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Bio sorption of heavy metals by using eco- friendly materials as an alternative source.

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ABSTRACT

During last 2 decades, extensive attention has been paid on the management of environmental pollution caused by hazardous materials such as heavy metals. Heavy metal biosorption is an efficient technology for the decontamination of metals from contaminated site in our environment. The influences of different experimental parameters such as pH, temperature, adsorbent dose, initial concentration plays an important role during the process of phytoremediation and/or biosorption. The microorganisms are capable of accumulating heavy metal ions as biosorbent agents, offering a potential alternative for the detoxification and recovery of precious metals from the waste. This article provides a selective overview of past achievements and present scenario of biosorption studies carried out on some promising natural biosorbents (algae, fungi, bacteria, yeast and some plants and their waste products) which could serve as an economic means of treating effluents with toxic metallic ions.

KEYWORDS: Algae, Bioremediation, biosorbent, fungi, yeast.

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INTRODUCTION

Heavy metals present in the industrial effluent cause health hazards to plants, animals, aquatic life and humans. At high concentrations metals are toxic to animals as they could be dispersed in water and consequently enter the food chain and affect the humans by magnification that causes serious health hazards[1]. Unlike organic pollutants, the majority of which are susceptible to biological degradation, heavy metals do not degrade into harmless end products[2].Treatment processes for heavy metal removal from water include precipitation, membrane filtration, ion exchange, adsorption and co-precipitation/ adsorption. Several methods are being used for the removal of heavy metal ions from aqueous medium by various materials (chemical precipitation, ion exchange, electrochemical treatment, membrane technologies adsorption on activated carbon etc,)[3]. Among the different heavy metals (Copper, Nickel, Zinc, Lead, Mercury, Cadmium and Chromium) Chromium is considered as dangerous one and has become a serious health hazard[4].Chromium is discharged to the environment through various industrial wastes including electroplating, tanning, steel industry, textile dyeing, manufacturing of pigments, refractory materials. Among different oxidation states of Chromium (-2 to +6) only Chromium +3 and +6 are present in the environment of which Chromium +6 is highly toxic due to its oxidizing nature[5]. Heavy metals such as Cadmium, Chromium, Copper and Lead are the main pollutants of fresh water[6], also they carcinogenic and persistent in nature[7].

BIOREMEDIATION

It is a state of the art technique used for heavy metal removal and for the recovery from polluted environments. The technique utilizes biological mechanisms to eradicate hazardous contaminants using microorganisms and plants or their products to restore polluted environments to their original condition.[8, 9, and 10]

The biosorption process involves a solid phase (sorbent or biosorbent; biological material) and a liquid phase (solvent, normally water) containing a dissolved species to be adsorbed (sorbate, metal ions). Due to higher affinity of the sorbent for the sorbate species, the later is attracted and removed by different mechanisms.

BIOSORPTION MECHANISMS:

The biosorption mechanisms are various and are classified according to various criteria:

According to the dependence on the cells metabolism, biosorption can be divided into,

1. Metabolism dependent and
2. Non metabolism dependent

According to the location where the metal removed from the solution is found, biosorption is classified as

1. Extracellular accumulation/ precipitation
2. Cell surface sorption/ precipitation and
3. Intracellular accumulation

Microorganisms, as heavy metal biosorbents offer a new alternative for removal of toxic or valuable metals can be used for remediation processes and it is always recommended that microbe used for bioremediation must have natural decontamination process and the method should be cost effective [11]. Moreover microorganisms can detect very less concentrations of toxic metals which serve as an added return to the remediation process [12].

FACTORS AFFECTNG BIOSORPTION

Temperature does not influence the process of biosorption between the ranges of 20^0-30^0 [13] but, pH seems to be the most important parameter in the process. It affects the chemistry of metals and the activity of the functional groups in the biomass and the competition of metal ions[14, 15]. The lower the biomass concentration there is an increase in the specific uptake. The increase in biomass concentration leads to the interference in the metal accumulation[16].

BACTERIA AS BIOSORBENT

Brierley *et al* [17] reported that *Bacillus* species to have high potential of metal sequestration and has been used in commercial biosorbent preparation. Ilhan *et al* [18] studied that *Staphylococcus saprophyticus* can be used for removal of Cr, Pb and Cu from industrial waste waters and the optimum pH values for Cr, Pb, Cu biosorption were found to be 2.2, 4.5 and 3.5 respectively.

Ping Hu *et al* [19] reported that the bacterium *Caulobacter cresentus* and related stalk bacterial species are known for their distinctive ability to live in low nutrient environments, a characteristic of most heavy metal contaminated sites.

Hima Karnika Alluri *et al* [20] noticed that cell walls of bacteria and cyanobactreia are principally composed of peptidoglycans which consist of linear chains of the disaccharide N- acetyl glucosamine, beta 1, 4 N-acetyl muramic acid with peptide bonds. The phosphodiester of teichoic acid and the carboxyl groups of teichuronic acid contribute to the ion exchange capacity of cell walls.

Lolo Wal Morgan *et al* [21] reported that three isolates were identified up to genus level based on their morphological, cultural, physiological and biochemical characteristics as *Genella* species, *Micrococcus* species and *Haffnia* species showed resistance to lead, chromium and cadmium.

Rocio Garia *et al* [22] observed that the *Bacillus* species showed a high capacity for the uptake of heavy metals (Cd>Cr>Pb>Mn) both in single and in mixed heavy metal solutions. The study indicated that the dead biomass of Bacillus species could be used as an efficient biosorbent material for the removal of heavy metals in aqueous solutions.

Mohammad Umar Mustapha *et al* [23] reported 21 bacterial colonies from electroplating industry. The result showed that isolates MH1, MH4, MH6, MH15 and MH21 were able to tolerate 50mg/l of Cr, Cu, Pb and Cd. MH1 and MH21 can tolerate 200mg/l of cadmium. Their isolates could be used efficiently to remove heavy metal in contaminated industrial effluents.

Rita Evelyne *et al* [24] reported that *Pseudomonas* species of bacteria shows resistance towards chromium. Bacterial strain isolated from electroplating industry showed higher reduction rate.

Munees Ahemad [25] reported that application of multifunctional plant growth promoting bacteria (PGPB) exhibiting chromium resistance and reducing traits when used as bio inoculants with phytoremediation plants, has resulted in a better plant growth chromium remediating efficiency in short time span.

ALGAE AS BIOSORBENT

Hassan Razaei [1] reported that, the biomass generated from the dried *Spirulina* species, was used for evaluating the biosorption characteristics of Chromium ions in aqueous solutions. The effect of agitation time, initial metal ion concentration, pH, temperature and biomass dosage were studied. It was found that the maximum metal uptake was observed at pH 5.0 for Chromium.Gupta *et al* [2] observed the uptake of chromium from aqueous solution by the green algae of *Spirogyra* species.

Kavitha *et al* [26] evaluated the removal of Chromium from aqueous solutions using marine based material using *Gracilaria corticata* powder. The maximum removal efficiency of 93.68% was obtained at a temperature of 323 k, pH of 4, and equilibrium time of 240 minutes at an optimum biosorption dosage of 20g/l of 44 micrometer particle size.

According to study conducted by Wael M Ibrahim *et al* [27] studied the batch adsorption of toxic Cu^{+2}, Cr^{+3}, $Cd^{+2}$and Pb^{+2} ions using marine macro alga *Ulva lactuca* and its activated carbon was examined. The maximum removal efficiency values for Ulva and activated carbon for heavy metal ions were found to be 64.5 and 82 mg/g for Cr^{+3} and 68.9 and 83.3 mg/g for Pb^{+2}.

FUNGI AS BIOSORBENT

Naba Kumar Mondal *et al* [28] reported that *Aspergillus niger* can be used as a biosorbent to remove Cr (6) from aqueous solution. *Aspergillus niger* showed the highest adsorption capacity at 11.792 mg/g at pH 2.0. Desorption study showed that nearly 94% of Cr (6) adsorbed on *Aspergillus niger* could be desorbed using 0.5 M EDTA.

M Fadel *et al* [29] studied that *Saccharomyces cerevisae* F-25 in alive form was found to be highly biosorbent for Mn^{+2} and biosorbed 22.5 mg Mn^{+2}/g yeast biomass. The optimum concentrations for maximum Mn^{+2} biosorption by *Saccharomyces cerevisae* in alive form were 4.8 mg Mn+2/l after 30 minutes at pH 7, agitation 150 rpm and yeast biomass concentration 0.1 g/ l at 30 degree centigrade.

Yunsong Zhang *et al* [30] reported that *Saccharomyces cerevisae* is one of the most common microorganisms available in large quantities are the by-product of the fermentation or pharmaceutical industry processes. It could be utilized as a biosorbent to remove or accumulate heavy metals, such as Cu^{+2}, Cd^{+2}, Pb^{+2} and Hg^{+2}etc, from waste water. The maximum adsorption capacity 88.16 mg/g for Pb^{+2} at pH 5.5, 40.72 mg/g for Cd^{+2} at pH 6.0 was obtained at 10 degree centigrade.

Rita Evelyne *et al* [31] reported that, in case of fungus as biosorbent, *Trichoderma* species could absorb Cr 6 onto its cell wall surface. The maximum efficiency of 97.39% was obtained at 5.5 pH. Helena Kshemiska *et al* [32] reported that a comparative study showed the sensitivity of the yeast *Pichia guilliermondii* to Cr (3) and Cr (6) as well as the uptake potential at growth inhibitory concentrations of chromium.

PLANTS AS BIOSORBENTS

Ahalya *et al* [33] 2008 reported that *Tamarindus indica* pod shells have the capacity to absorb Chromium (6) following the chemisorptions mechanism and ion exchange method. According to Hima Karnika Alluri *et al* [3] suggested that seaweeds due to large surface area have several advantages for biosorption as they contain many polyfuntional metal binding sites for both cationic and anionic metal complexes.

According to study conducted by Khairia M Al-Qahtain *et al* [34] studied the use of several cortex fruit wastes, including banana, kiwi and tangerine peels, for removing toxic and heavy element like Cd, Cr, and Zn ions from aqueous solutions. The result showed that kiwi and tangerine cortex with 1mm particle size showed better biosorption capability compared to banana cortex. Further they concluded that the natural biosorbent was effective for the removal of pollutants from an aqueous solution.

Hala Ahmed Hegazi [35] reported that the agricultural and industrial waste by- products such as rice husk and fly ash used for the elimination of heavy metals from waste water, results showed that low cost adsorbents can be efficiently used for the removal of heavy metals wit concentrations range of about 20-60mg/l. Further rice husk was effective in the removal of Fe, Pb and Ni where as fly ash was effective in the removal of Cd and Cu. Further Qaisar Manzoor *et al* [36] also studied the *Zea mays* immobilized biomass for adsorption of chromium (3) and chromium (6) were adsorbed up to 277.57 and 208.6mg/l.

Wiwid Pranata Putra *et al* [37] investigated the efficiency of coconut tree saw dust, eggshell and sugarcane bagasse as alternative for the removal of Cu, Pb and Zn ions from aqueous solutions. Batch adsorption studies were carried out to evaluate the effects of pH and concentration on adsorption capacity. The optimum biosorption condition was found at pH 6.0, 0.1 g biomass dosage and at 90 minutes equilibrium time. The maximum adsorption capacities estimated from Langmuir's isotherm model for Cu, Pb and Zn were 3.89, 25.00 and 23.81 mg/g for coconut tree saw dust, 90.9 and 35.71 mg/g for eggshell and 3.65, 21.28 and 40.00 mg/g for sugarcane bagasse respectively.

Rita Evelyne *et al* [38] reported that, in plants the biosorption depends on translocation and accumulation of Cr inside the plant depends on the oxidation state of the supply, concentration of chromium in the media, as well as plant species. *Callitriche caphocarpa* (water- starwort) an aquatic widespread was found to an excellent chromium accumulator.

CONCLUSION

Biosorption is being demonstrated as a useful alternative to conventional systems for the removal of toxic metals from environment. The development of the biosorption process requires further investigation in the direction of modelling, regeneration of biosorbent material and for testing of immobilized raw biomasses with industrial effluents. Due to the extensive research and significant economic benefits of biosorption, some new biosorbent materials are poised for commercial exploitation. The major advantages of biosorption over conventional treatment methods include low cost, high efficiency, minimization of chemical and biological sludge, and regeneration of biosorbent and possibility of metal recovery.

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