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BIOSORPTION: A GREEN APPROACH FOR HEAVY METAL REMOVAL FROM WATER AND WASTE WATERS

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ABSTRACT: Biosorption is an efficient technique for the removal of heavy metal contaminants from water or waste water. The water pollution due to heavy metals is one of the challenging issues in the world. The conventional methods are applying for the removal processes of heavy metal are expensive or takes long time or has less efficiency or not economical. As the availability of cheap bio sorbents, it becomes more reliable and economical process. Most of the biosorbents are waste materials of the part of animal and plants and their efficiency can increase by their chemical modifications. Biosorption process not only used to remove heavy metals but can also be used in the metal recovery. Metals cannot invent in laboratories or industries but they persist in the water bodies. Most of heavy metals are essential for the growth and development of organism below the considerable limits but beyond the limit they are definitely hazardous to all living organisms. Biosorption process is a part of sustainability and can remove the metallic pollutant at their sources and minimize the fresh water pollution. Cost is also an effective parameter for applying a process in the large scale and biosorption is very cheap and requires minimization of chemicals or instruments/apparatus.

KEYWORDS: Biosorption, Metallic pollutants, Removal processes, Cost, Recovery

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1.INTRODUCTION

The uncontrolled discharge of waste waters from different industries is a serious environmental problem encountered in many parts of the world [1]. Water pollution due to heavy metals has become one of the major environmental problems that causes serious health hazards [2]. The heavy metals are

major inorganic contaminants due to their toxicity and mobility in water [3]. Contamination of the environment with heavy metals has increased beyond the recommended limit and is harmful to all life forms [4-6]. Heavy metals are among the leading health concerns all over the world because of their resulting long-term cumulative health effects [7]. The toxicity and bioaccumulation tendency of heavy metals in the environment is a serious threat to the health of living organisms [8]. Some heavy metals are essential for the growth and development of the living organisms under considerable limits. The majorities of heavy metals are toxic even at very low concentrations and are capable of entering in the food chains. Through food chain they can accumulate in the cells and tissues of living organisms and can cause serious problems [9]. Their nature on human may be toxic, neurotoxic, carcinogenic and mutagenic [10]. The exposure of heavy metals into natural environment may due to natural or anthropogenic activities. The natural sources of heavy metals in the environment are metal corrosion, volcanic eruption, weathering, soil erosion, leaching and sediment re suspensions. The anthropogenic activities for heavy metal exposure are refineries, coal burning in power plants, high tension lines, textiles, plastic, microelectronics, and wood preservation and paper processing plants [11-18]. Conventional method used for the removal of metals and heavy metals from water or waste water are chemical precipitation, carbon adsorption, ion exchange, evaporations and membrane processes, ultra filtration, electro winning, pre concentration and reverse osmosis [19-22]. The biosorption process used for the removal processes is an efficient, low cost, takes no longer time, harmless to environment and economical [20-25].

BIOSORPTION AND BIOSORBENTS:

Biosorption can be defined as the capability of the biological materials to take up heavy metals from water or wastewaters through metabolically or physico-chemical pathways of uptake or as the property of certain biomass to bind and concentrate selected metal ions or other contaminants from aqueous solutions [26-28].The mechanism of biosorption depends on the type of biomasses and its properties, chemical nature of water or waste water and atmospheric conditions [27]. The mechanism of biosorption is two types' metabolism dependent and metabolism independent [29]. The uptake of metal ions through cell wall or cell membrane is depending on the cell's metabolism. Such type of metabolism generally takes place in living cells and depends on the reaction of metal ions with an active defense system of the various microorganisms. In non metabolism dependent biosorption mechanism, metal uptake takes place through physical adsorption, ion exchange and chemical sorption. Cell walls of microbial biomass, mainly composed of polysaccharides, proteins and lipids have different functional groups for interactions with metal ions such as aldehydic, ketonic, amide, carboxyl, sulphate, phosphate and amino groups. This type of biosorptionusually rapid than metabolism dependent mechanisms and can be reversible [30,31]. The metal uptake by biosorbent is measured by the parameter q_e, it is the amount of metal accumulated per gram of biosorbent. The mechanism of biosorption is effected by different factors i.e. pH of metallic solutions, amount of

biosorbent, temperature and concentration of metallic solutions. The optimized conditions i.e. lower metal ion concentration, higher acidic pH , higher dosage of biosorbent and moderate temperature have been observed for the biosorption process applying for the removal of heavy metals from waste waters in a large scale [30-34].Any biological waste or excess material that can remove metallic pollutants from water or waste water is generally termed as biosorbents. Biosorbents are cheaper, more effective alternatives for the removal of metallic elements, especially heavy metals from aqueous solution. The biosorbents, unlike mono functional ion exchange resins, contains variety of functional sites including carboxyl, imidazole, sulphydryl, amino, phosphate, sulfate, thioether, phenol, carbonyl, amide and hydroxyl moieties [19]. The main characteristics of biosorbents are listed below:

1. High adsorption capacity.
2. They should be readily and abundantly found in a location.
3. Cheap or low priced or low economical value.
4. Possible metal recovery. The attached metal on biosorbent should be easily recovered and biosorbents reusable.

Various potential biosorbents cited in the literature have been used for the removal of various metal ions such as Cu (II), Pb (II), Zn (II), Cd (II), Cr (VI), Hg (II), Ni (II) and Fe (II) from waste waters (Fig.1). These biosorbents are Rice husk [35,36], Wheat waste [37], Coconut waste [38], Walnut shell [39], Sago husk ash [40], Chest nut shell [41], Peanut hull [42], Lemon peel [43], Coir pith waste [44], Mango peel [45], Banana peel [46], Orange peel [47], Coconut coir pith [48], Tea waste [49], Deodar leaves [50] and Banjh leaves [51]. The capability of microorganisms to bind metal ions is a well-known trend. The common category of micro organisms includes algae, fungi and bacteria can also be potential biosorbents. The bacterial species *Pseudomonapacitida*, *Anthrobacter*, *E. coli* and *Enterobacter sp.* have been used for the removal of Zn (II), Cd (II), Cr (VI) and Ni (II) [52-54]. The common algal species such as *Spirogyra sp*., *Sargassumummuticum*, *Chlorella miniata*and *Spirulina platensis* were found to be potential biosorbents for Pb (II), Zn (II), Cd (II) and Cr (VI) [55-58]. The better biosorption capacity of some fungi was found to remove Cd (II), Ni (II), Cu (II) and Cr (VI) from the waste water [59-66].

Common Natural Biosorbents

(available abundantly)

⇓

Contain Multi-Functional Groups To Bound Heavy Metal Ions

⇓

Algae, fungi, bacteria, waste plant leaves, barks, peels, agriculture crop wastes, hulls, shells, waste roots and stems,weeds and some waste and dead animal parts

Fig. 1 Some commonly used biosorbents

ADVANCES OF BIOSORPTION OVER CONVENTIONAL METHODS:

The conventional methods used for the removal of metals or heavy metals are not more efficient, expensive, takes longer time for removal process, incomplete removal, generates toxic compounds and sludge that requires safe disposal and cannot apply for a large scale economical removal process. Biosorption have following advantages over conventional methods-

1.The process is based on the choice of biosorbents and which is generally abundant. It is therefore, the biosorption process is very cheap.

2.Regeneration is possible in biosorption process. The biosorbent can be reused and make the process more economic.

3.The metal may be recovered from the surface of biosorbent after being adsorbed from the waste waters.

4.The effectiveness of the process can be enhanced as applying the optimized conditions i.e. high acidic pH, lower metal ion concentrations, higher dosage of sorbents, moderate temperatures and suitable contact times.

5.The performance of biosorbents can be increased by their chemical modifications, reducing particle size and also by adding some artificial adsorbents.

6.Biosorption is capable for the competitive performances as very similar to ion exchange processes. Although the biosorption is a reliable removal process but some disadvantages may effect on its performances. The main disadvantages are early saturations and metal desorption is necessary for the reuse of biosorbents, the improvement of biosorbents cannot possible through genetic engineering and it have no potentials for altering metal valency states [20].

RECENT STUDIES:

Many reports have appeared on the development of low – cost adsorbents prepared from cheaper and readily available materials [67-73]. Solid substance with large surface area, micro porous character and chemical nature of their surface have made them potential adsorbents for the removal of heavy metals from industrial waste water [74]. The adsorption behavior of peanut husk charcoal, fly ash, and natural zeolite for the removal of Cu (II) and Zn (II) ions from waste water was reported by Salam and coworkers [75]. The experimental results showed that peanut husk charcoal, fly ash and natural zeolite all were potential biosorbents to take cationic heavy metal species from industrial wastewater in the order fly ash < peanut husk charcoal < natural zeolite. The maximum adsorption capacity (qe) of Cr (VI) and Ni (II) ions on to the surface of cyanobacterial biomass was found 103.09 and 84.75 mg/g respectively by Das [76]. The experimental results show that dried biomass of Oscillatorialaete-virens was a potential biosorbent to remove Cr (VI) and Ni (II) ions from polluted water. The biosorption of Hg (II) ions on some fungal biomasses Aspergillus flavus I–V, Aspergillus fumigatus I-II, Helminthosporium sp., Cladosporium sp., Mucorrouxii mutant, M. rouxii IM-80, Mucorsp 1 and 2, and Candida albicans, was carried out by Juarez et al [77]. The biomasses of the

fungus M. rouxii IM-80, M. rouxii mutant, Mucor sp1, and Mucorsp 2 were very efficient removing the mercury from aqueous water, using dithizone, reaching the percentage of removals: 95.3%, 88.7%, 80.4%, and 78.3%, respectively.Shouman [78] et. al. considered the waste of palm branches (PB) was able to remove chromium (VI) from aqueous solution by batch and column experiments. The results of Cr (VI) removal performances were pH dependent. The maximum adsorption capacity obtained from the Langmuir model for the chitosan coated oxidized palm branches was found 55 mg/g.The Fava Beans were used by Etorki [79] et. al. as low cost adsorbent material for removal of Pb (II), Cd (II) and Zn (II) ions from aqueous solutions. The recorded biosorption of Fava beans for selected heavy metals was 100% for Pb (II), 92.86% for Cd (II) and 36.86 for Zn (II) at 2 g dose amount of Fava beans powder.Sugarcane Bagasse has been used for the removal of Cd (II) and Ni (II) from aqueous solutions by Tchoumou and cowrkers [80]. The maximum adsorption capacity was observed, 7.88 mg/g for Ni (II), and 14.31 mg/g for Cu (II) onto Sugarcane Bagasse, which indicates that Bagasse adsorbs more Cu (II) than Ni (II) under the same batch conditions. The use of groundnut shell as an low cost biosorbent for the removal of copper, lead and zinc was reported by Janyasuthiwong [81] et. al. The highest removal efficiencies with groundnut as the adsorbent were 85% at pH 5.0 for Cu and 98% at pH 3.0 for Pb and Zn. The biosorption of Pb (II), Zn (II) and Ni (II) from contaminated water using Stenotrophomonasmaltophilia and Bacillus subtilis was investigated by Wierzba [82]. The adsorption capacity of the three metals was calculated 133.3, 47.8 and 54.3 mg/g for Pb (II), Zn (II) and Ni (II), respectively. Lead biosorption on to the waste biomass of Pseudomonas aeruginosa and Enterobacter cloacae was investigated by Bojórquez et. al. [83]. About more than 72 percent lead was removed by both biomasses. The waste materials such as coconut tree sawdust (CTS), eggshell (ES) and sugarcane bagasse (SB) as low-cost biosorbents for the removal of Cu (II), Pb (II) and Zn (II) ions from waste water solutions was investigated by Putra and coworkers [84]. The maximum adsorption capacities of Cu (II), Pb (II) and Zn (II) were 3.89, 25.00 and 23.81 mg/g for CTS, 34.48, 90.90 and 35.71 mg/g for ES, and 3.65, 21.28 and 40.00 mg/g for SB, respectively.

CONCLUSION:

The present review article discusses the introduction of biosorption and heavy metals, advances of biosorption over traditional methods, recent information regarding the utilization of waste materials as biosorbents and a detailed review of literature aspect biosorption. Recently, a large number of naturally found materials have been used for the removal process. The area of biosorption can be enlarged; if the other industrial and domestic wastes are utilized with the naturally occurring materials. Some waste product from industrial and agricultural activities and natural materials represents potentially economical alternative. Research is still in progress as different areas related to biosorption are being explored.

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