's crust. Arsenic is present in lithosphere, hydrosphere and biosphere. In lithosphere arsenic is found in earth's crust, soils and rocks. In hydrosphere arsenic is found in ground water, surface water, ponds, oceans, wells etc and in biosphere it involves ecosystem and food chain. Arsenic enters in paddy fields and in drinking water

by natural and anthropogenic sources.

Through food about 25-50  $\mu\text{g}$ / day arsenic is exposed to humans and it is the biggest source of arsenic exposure and in fewer amounts through drinking water and air. In case of foods, fish and shell fish contains highest level of arsenic. In this arsenic is found primarily as organic compounds which is highly non-toxic.

Workers from smelters and humans which are present surrounding to it are exposed to inorganic arsenic through air and higher level of inorganic arsenic present in soil through natural minerals.

Another source of inorganic arsenic is burning plywood treated with Arsenic wood preservative. Arsenic poisoning accidents in industry involved the production of Arsine which is highly toxic gas (US EPA, 1984).

Arsenic is also present in pesticides and if such pesticides are used in vineyard then arsenic is also found in wine. Arsenic is absorbed orally or inhaled then distributed widely and excreted through urine. After consuming inorganic arsenic, its low level dose excreted with in a few days. Arsenic remains in hairs and nails can be detected even after years and years (<http://en.wikipedia.org/wiki/arsenic>). Presence of Arsenic in hair and nails can be used as an indicator for past exposure of arsenic. Concentration of arsenic and its metabolites in hair, nails, urine and blood can be used as biomarker of arsenic exposure. Anyway, prior to urine sampling consumption of some seafoods is avoided as this may confound inorganic arsenic estimation (EHC, 2001).

Arsenic level continuously increases in environ-

ment by animal feeding activities and also by use of fertilizers. Coal burning, mining, copper smelting like industrial activities are the main cause of rising concentrations of arsenic in atmosphere. Two main industrial processes like production of energy from fossil fuels and smelting of non-ferrous metals lead to arsenic pollution of air, water and soil (Chilvers *et al.*, 1987).

In countries like Bangladesh, Chile, China and other various countries all over the world inorganic arsenic is present in ground water while organic arsenic compounds like arsenobetaine are present in sea foods like fish which is the major source of exposure to arsenic in humans (EHC, 2001).

Inhalation of absorbed arsenic airborne particles highly depends on size and solubility of particles. Soluble arsenic compounds are easily absorbed in human body through gastrointestinal tract. When inorganic arsenic is methylated in human body metabolites of inorganic arsenic are excreted in urine (EHC, 2001).

Arsenic disrupts ATP production in human body by various mechanisms. At the time of Citric acid cycle, arsenic disrupts pyruvate dehydrogenase. It uncouples oxidative phosphorylation by competing with phosphate and thus retard energy linked reduction of  $\text{NAD}^+$ , ATP synthesis and mitochondrial respiration. Increase in Hydrogen peroxide production may increase formation of oxygen reactive species cause increase in oxidative stress. Such types of metabolic intervention cause death due to multiple system organ failure, probably from necrotic cell death and not from apoptosis. Some postmortem

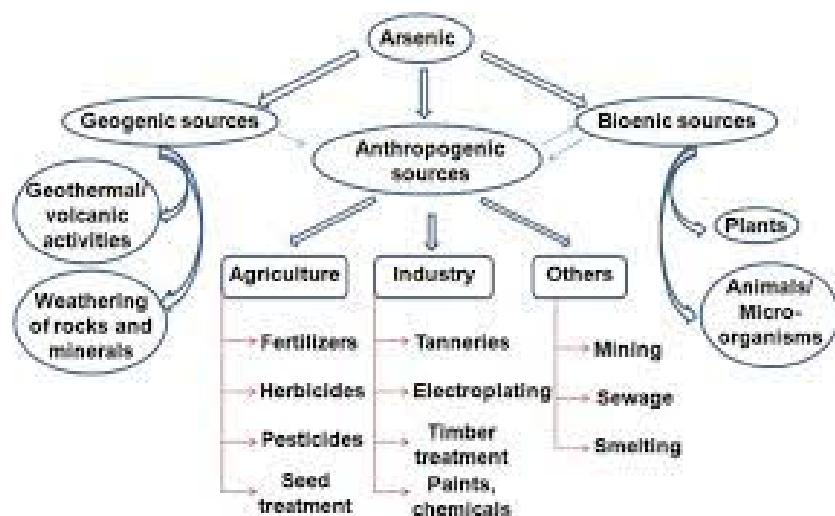


Fig. 1.

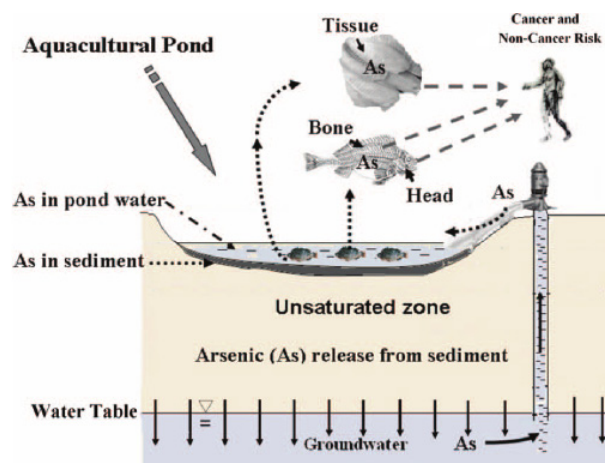


Fig. 2. Showing how arsenic enters in water and then to human body (adapted from Kar *et al.*, 2011).

reports divulge formation of brick red colored mucosa formation due to severe hemorrhage.

Below is the figure 1 showing source of arsenic in paddy fields and drinking water (adapted from Sahoo and Kangjoo, 2013).

Arsenic (V) is dominant in aerobic environment, generally in the form of arsenate ( $\text{AsO}_4^{3-}$ ) in many protonation states like  $\text{H}_3\text{AsO}_4$ ,  $\text{HAsO}_4^{2-}$ ,  $\text{H}_2\text{AsO}_4^{2-}$  and  $\text{AsO}_4^{3-}$ . Arsenate and other anionic forms of arsenic play a role like chelates and when metal cations present they can be precipitate. In specific conditions only metal arsenate complexes are stable. Under acidic and moderately reducing conditions Arsenic (V) co-precipitates with and adsorbs onto iron oxyhydroxides. Although, increase in pH increase mobility of arsenic also.

In reducing conditions Arsenic (III) dominates and exists as arsenite ( $\text{AsO}_3^{3-}$ ) and its protonated forms are:  $\text{H}_3\text{AsO}_3$ ,  $\text{H}_2\text{AsO}_3^-$ ,  $\text{HAsO}_3^{2-}$ . With metal sulphides arsenite can be adsorb or co-precipitate and also it has higher affinity for other sulphur compounds (Evanko and Dzombak, 1997).

Arsenic is often present in anionic form so it does not form complexes with simple anions like  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ . Speciation of arsenic also includes organometallic forms such as methylarsenic acid ( $(\text{CH}_3)\text{HAsOOH}$ ) and dimethylarsenic acid ( $(\text{CH}_3)_2\text{AsO}_2\text{H}$ ) (Evanko and Dzombak, 1997).

### Toxicity of Arsenic

It is in the order of Arsine gas > Inorganic arsenic III > Organic arsenic III > Inorganic arsenic V > Organic arsenic V > Elemental arsenic (Chaurasia, 2015).

### How Arsenic diseases caused in Humans

Humans exposed to arsenic mainly by inhalation, ingestion or dermal contact. By using contaminated food, water, rice or through other sources humans come in contact of arsenic. Chronic exposure of arsenic causes formation of 'Reactive oxygen species' (ROS) which leads to destruction of DNA, oxidative stress, induce genome instability, immunomodulation and inflammation which commence cancer (Rao *et al.*, 2017). Through smoking of cigarettes, wines, drugs etc acute exposure of arsenic occurs (Sahu, 2007). Sign of Arsenic poisoning are vomiting, diarrhea, abdominal pain, haematuria, burning and dryness happens in mouth and throat, facial edema and cramps in muscles happens due to dehydration, abnormalities in cardiac (Sultana, 2015). Arsenic enters in food cycle through consumption of food crops grown on the soil polluted with arsenic especially rice and drinking arsenic polluted water (Zhao, 2010).

Methylated organic and inorganic species in trivalent form which inhibit the activity of proteins by reacting with thiols present in protein causes toxicity of arsenic in humans. Arsenic (III) reacts with thiol present in protein and inhibits the enzyme which depends on thiol. Arsenic (III) also degrade Iron-sulphur clusters present in protein. Cancer is caused by several mechanisms like genotoxicity, oxidative stress, altered DNA methylation and cell proliferation, tumor promotion (Hughes, 2002). Arsenic (V) is same in configuration to phosphate and in various enzymatic reactions esters of arsenic (V) easily hydrolyze then esters of phosphate which cut off the oxidative phosphorylation mechanism and supply of energy to cells deprives (Westheimer, 1987; Gresser, 1981).

Arsenic (III) is more toxic due to its protein inhibition properties. Concentration of arsenic (III) is more in water at acidic and neutral pH. Diseases originated by chronic exposure of arsenic are malignancies, neuropathy, skin damage, arsenicosis, chronic respiratory problems like chronic cough, loss of appetite and weight, lethargy, fatigue, burning of eyes, enlargement of spleen and liver, working capacity loss, dyspepsia, anemia, nausea, edema in leg, congestion of conjunctiva (Sultana, 2015), cardiovascular and gastrointestinal damage, vascular disorders like black foot disease, damage of mucous membranes (Fields, 2000), mutagenic, skin lesions, genotoxic, damage to central nervous system, lung

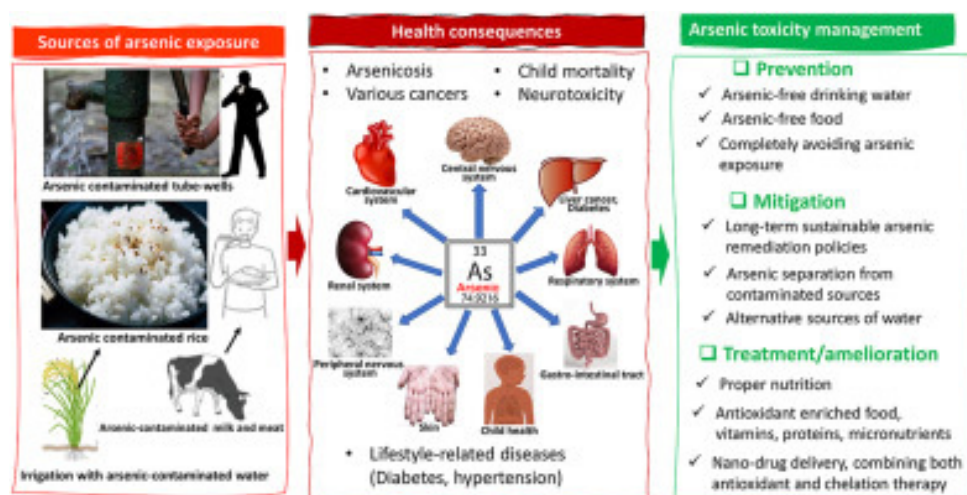


Fig. 3.

and skin cancer (Rivas, 2010; Bose, 2011). For long time when less contaminate arsenic water is consumed then pigmentation change, hyperkeratosis, nausea, muscular weakness, neurological disorder and also cancer of bladder and kidney occurs (Rao, 2017).

Acute exposure of Arsenic causes esophageal, bloody diarrhea of 'rice water' (Jain, 2000; WHO, 1981). All these Arsenic toxicities causes panic conditions all over the world especially in some countries like USA (Lin- Fu, 1980), Japan and Chile (Roychowdhury, 2002; Mandal, 2002), India (West Bengal), Bangladesh (Al- Rmalli, 2005; Naseem, 2010). Figure 3 showing how humans exposed to arsenic and diseases caused by arsenic (adapted from Rahman *et al.*, 2021).

#### Effect of arsenic polluted water on crops irrigation and soil

Route of exposure of arsenic is through water to soil and from soil to crop and arsenic enter in any edible part of crop when crops are irrigated by arsenic polluted water. When arsenic polluted water is used for irrigation of crops then the amount of arsenic raised per year is  $1\mu\text{g/g}$ . As a result of this yield of crops decreases, human health risk and entrance of arsenic in food chain and this ultimately disturbs ecosystem. When for irrigation purpose long time and constantly arsenic contaminated water is used then soil accumulate and increases the level of arsenic five times more than that of the normal soil. Dietary arsenic intake occurs when crop absorbs arsenic and it cause harm to human health.

Exposure of arsenic via intake of rice aroused attention of researchers throughout the world. The highest concentration of arsenic in rice up to  $2.05\text{mg/kg}$  was reported in the southern part Gopalganj, Rajbari and Faridpur of Bangladesh (Islam *et al.*, 2004a). In Western Bangladesh Nawabgong and Naogon arsenic concentration in rice observed was up to  $1.8\text{mg/kg}$  (Mehrag and Rahman, 2003). Arsenic pollution in India in paddy fields, especially in West Bengal has long history and many studies from this area also show high arsenic concentration in rice. Arsenic concentration in rice collected from Murshidabad district of West Bengal according to Roychowdhury *et al* was varied from  $0.09- 0.66\text{mg/kg}$  in 2002. Average concentration of raw rice obtained from Sathira district which is highly Arsenic polluted area of Bangladesh was  $0.57- 0.69\text{mg/kg}$ .

Concentration of Arsenic rice studies from other Asian countries ranges from like China  $0.31- 0.7\text{mg/kg}$  (Xie and Huang, 1998); Taiwan  $0.1- 0.61\text{mg/kg}$  (Lin *et al.*, 2004); Thailand  $0.06-0.5\text{mg/kg}$  (Adamako *et al.*, 2011); Korea  $0.24-0.72\text{mg/kg}$  (Lee *et al.*, 2008); Japan  $0.07- 0.42\text{mg/kg}$  (Meharg *et al.*, 2009).

This concentration of arsenic in rice indicates global arsenic problem in all food stuffs. However there is no arsenic limits for arsenic in rice in EU and US (Francesconi, 2007). But China has set the maximum contamination levels (MCL) of arsenic in rice was  $0.15\text{mg/kg}$  (Zhu *et al.*, 2008). From above range it is clear that in Asian countries limit of Arsenic in rice has exceeded the MCL. The high Arsenic concentra-

tion in Bangladeshi rice result in significant Arsenic levels in staple foodstuffs.

### Removal of Arsenic/ Non-essential heavy metals

Various physical and chemical methods are used to remove arsenic from the environment like Ion exchange, Ultrafiltration, Reverse osmosis, Electrodialysis, chemical precipitation, electrochemical treatment. Other methods used are solar oxidation, oxidation and coagulation methods. All the above methods are capable of removing heavy metals contaminants from environment but all these methods are linked with various disadvantages like they are costly, incomplete removal of metals, labor- exhaustive, lack of selectivity in treatment process, requirement of energy and other high reagent, membrane's fouling, production of toxic slurry and other toxic materials which need careful destruction (Ahalya *et al.*, 2003; Shamin, 2018; Kanamarlapudi *et al.*, 2018, Tiwari *et al.*, 2021). When contaminated solution in bigger amount containing heavy metals contaminants are treated then membrane filtrations and chemical precipitation methods become so costly. These methods are also inefficient in removing heavy metals contaminants when in contaminating solution their concentration is low (Kanamarlapudi *et al.*, 2018; Tiwari *et al.*, 2021). Because of all this disadvantages there is need of method which is natural, ecofriendly and also inexpensive in removal of heavy metals pollutants.

### Biological methods

Biosorption is an eco friendly substitute of these methods. Biosorption has many advantages against these methods. In biosorption naturally available biomass like bacteria, fungi, algae even agriculture, vegetable and fruits, industrial waste and herbal plant parts is used as biosorbent for removal of heavy metal. These biosorbents has functional groups on their outer layer which sequester the heavy metal ions. Through desorption of metals from biosorbents recovery of biosorbents is possible and biosorbents can be used back which makes this method economical. Chemically and physically modified biosorbents can be used for excessive removal of heavy metal contaminants from contaminating solution (Kanamarlapudi *et al.*, 2018; Tiwari *et al.*, 2021).

### Biosorption

Process of biosorption is a natural, cheap, fast and

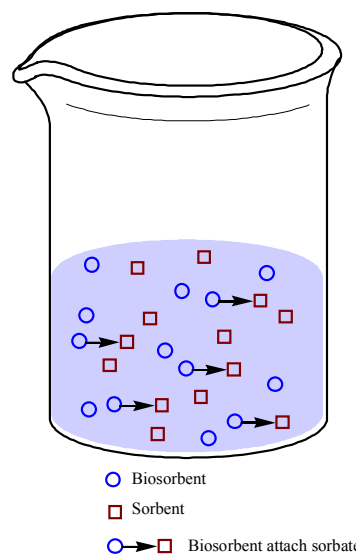


Fig. 4. Different phases of biosorption in solution (Adapted from Tiwari *et al.*, 2021).

environment friendly treatment technology (Michalak *et al.*, 2013; Bilal *et al.*, 2018). This is a physio chemical process. Biosorption termed as efficiency of biosorbent to accumulate heavy metals or pollutants from contaminating solution through metabolically mediated (by using energy in form of ATP) or physio chemical pathways (without using energy /ATP) or feature of some particular living and non-living biomass which bind and reduce metals or contaminants from even dilute solutions (Ahalya *et al.*, 2003; Shamin, 2018; Tiwari *et al.*, 2021).

Advantages of biosorption over physical and chemical methods is that less expensive, recovery of biological material used, efficiently high, complete removal of metals, no nutrient requirement additionally. Biosorption is highly selective for specific metals uptake or contaminants and their removal, minimization of accumulation of sludge or reduced volume of production of toxic materials, low operating cost, Metal desorption is easy and cheaper, production of biosorbent is cheap, at a time uptake of multiple heavy metals, large amount of waste water treatment, biosorption is effective as it is functional over broad range of conditions like pH, temperature, metallic ion concentration etc (Ahalya *et al.*, 2003; Michalak *et al.*, 2013 ; Bilal *et al.*, 2018; Shamin, 2018, Tiwari *et al.*, 2021).

There are 2 phases in biosorption one is solid phase (biosorbent/biological material) and other one is Liquid phase (solvent) in which the dissolved

contaminants/metals (sorbate) are present which is to be sorbed or removed. As biomass have higher binding affinity towards heavy metals contaminants so these metals get attracted and bound on the surface of biomass by several mechanisms. This process of binding of metals or contaminants with biomass continues till equilibrium is established between bound sorbate and biomass and its remaining portion in solvent. The intensity of biomass affinity for the sorbate or heavy metal to be removed determines biomass distribution between solid and liquid phase (Ahalya *et al.*, 2003; Tiwari *et al.*, 2021). Below is the figure showing two phases of biosorption and metal binding to biosorbent (Fig. 4).

In this paper mixture of different herbal plant biosorbents are used to remove arsenic from aqueous solution. Adsorption Isotherm model was studied after calculating % of removal and uptake capacity of mixed biosorbent to remove arsenic from solution. Here, *Asparagus racemosus* roots (Shatavari), *Ricinus communis* roots (Erandmool), *Citrus medica* fruit (Nimbu), *Vina rosea* leaves (Sadabahr), *Bacopa monnieri* panchang (Brahmi) are used as biosorbents to remove arsenic from solution. Screening of all these biosorbents was done to remove arsenic from solution and then they are mixed in a ratio and further capacity of mixed biosorbent was examined to remove arsenic from solution.

## Materials and Methods

### Apparatus

A Shimadzu UV-Visible spectrophotometer 1800 with 1 cm quartz cell was used for the absorbance analysis and Toshcon pH Meter (model- TMP3) was used.

### Reagents

Analytical grade chemicals are used and distill water is used for dilution of reagents and samples. Standard Arsenic III solution was prepared by taking 0.3478 g of sodium arsenite in 200 ml of water. Working standard was prepared by taking 1.4 ml from stock solution in 100 ml volumetric flask and make up to the mark with water. Hydrochloric acid 0.4 mol/l solution, 2% potassium iodate, 2 mol/l sodium acetate solution, 0.1% azure B were used.

### Procedure

An aliquot of sample containing 5 ml of arsenic III

was taken in 10 ml calibrated volumetric flasks. 1 ml, 2% Potassium iodate solution followed by 1 ml, 0.4 mol/l hydrochloric acid was added and the mixture was shaken then addition of 1 ml, 0.1% azure B and 2 ml, 2 mol/l sodium acetate solutions. Solution was kept for 5 minute and absorbance was taken at 644 nm against the corresponding reagent blank. A graph was plot against the absorbance obtained and equation was calculated (Cherian and Narayanan, 2005) to calculate concentration of arsenic removed.

### Determination of arsenic in plant biomass

The adsorbent dose of mixed biosorbent taken here was 0.1, 0.5, 1.0 and 1.5 g. Above plant biomasses then taken in 50 ml flasks and in these 25 ml of different concentrations of arsenite solution was added and it was stirred on magnetic stirrer for 3 hr at room temperature. (30±2°C). This solution was filtered through Whattman 42 filter paper.

Different concentrations of arsenite was prepared by dissolving arsenite into distill water. The pH was adjusted by pH meter Toshcon (model- TMP3) using 0.1N sodium hydroxide and 10% hydrochloric acid solution.

From above solution 2 ml of Arsenic III solution was taken in 10 ml volumetric flasks then 1 ml, 2% Potassium iodate solution followed by 1 ml, 0.4 mol/l hydrochloric acid was added and the mixture was gently shaken. This was followed by addition of 1ml, 0.1% azure B and 2 ml, 2 mol/l sodium acetate solutions. Solution was kept for 5 minute and absorbance was taken at 644 nm against the corresponding reagent blank.

### Batch study

The experiments were performed discontinuously in 50 ml flasks on a magnetic stirrer and were carried out considering four variables, including pH of solution 7 and 8, adsorbent dosage 0.1, 0.5, 1.0 and 1.5 gm, contact time 3 hour, initial concentration of arsenic 3 and 5 mg/l. The percent removal (% R) and was calculated by the following equations (Kamsonlion *et al.*, 2012).

$$\text{Percentage of Removal } R\% = \frac{(C_i - C_f) \times 100}{C_i}$$

$C_i$  is initial concentration of As (III) in solution (mg/l)

$C_f$  is final concentration of As (III) in solution (mg/l)

Uptake capacity ( $q_e$  in mg/g) is the amount adsorbed/ unit mass of adsorbent or biomass was

calculated by equation given below.

$$q_e \text{ (mg/g)} = \frac{(C_i - C_f) \times V}{M}$$

$C_i$  is initial concentration of As (III) in solution (mg/L)  
 $C_f$  is final concentration of As (III) in solution (mg/L)  
 $q_e$  is equilibrium uptake of As (III) ions (mg/g)  
 $V$  is the volume of As (III) solution in l.  
 $M$  is the mass or weight of adsorbent/biosorbent in gm.

### Adsorption Isotherms

The capacity of biosorbents was analyzed with isotherm models using different concentration of metal

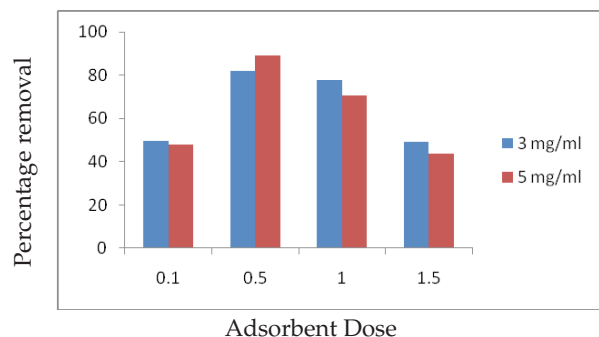


Fig. 5. Showing graph between percent removal versus adsorbent dose at pH 7 of Mix Biosorbent

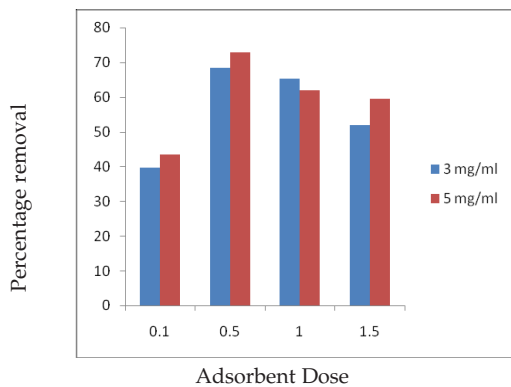


Fig. 6. Showing graph between percent removal versus adsorbent dose at pH 8 of Mix Biosorbent

ions. Langmuir and Freundlich adsorption isotherm were used to predict the experimental data. Langmuir model is given by equation,

$$q_e = \frac{Q_L b C_e}{1 + b C_e}$$

$q_e$  and  $Q_L$  is "observed" and "maximum uptake capacity" in mg/g,  $b$  is equilibrium constant and  $C_e$  is equilibrium concentration in mg/l. The above equation of Langmuir model can be rearranged to

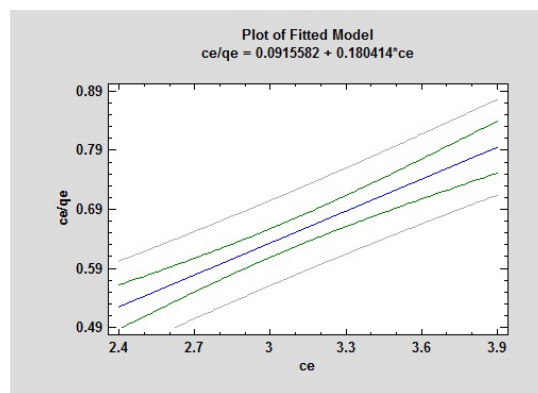


Fig. 7. Showing Langmuir isotherm model plot between  $C_e/q_e$  vs  $C_e$

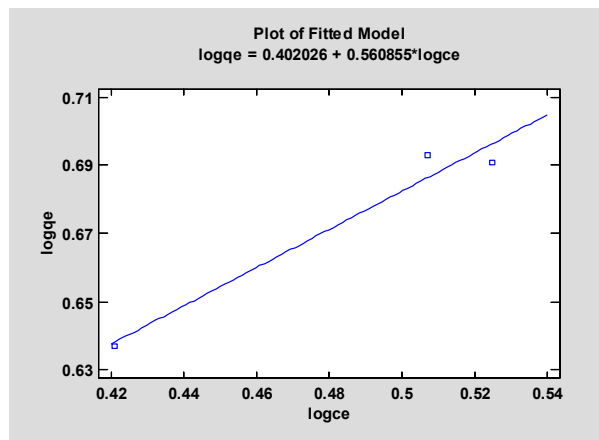


Fig. 8. Showing Freundlich isotherm model plot between  $\log q_e$  vs  $\log C_e$

Table 1. Uptake capacity of Mix Biosorbent at 3 mg/l and 5 mg/l at pH 7 and 8

Dose (gm)	3 mg/l Uptake Capacity (mg/ml)		5 mg/l Uptake Capacity (mg/ml)		
	pH 7	pH8	Dose (gm)	pH 7	pH 8
0.100	2.60	2.68	0.100	4.34	4.39
0.500	2.87	2.89	0.500	4.71	4.80
1.0	2.93	2.94	1.0	4.90	4.91
1.5	2.97	2.97	1.5	4.95	4.94



**Table 2.** Adsorption Isotherm (Langmuir and Freundlich model) Parameters for adsorption of Arsenic (III) ions on biomass.

Langmuir Isotherm Model			Freundlich Isotherm Model		
$Q_L$ (mg/gm)	$b$ (l/g)	$r^2$	$K_f$ (mg/g)	$n$	$r^2$
0.507	1.92	0.97	2.53	1.78	0.98

obtain linear form by following equation.

$$C_e = \frac{1 + C_e}{b Q_L Q_L}$$

Freundlich adsorption isotherm is a non linear adsorption model which is purely empirical in nature based on heterogeneous biosorbent surface which is given by following equation.

$$Q_e = K_f C_e^{1/n}$$

$K_f$  and  $n$  is Freundlich constant which is related to "adsorption capacity" and "adsorption intensity" respectively. Logarithmic form of Freundlich model can be used to get linear form of equation to determine Freundlich constants. The Freundlich constant can be obtained by drawing the  $\log q_e$  versus  $\log C_e$  which is based on experimental data in light to linear equation (Dada *et al.*, 2012; Khoshnamvand *et al.*, 2017; Akbari *et al.*, 2018; Dogan *et al.*, 2000).

$$\log q_e = \frac{1}{n} \log C_e + \log K_f$$

Correlation coefficient values, i.e.  $r^2$  were determined from Langmuir and Freundlich adsorption isotherm models.

## Results

The graph between Adsorbent dose and percent removal at pH 7 and 8 shows that with at 3 mg/l and 5 mg/l at low adsorbent dose there is no removal of arsenic but with increase in dose removal capacity also increases and at higher adsorbent dose it will decrease.

### Adsorption Isotherm model

Freundlich Isotherm is more appropriate to describe the equilibrium adsorption of Arsenic on Mix Biosorbent. The  $r^2$  value for Freundlich isotherm is 0.98. However,  $K_f$  and  $n$  are characteristic parameter of sorbent-sorbate system. In this model adsorbent surface areas are not uniform and have different absorption force. The intensity of adsorption,  $n$  1.78 lies with in the range of 1- 10 ( $1 < n < 10$ ) which suggest that adsorption of arsenic on Mix biosorbent is favorable.

## Conclusion

Arsenic is non-essential heavy metal and along with it is highly toxic and carcinogenic. Removal of arsenic is necessary because percentage of arsenic in rice fields and in drinking water continuously increase. For removal of arsenic mixed biosorbent was prepared using different herbal plant parts which are Shatavari roots, Erandmool roots, Sadabahar leaves, Brahmi panchag and Nimbu fruit. In this study removal of arsenic using ultraviolet spectroscopy was done. Parameters studied for biosorption experiment was pH 7 and 8, initial arsenic concentration 3 mg/l and 5 mg/l, time 3 hour and adsorbent dose 0.1, 0.5, 1.0 and 1.5 g was studied. The highest removal of arsenic was done at 0.5 and 1.0 gm adsorbent dose. Adsorption Isotherm model study show that Freundlich model supports arsenic removal from aqueous solution. Coefficient correlation value for Freundlich model is 0.99 and value of  $n$  obtained was 1.78. In this study different biosorbents mixture are used which means heterogeneous biosorbent surface and nature of Freundlich model was also based on heterogenous biosorbent surface.

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