Arsenic Remediation of the Waste Water using Adsorbent: A Review

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Abstract:

Heavy metals, mixed at above permissible limit either in the water or air is a potential threat to the living organism and vegetation. Heavy metals from wet processing industries accounts for a major portion of water pollution. Heavy metals like Cu, As, Zn, Fe, Pb, Cd are found either in free state or combined one. Out of them As, because of its notoriously toxic nature, overshadowed its contribution in applied chemistry. More than 21 countries are marked by WHO as high risk region. There is an emergence of processing As containing water to reduce the concentration level. Many a technologies are available to treat such kind of water, but out of these, because of outstanding characteristics possessed, adsorption have upper hand over other conventional technologies. In the current review, the ill effects of arsenic on human health and society along with its remediation techniques comparison are presented. More emphasis attributed towards remediation by adsorption using commercially available and low cost adsorbent. Outstanding performance of some low cost adsorbent such as developed carbon from agro waste, industrial by product and biosorbents has been discussed. A little of cost evaluation is also done.

Key words: Arsenic, Biosorbents, Arsenate, Red mud.

1.Introduction:

Waste water from wet processing industries contains various contaminates including dyes ,heavy metals, numerous chemicals which are harmful for the living being and the vegetation which are in direct or indirect contact of the wastewater[1-3]. Heavy metals like As, Cr, Cu, Ni, Zn, Pb, Cd which are not biodegradable adds on to a major part of water pollution and its considered to be a serious threat by WHO[4]. Because of these reasons, demands of resolution of the issue by the best possible way are rapidly expanding. Out of available techniques for removal of heavy metal from the wastewater, the challenge is to pick the one which can produce optimum results. Adsorption techniques have proven to be the best out of the available conventional methods because of its large number of advantages. Adsorption by activated carbon is widely used process. But the commercial activated carbon present in market is expensive material[5]. As the substitute of that, a large number of agro based natural compounds have been used to prepare the activated carbon having the lower cost as well as cheap at the same time[6-7]. Now a days a biosorbents which is good substitute of conventional adsorbent have been under research extensively.

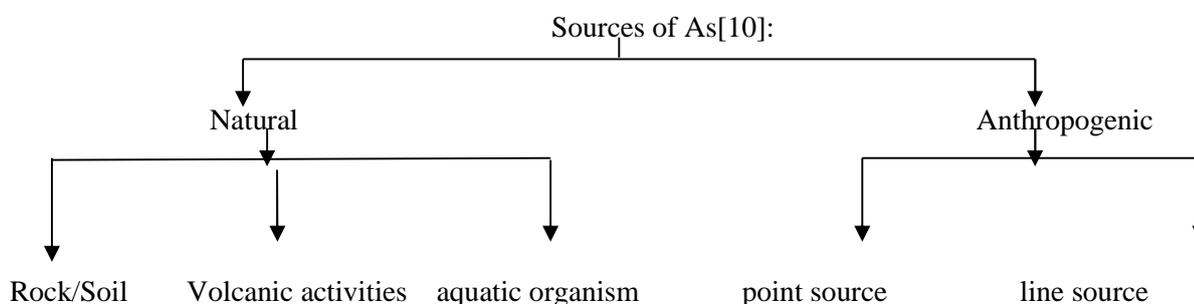Table 1: Maximum Contamination Limit Standards (MCLS) [7]

Heavy Metal	Atomic Number	MCLS(mg/l)
Copper	29	0.25
Arsenic	33	0.50
Cadmium	48	0.01
Lead	82	0.006
Nickel	28	0.20
Chromium	24	0.05
Fluoride	09	1.5

The Notoriously Toxic behavior of Arsenic overshadowed its importance in applied chemistry. This heavy metal contributes to water as well as air pollution to a great extent . Its presence in ground water adversely hampers the aquatic organism and in drinking water may result in severe health issues, sometimes deaths for those who are consuming it [5]. There are 21 countries across the world suffering from As caused pollution. Bangladesh is severely effected ant is at high risk followed by West Bengal region. The largest population currently at risk is in Bangladesh followed by West Bengal in India. Permissibility limit of As in the drinking water is 10 μg/L by WHO and the value in west Bengal shoots to threatening value of 50 μg/L [6].

2. Arsenic:

Arsenic having at. no equals to 33 is ubiquitous and comprising about 0.00005% of the earth's crust, ranks 20th in natural abundance, 14th in the seawater, and 12th in the human body[7]. Arsenic exhibits various oxidation states and they are −3, 0, +3 and +5 [8]. In natural water, generally arsenite [arsenic(III)] and arsenate[arsenic(V)] are found[9].

2.1 Sources of Arsenic:

Sources of As[10]:

Natural

Anthropogenic

Rock/Soil   Volcanic activities   aquatic organism   point source   line source

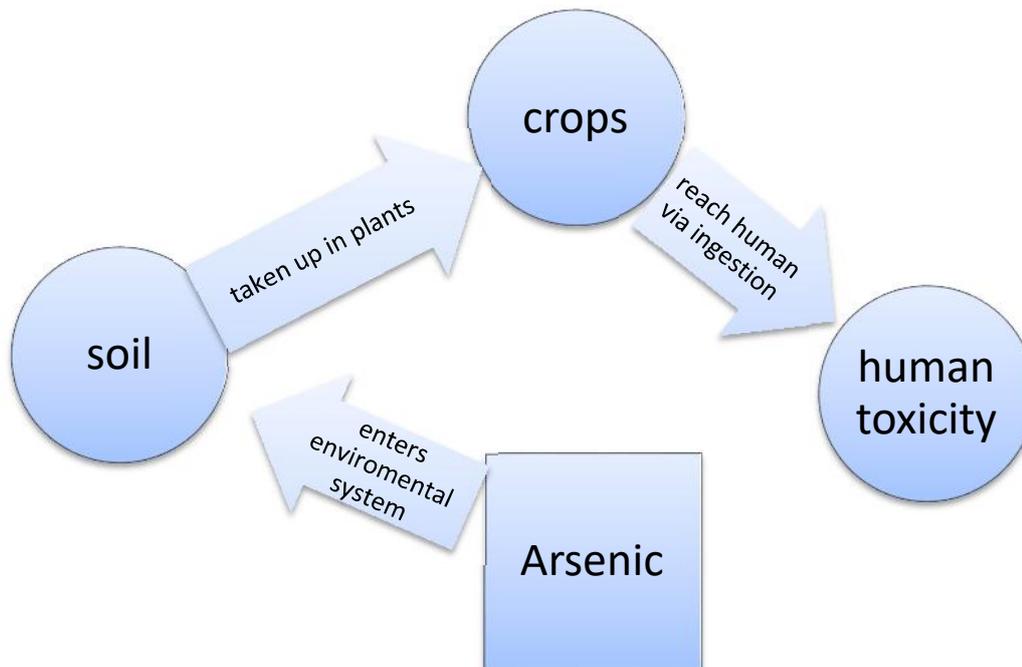### 2.2 Ill effects of Arsenic on human health:

The poisonous nature of arsenic is very well known since ages[11]. The elevated concentration of arsenic can be easily found in ground water because of easy dissolvability of arsenic from the bedrock into the surrounding water [12-13]. All organs of human body may get affected in one way or the other if consuming arsenic contaminated water for long time [14-15].

Table 2: Effect of arsenic on different part of body[16-18]:

Sr. No	Body part or system	Ill effect of arsenic
1.	Nervous system	1. Impaired intellectual function 2. Neuropathy
2.	Cardiovascular	1. Coronary heart disease 2. Hypertension 3. Heart attack
3.	Skin	1. Skin lesions 2. Skin cancer
4.	Renel system	1. Kidney cancer 2. Bladder cancer
5.	Endoclrine system	1. Diabetes
6.	Respiratory system	2. Pulmonary tuberculosis 3. Lung cancer

2.3 Indirect consumption of arsenic:

The broad interrelation of poisonous nature of arsenic and vegetation, environment getting hampered in many ways are extensively taken into consideration by researchers of the same field. One way of getting human health affected by arsenic is direct consumption of ground water containing arsenic and the other method is indirect consumption of arsenic. The later method is discussed below[25]:

2.4 Social hazards and poverty:

Apart from the effects on human health, arsenic is also considered as social phenomenon[19]. Implications of victims and their families are created by arsenic poisoning in the affected areas. Social isolation, social injustice and many more socio-economic problems due to arsenicosis, a disease caused by arsenic are reported[20-21]. Arsenicosis ,likely to effect the poor class of the society who do not have proper diagnosis facilities, proper medication, dietary deficiency and an alternate drinking water source[22-24]. Arsenicosis disease and poverty have a direct relationship. The victims and their families suffer from the enhanced economic burden. Majority of arsenicosis patient remains untreated due to insufficiency of money and resources[23].

3. Arsenic remediation techniques:

3.1 Oxidation/precipitation technology:

The most of oxidation reactions involved are not responsible for removal of arsenic from the solution but optimizes the other processes i.e oxidation step is coupled with other separation technology in order to convert arsenite to arsenate because below pH 9.5 arsenite is non charged[26]. In oxidation the removal of electrons takes place from the chemicals and the chemical forms is being altered [27]. Direct oxidation of arsenite can be done through various chemicals like ozone, gaseous chlorine and solid manganese oxide. Arsenite's oxidation can be catalyzed by UV radiations in presence of ferric iron, cirate or sulfate [28-30].

Precipitation: solid minerals having low solubility, like calcium arsenate can be formed from dissolved arsenic. Filtration and sedimentation can be used to remove the so formed solid. When flocks are formed by addition of coagulants, the phenomenon known as co precipitation results.

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Table 3: Comparison of Major oxidation/precipitation technologies [31-33]:

	Technology	Pros	Cons
1.	Chemical oxidation	Simple in nature, quicker response, kills microbes, other impurities also get oxidized	Control of Ph is not very efficient, need of oxidation step
2.	Air oxidation	Other organic and inorganic impurities also get oxidized, simple in nature, cost efficient	Majorly removes arsenic(V) and oxidation process get accelerated.

3.2 Coagulation and Filtration:

One of the most widely used and documented technology for removal of arsenic is Coagulation and Filtration by making use of lime softening or metal salts. Odor and color could also be removed by it. However, the optimal conditions for removal of other constituents, mainly fluoride and phosphate may differ from that of arsenic removal. The removal of arsenic using metal salts of aluminum and iron are one of the oldest technologies known [34-35]. Ferric and aluminum salts have proven to be excellent removal agent for arsenic under optimum condition and yields approximately 99% removal [36]. The removal of arsenic by Coagulation and Filtration is achieved by successive mechanism of precipitation, co precipitation and adsorption [37]. Each of the three mechanism contribute to contaminant removal independently. Role of direct precipitation is not of much importance for arsenic removal but co precipitation and adsorption plays a vital and active role.

Table 4: Comparison of Major coagulation technologies [38-40]:

	Technology	Pros	Cons
1.	Softening of lime	Easy availability of chemicals	pH readjustment is required
2.	Alum coagulation	Availability of durable powdered chemicals are there, easy operation, low capital investment, operatebility over wide pH range.	Removal efficiency is poor, sludge produced is toxic in nature.
3.	Iron coagulation	Easy avilabilty of chemicals, efficiency is better then that of alum coagulation.	Removal efficiency is fair, reqirement of sedimentation and filteration.

3.3 Ion exchange and sorption:

Flocks of various solid materials such as aluminum hydroxide and iron possess high affinity for dissolved arsenic. The arsenic from the solution get strongly attracted to the sorption sites on the surface and by this way separation takes place. A special case of adsorption can be considered as ion exchange process and it involves reversible transport of adsorbed ion on to solid surface.

3.3.1 Ion exchange resins:

Water treatment utilizes synthetic resins to remove dissolved solid impurities and the basis of these resins are the matrix, which are cross linked polymer skeleton. The matrix are attached by functional groups by means of covalent bonds and fall in group of four, i.e Strongly acidic, Strongly basic, weakly acidic and weakly basic [41]. For the establishment of chloride ions at the surface so that it could be easily replaced by arsenic ion, the resin is pretreated with hydrochloric acid [42].

3.3.2 Activated Alumina:

Granulated form having very high surface area in the range of 200-300 m^2 /g. a very large number of active sites for sorption results from this high surface area. Earlier activated alumina was used for removal of fluoride but later on it is very well observed that the material can be used for removal of arsenic up to a great extant [43].

Table 5: Comparison of Major ion exchange and sorption technologies [44-49]:

	Technology	Pros	Cons
1.	Ion-exchange resin	Capacity and medium are well defined, independent of pH	Cost of medium is high, maintenance is high, disposal of sludge resulting from regeneration is a major issue
2.	Activated alumina	Commercial availability is high, good removal capacity.	Frequent replacement is required i.e after 4-5 regeneration.
3.	Iron coated sand	Efficient in removal of both, As(III) and As(V), no requirement of regeneration, cost is less.	Waste produced is solid and toxic in nature.

3.4 Membrane separation:

The membrane which are used for separation here are selective in a way that it permits molecules of one type to pass through it but other are rejected [50]. Membrane separation are broadly classified in two groups, i.e low pressure membrane which are operated in a pressure range of 10-30 psi and high pressure membrane operates at 75-250 psi [51]. Ultrafiltration and micro filtration falls under the category of low pressure membrane while reverse osmosis and nanofiltration are the types of high pressure membrane [52]. It has been observed that low pressure membrane suits best for the removal of dissolved arsenic.

Table 6: Comparison of membrane technologies [53-58]:

	Technology	Pros	Cons
1.	Reverse osmosis	Sludge produced is non toxic	Maintenance and operational cost is high
2.	Nanofiltration	Removal efficiency is excellent and well defined in nature	Capital and operational cost is very high, requirement of pre conditioning.
3.	Electrodialysis	Other complex contaminants can also be removed.	Residual water produced is toxic.

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3.5 Other emerging technologies:

In recent years, the search for novel technologies for removal of arsenic in order to reduce the cost of operation, non hazardous compounds and its applicability in remote and rural area accelerated and enormous amount of research has been done in the same field. Various new technologies and advancement results from the revolution. Other than the conventional techniques discussed in earlier part of the paper ,other handy techonologies like Bioremediation, Foam flotation and solvent extraction can also be used for arsenic removal depending upon the need of the process [59-61].

4. Remediation of arsenic using adsorption:

Adsorption process has proven to be best heavy metal removal technique and its overshadowed the use of other typical sophisticated high cost conventional techniques because of the merits like Utilization of industrial, biological and domestic waste as adsorbents, Low cost of adsorbent, Low operational cost, Easy availability, Ease of operation compared to other processes, Capacity of removing heavy metal ions to a much lower level, Reuse of adsorbent after regeneration [62].

The use of biological materials, polymeric resins, activated carbon or mineral oxides are providing the reason of excitement for the researchers to go ahead and make use of them to synthesize the best possible adsorbent at an expense of optimum cost[63-64].

The use of charcoal was very prominent by ancient hindus for purification of water and in ancient Egypt carbonized wood was used as medical adsorbent[65]. In the modern world, the use of activated carbon was first reported in 1930 in U.S.A[66]. The dependency of surface chemistry is on temperature and activation conditions. The activation could be acidic or basic in nature and is responsible for refining the pore structure. The metal ions gets adsorb on the acidic group of activated carbon[67]. The surface area is not the prime factor for adsorption and its high magnitude doesn't necessarily responsible for good adsorption capacity[68]. The dependency of adsorption capacity is more on the chemical properties of adsorbate, ionic strength, pH, etc [69].

Adsorption dynamics:

The following are the consecutive steps in general accepted terms of the adsorption dynamics [70]:

• Adsorbate's transport from bulk of solution to the adsorbent's external surface by diffusion through liquid boundary layer.

• Adsorbent's external surface to inner porous structure mass transfer takes place by pore diffusion.

• Surface diffusion along the porous surface.

• Adsorbate's adsorption on the active sites.

4.1 Classification of adsorbent:

Adsorbent in this paper is classified as commercial adsorbent and low cost adsorbent.

4.1.1 Commercial adsorbent.

4.1.1.1 Synthetic adsorbent:

Production of activated carbon can be done through the carbonization of the raw material at temperature somewhere around 600°C followed by physical or chemical activation using oxidizing agents or different acids [71-72]]. Chemical activation reduces the temperature requirement of the process. Many types of activated carbon are synthesize for the removal of arsenic. Activated carbon impregnated with iron is used for arsenic removal [73].

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Table 7 : prepration of activated carbon from some widely used feedstocks coupled with activant:

Feedstock	Activating agent	Operating conditions	Reference
Coconut shell	Con. H_2SO_4	Inoculation of H_2SO_4 at 150°C for 24 h.	74
	H_3PO_4	Heating at 150°C	75
		Carbonization at 600°C and activated with H_2SO_4	76
		Treatment with phosgene or chlorine gas at 180°C	77
Almond shell	-	At 606°C ,heating in presence of CO_2	78
	H_3PO_4	Physical activation at 400°C-800°C and chemical activation using H_3PO_4	79
Slurry from fertilizer industry	H_2O_2	Heating at 800°C for 1 h	80
Palm tree cobs	H_2SO_4 or H_3PO_4	Heating at 730°C for 6 h	81
Petroleum coke	H_2O or KOH	Heating at 700-850°C for 4 h	82
Raffination earth	H_2SO_4	850° and 10% (v/v)	83
Algerian coal	KOH or NaOH	930°C	84
Oat hulls	Steam	Pyrolysis at 450°C in presence of inert nitrogen	85
Pine saw dust	$Fe(NO_3)_3/CO_2$	Heating at 850°C for 6 h	86
Eucalytus woodchars	-	700-850°C in presense on CO_2	87
Bituminous coal	ZnCl2	400-700°C in presense on N_2	88

4.1.1.2 Commercial activated carbons:
As(III) and As(V) both are extensively removed from the water by the use of activated carbon as adsorbent [89]. Activated carbon impregnated with various metals like silver and copper are also used for arsenic remediation [90]. Carbon steel wool in combination with activated carbon efficiently removes arsenic and iron–arsenic electrochemical reactions is solely responsible for steel wool's adsorption ability [91].

4.1.2 Low cost adsorbent:

4.1.2.1 Agro products and by products:
The by product from agriculture is currently used as feed for animals or remain unused. Product of such type like rise husk have proven to be good adsorbent for arsenic remediation [92]. Many other agro wastes like wood apple's shell, coconut's shell, almond's shell etc have drawn the attention of the researchers because of the fact that they do their non hazardous nature and very low cost. Moreover, their availability is good and they have all the potential to replace the existing commercial activated carbon or synthetic adsorbent.

Industrial waste or by products:

4.1.2.2 Industrial by products:

4.1.2.2.1 Coals and chars:
Bone char, peat, lignite char and bio char are already doing good in the water treatment industry and showing good future scope as a substitute for commercial adsorbent [93-94]. They are locally available, plentiful and inexpensive. A blend of bone char and hydroxylapatite were used for Arsenic(V) removal from aqueous solution and bone char proved as a very good sorption agent [95]. By product of bio char proven to be an excellent adsorbent and removed As^{3+}, Cd^{2+},
Pb^{2+} from water up to a great extent [96]. Fast pyrolysis of Oak wood, oak bark, pine wood, and pine bark yields their chars at 400°C. pine wood char < oak wood char < oak bark char < pine bark char is the obtained order for As(III) removal.

4.1.2.2.2 Red mud:
When caustic leaching is done to the bauxite ore in the production of alumina, the waste produced is known as red mud. A large amount of red mud is produced in Bayer's process [97]. Red mud is considered to be a god

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alternate for the arsenic removal adsorbent [98].when red mud is subjected to heat and acid treatment increases its adsorptive capacity. For the treatment of arsenical wastewater, researchers suggests the use of red mud in liquid phase [99]. Chemically or physically modified Bauxsol, which is red mud neutralized by sea water when coated with sand or alone acts as a good adsorbent for arsenic contaminated water treatment [100].

4.1.2.2.3 Slag from the blast furnace:

Enormous amount of slag from the blast furnace is generated in the steel production and used for slag cement. In recent times, it is used as economic and effective scavenger and frequently getting used in remediation of aqueous arsenic [101-102]. A novel type of adsorbent is produced by loading of iron(III) oxide on to incinerator slag, as result of which lead to strong bonding of iron oxide with slag because of Fe–Si surface complexes formation. The adsorbent thus formed have good removal capacities for both arsenate and arsenite. Other metallic elements including calcium are also effective for arsenate and arsenite [102]. Oxides of slag coupled with TiO_2 adsorbent is successfully used to done photocatalytic oxidation of arsenite for its removal, the oxidation step was at good pace but adsorption rate was slow [102]. By procts of steel manufacturing like Ca–Fe oxides, iron oxides, calcium hydroxides and elemental iron are tested as adsorbent in a way that all these are placed as permeable reactive barrier for the contro of arsenic release [102]. oxygen gas sludge (OGS), basic oxygen furnace slag (BOFS), electrostatic precipitator dust (EPD), Evaporation cooler dust (ECD) removed arsenate and arsenite effectively.

4.1.2.2.4 Hydroxide waste of Fe(III)/Cr(III):

Fe(III)/Cr(III) are generated as a result of precipitation from the solution when Chromium(VI) compound in the wastewater deduces to Cr(III) under acidic conditions when Chromium(VI) is used as corrosion inhibitors in cooling water systems in industries. The sludge thus produced is discarded as waste. The waste is used by researchers to treat As(V) solution. The result obtained is positive [103]. The waste from electroplating, i.e the chrome sludge also used to treat arsenic solution and its maximum sorption capacity was found to be 21 mg/g [104].

4.1.2.2.5 Fly ash:

The byproduct of coal combustion i.e the fly ash produced in large volumes, large quantity of land and water is required for its disposal. In the past it is being used for the manufacturing of bricks and cement. Bottom ash can also be used as adsorbent [105]. One of the major issue in waste management across the globe is Resource recovery from coal fly ash. Recently enormous efforts are put in in order to make utilization of aluminosilicate as adsorbent which is a chemical compound obtained in fly ash [106]. The fly ash produced in coal power station is immensely examined to make its use in arsenic treatment and considerd to be as good sorption agent for arsenic [107].

4.1.2.2.6 Miscellaneous:

hematite and feldspar are employed to As(V) removal from aqueous systems at differen adsorbent particle size, pHs, and temperatures. The operation followed first order kinetics and fitted Langmuir isotherm. 100% was the maximum removal with hematite at a pH of 4.2 and 97% with feldspar at a pH of 6.2 when the concentration of arsenic was 13.35μmol/L [108]. Recently, Brazilian manganese ore mine's waste known as pisolite are used for arsenic removal [109]. Good removal efficiency for both, As(III) and As(V) are obtained using ferruginous manganese ore and it also does not require any pretreatment [110].

4.1.2.3 Soils and constituents:

4.1.2.3.1 Soils:

Olivier loam, Windsorsand and Sharkey clay were used to study As(V) adsorption kinetics. The initial retention rate of As(V) was rapid and detoriate with increasing time. The sorpion kinetics was well described by multireaction model [111]. Mixture of soil/bentonite were used for fixation and removal of As(III) and As(V). bentonite clays get mixed with Murram soil or Masatsuchi soil. Masatsuchi soil able to remove more arsenic [112]. Wasco, Fallbrook, and Wyo which are three arid soi from California were set to test under varying As concentration, ionic strengths and pH. Low level of background arsenic was detected. Oxidation

of arsenite to arsenate was not detected below 9 pH. The highest affinity was shown by wyo soil for arsenic [113].

4.1.2.3.2 Sand:

Different varieties of sands are tested for remediation of arsenic [114]. Large number of pores and high surface area is there in iron oxide coated sand [115]. Sand coated with iron oxide and Manganese greensand are used to treat arsenic containing tap water, the performance observed was poor [116]. Modified surface of sand prepared by coating of $BaSO_4$ and Fe on quartz sand used for the removal of arsenate and arsenite [117]. Examination of rapid oxidation of arsenite and sorption charecterstics of arsenate was done on the surface of biogenic manganese oxide [118]. Adsorption (single and multicomponent) of arsenate, copper and chromate was done by making use of sand coated with iron oxide. The result shown good adsorption of arsenate and copper on to adsorbent [119].

4.1.2.3.3 Clay minerals:

Clay minerals are hydrous aluminum silicates may be with some amount or not of cations like magnesium and iron. Montmorillionite, illite and kaolinite are typical clay minerals [120]. Clay minerals are in abundance in terrestrial and aquatic environments. They possess large surface area when finally divided and they have great affinity towards anionic, cationic and neutral metal species in terms of adsorption [121-123].

4.1.2.3.4 Zeolites:

Zeolites are hydrated, crystalline, alluminosilicates of alkaline earth and alkali cations, having three-dimensional, infinite structures [124]. Excellent adsorption and ion exchange characteristics of zeolites catching the eye of researchers in the recent time [125]. Its tendency of exchanging the cations without being change in its structure and reversibly gaining and loosing water makes it stand out [126]. Analcime, chabazite, clinoptilolite, erionite, ferrierite, mordenite and phillipsite are some common zeolites [125]. Zeolite modification can be done by ion exchange and used for different metal adsorption.

4.1.2.4 Oxides:

Because of the abundance of oxides and clay mineral in terrestrial and aquatic environment, their use in arsenic removal is prominent. Various types of oxides are used for arsenic remediation and they are discussed below:

4.1.2.4.1 Single oxides:

4.1.2.4.1.1 Manganese dioxide or Birnessite:

In environmental chemistry, minerals of oxides of manganese have important uses. Na- and K-substituted Synthetic birnessite are investigated because of its property to readily adsorb and oxidize As(III) type reduced species and their layered sheet structure allows good adsorption capacity [127-128]. Mechanism of Birnessite's oxidation of arsenite is important and emeeging. As(V) and Mn(II) release to the solution results from the coupling of MnO_2 surface's reductive dissolution with of Birnessite's oxidation of arsenite [129].

4.1.2.4.1.2 Biogenic manganese oxides:

Oxidizing bacteria for manganese-iron catalyzes the oxidation of Mn(II) in surface water. The removal of these bacteria are done by filtration upon which, a coating is formed which acts as arsenic removal agent [130]. This method is considered as an excellent alternative for conventional methods of arsenic removal for the solution having low concentration of arsenic.

4.1.2.4.1.3 Activated alumina:

Large surface area and distribution of micro and macro pore are the characteristics possessed by activated alumina prepared by aluminum hydroxide's thermal dehydration. The environmental regulatory agency of united nation declared Activated alumina as one of the most promising material for arsenic removal. The dependency of adsorption on Activated alumina is mainly on pH and best result obtained at its value equals 7.6 [131]. Iron impregnation on Activated alumina is done for arsenic removal from the drinking water. The result reveals exothermic adsorption of arsenic and very high adsorption yield as in compare to that of Activated alumina alone [132]. Mesoprous alumina was prepared to overcome the flaws in conventional

Activated alumina like slow kinetics, ill defined shape etc. the result yields rapid adsorption kinetics and even pore size distribution [133]. Activated alumina supported by manganese proved to be a very better adsorben for arsenic remediation than Activated alumina [134].

There are various other single oxides iron oxides, Lanthanum hydroxide, Zirconium oxide which are used in combined state witrh other compounds or alone acts as good adsorbent for sorption of arsenic from the solution in a very effective way and the sorption capicites yiel are excellent.

4.1.2.4.2 Mixed oxides:

4.1.2.4.2.1 Portland cement:

Hardened Portland cement is used for the removal of arsenate and arsenite. The result shown better sorption for arsenate then for arsenite [135]. Combination of Portland cement with iron oxide also used as adsorbent [136].

4.1.2.4.2.2 Sea sediments:

MnO2, Fe2O3 and SiO2 are the major constituents of sea nodules and its adsorption characteristics have been investigated for arsenite and arsenate. The results shown was favorable and its removal efficiency is high [137].

Other mixed oxides like Soil aquatic sediments and Mixed rare earth oxides are also examined for arsenic remediation.

4.1.2.5 Metal based adsorbent:

Metal-loaded polymers make use of macroporous polymers, biopolymer gels, cation-exchange resins and chelating agent. Classification is based on metals. A good review of polymers for remediation of arsenic is given [138].
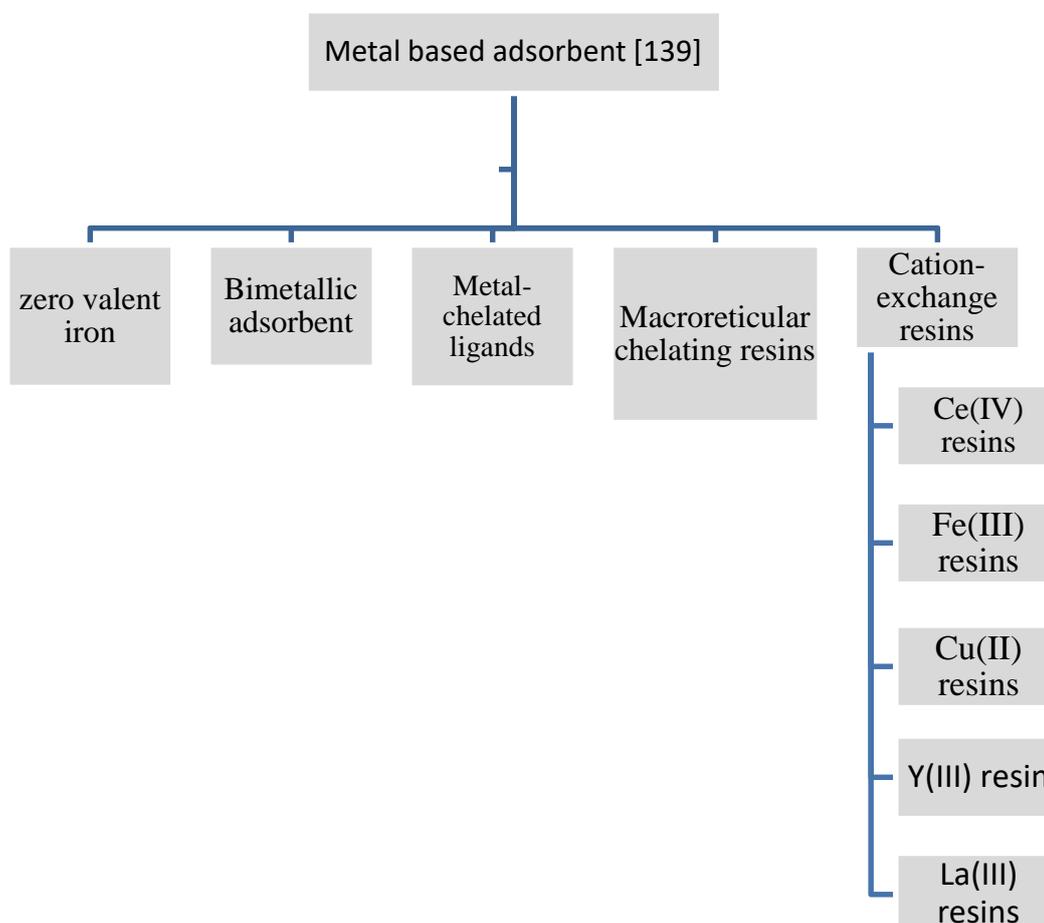
4.1.2.6 Biosorbents:

Biosorbents have strong tenedency to remove contaminants like heavy metals from the aqueous solution. fungi, algae, bacteria are some typical example of Biosorbents. There results for heavy metal remediation are encouraging [140]. Biosorption is a phenomenon in which biomass makes passive metal's immobilization. Metal binding occurs at rapid rate and there is no effect of metabolism on the process [141]. Different types of bioadrobents like Chitin and chitosan, Cellulose sponge, Biomass, Water hyacinth are there which are setting trends in arsenic remediation.

5. Cost evaluation:

The cost of adsorbent made out of the waste was not provided in the literature. The cost actually, depends on the local factors like processing conditions, availability etc. deep discussion regarding the cost was not presented in any paper. The cost of adsorbent vary from country to country depending upon their economic status. The cost of chemical modification are seldom discussed in research papers. Moreover batch studies are shown in most of the research but not the column one. Most of the research which are there in the papers are carried out at laboratory scale. Exploration of pilot plant study and evaluation of cost need to be explored.

6. Conclusions:

Heavy metals being a severe threat to human being and vegetation since ages. They contribute to major part of water pollutant. In our review, documentation of arsenic is done. The ill effect of arsenic on human being and their society is observed. It is clear that none of the technology is fool proof solution for arsenic remediation. Out of the available methods, the adsorption process stands out. Thorough study of activated carbon is done. Removal efficiency and regeneration problem prevails with the activated carbon as only few milligram of metal get removed per gram of carbon. Thus use of commercial activated carbon is expensive. Cost for using activated carbon in developing countries is main issue. Hence there require a cost efficient adsorbent having good adsorption capacity.

Currently the consumption of arsenic containing water by 120 million people is more than 100 times that of the permissible limits of WHO [142]. The maximum impact against the arsenic contamination is suggested as switching to alternate source of drinking water or to gig deep the wells that supply arsenic free water from the old aquifers. This approach lead to a common conclusion that there could apply a number of low cost approaches in developing and underdeveloped nations [143]. At the very end, when these basic approaches exhausted then only mitigation of arsenic contamination by arseic would recive contribution from adsorption technique.

On the households level or community level, the basic screening of the sorption media and the best possible treatment method initially can be extracted using the present review in developing and underdeveloped nations. Various literature are listed for further arsenic removal/adsorption methods ,the cited literature is provided in the reference

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