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Microorganisms and Biosorption of Heavy Metals in the Environment: A Review Paper

Mohammed Umar Mustapha[1]* and Normala Halimoon[2]

[1]*Desert Research Monitoring and Control Centre, Yobe State University, Damaturu, Nigeria*
[2]*Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, Serdang, Selangor, Malaysia*

Abstract

Industrial waste water and sediment containing heavy metals causes many ecological and health related problems. Many conventional methods were already being used to decontaminate the environment from adverse effect of these pollutants but yet most of the methods used are very expensive and far away from their best possible performance. The capability of microorganisms to bind metal ions is a well-known trend. Different experimental data are documented and presented for different metals and biomass types. In this review a brief overview of the potential of biosorbents and biosorption processes were critically reviewed. This briefly describes biosorption process and some of the analysis of different low-cost biosorbents used for heavy metal remediation from waste stream.

Keywords: Microbes; Potential; Heavy metals; Biosorption

Introduction

Heavy metal pollution has become one of the major environmental problems that pose serious health hazard [1]. Different type industries use different type of heavy metals and directly or indirectly discharge wastewater containing toxic substances into the environment [2].

Trace amounts of heavy metals are required by living organism including copper, iron, zinc but however excessive levels of these metals can be toxic to the organism due to their toxicity and accumulation behavior [3].

Different methods have being used to decontaminate the environment from adverse effect of these pollutants but yet most of the methods used are not cost effective and far away from their best possible performance [4].

Consequently the need to replace with biological method with are cheap and efficient method of treating metal-bearing effluents as these method may provide a possible way out to metal removal from contaminated environment [5].

Sources of Heavy Metals

The world anthropogenic emissions are larger than or equivalent to natural emissions for the majority of trace metals [6] the metals ions coming from anthropogenic sources may be accumulated in aquatic organisms and transfer to humans through the food web. Consequently, human health risks may occur because water organism contaminated by heavy metals can cause many health related problems [7,8].

Biosorption by Microbes

Biosorption can be defined as the removal of metal or metalloid species, compounds and particulates from a solution by low cost biological materials [9]. All biological materials can be useful biosorbents for metals sequestration with the exception of mobile alkali metal cations like sodium and potassium ions, and this can be a significant passive process in living and dead organisms [10] several cheap biosorbents for the removal of metals mainly arrive under the following categories: bacteria, fungi, algae, plants, industrial wastes, agricultural wastes and other polysaccharide materials [11]. In general, all types of biomaterials used for biosorption were found to have good biosorption capacities towards all types of metal ions. Many researchers study the biosorption for heavy metal removal which involved the use of either laboratory-grown microorganism or biomass generated by different processing industries or wastewater treatment units [12,13].

Mechanism Involved in Biosorption

Microbes are organisms that are capable of tolerating unfavorable circumstances, and these mechanisms evolved for the past millions of years [14]. The ability of microorganisms, example bacteria, fungi, algae and plants biomass to remove heavy metal ions and radionuclide and, or to promote their transformation to less toxic forms has attract the attention of various environmental scientist, engineers and biotechnologist for many decades. Therefore, various concepts for bio-removal of heavy metals from waste streams and bioremediations of contaminated environment are being anticipated, some of which were brought to pilot or industrial level [15-21]. There are many mechanism involve in biosorption some are not fully understood. Biosorption mechanism may be classified according to dependence on the cell's metabolism which is called metabolism dependent or according to the location where the metal removed from solution is found which is called Non -metabolism dependent/ metabolism independent like extra cellular accumulation/ precipitation, Cell surface sorption/ precipitation and Intracellular accumulation [22,23].

During metabolism independent, metal uptake is by physicochemical interaction between the metal and the functional groups present on the microbial cell surface. This is based on physical adsorption, ion exchange and chemical sorption, which is not dependent on the cells' metabolism [24]. Cell walls of microbial biomass, mainly composed of polysaccharides, proteins and lipids have abundant metal binding groups such as carboxyl, sulphate, phosphate and amino groups

***Corresponding author:** Mohammed Umar Mustapha, Desert Research Monitoring and Control Centre, Yobe State University, Damaturu, Nigeria, Tel: +234 (803) 625 0046; E-mail: umardrc@gmail.com

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[24,25]. This type of biosorption, i.e., non-metabolism dependent is relatively rapid and can be reversible as explain in details in Figure 1.

These detoxifying mechanisms of bacterial can be categories into:

i. Intracellular sequestration

ii. Export keeping the toxic ion out of cell by altering a membrane transport system involved in initial cellular accumulation.

iii. Reduced permeability

iv. Extracellular sequestration by specific mineral-ion binding. Extracellular detoxification of the toxic cations or anions by enzymatic conversion from a more toxic to a less toxic form (Tables 1-4).

Bacteria as Biosorbents of Heavy Metals

Bacterial biosorption is mainly used for the removal of pollutants from effluents contaminated with pollutants that are not biodegradable, like metals ions and dyes. However, their isolation, screening and harvesting on a larger scale may be complicated but still remain one of the efficient way of remediating pollutants. Different bacterial strains were used for the removal of different metal ions. Table 1 below shows the biosorption capacity of different metal ions by different bacterial biomass. Bacteria have evolved a number of efficient systems for detoxifying metals ions they develop these resistance mechanisms mostly for their survival.

Algae as Biosorbents of Heavy Metals

Algae are efficient and cheap biosorbents as the requirement of nutrient by algae is little. Based on statistical analysis on algae potentiality in biosorption, it has been reported that algae absorb about 15.3% - 84.6% which is higher as compared to other microbial biosorbents. In all the type of algae brown algae was known to have high absorption capacity. Biosorption of metal ions occurs on the cell surface by means of ion exchange method. Brown marine algae has the capacity to absorbed metals like Cd, Ni, Pb through chemical groups on their surface such as carboxyl, Sulfonate, amino, as well as sulfhydryl.

Fungi as Biosorbents of Heavy Metals

The use of fungi as bio sorbents material has been shown to be efficient material is also one of the cost-effective and eco-friendly methods with serves as an alternative to chemically bound treatment process. The capability of the many type of fungi to produce extracellular enzymes for the assimilation of complex carbohydrates for former hydrolysis makes capable the degradation of various degrees of pollutants. They also have the benefit of being relatively uncomplicated to grow in fermenters, therefore being appropriate for large scale production. Another benefit is the easy separation of fungal biomass by filtration because of its filamentous structure. In comparison to yeasts, filamentous fungi are less sensitive to variations in nutrients, aeration, pH, temperature and have a lower nucleic content in the biomass [26,27].

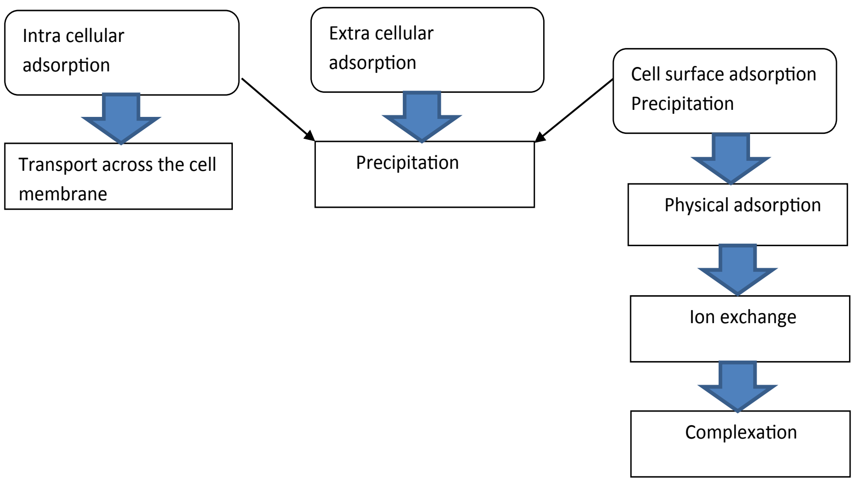

Figure 1: Mechanisms of biosorption based on location of where metal removed are found [28].

S/N	Heavy Metals	Sources
1.	Chromium	Electroplating industry, leather, chrome plating, petroleum refining, tanning, textile manufacturing and pulp processing units. It exists in both hexavalent and trivalent forms
2.	Copper	Electroplating industry, metal refining, plastic industry and industrial emissions
3.	Cadmium	Metal smelting and refining, phosphate fertilizers, Paint pigments, pesticides, plastics, polyvinyl and copper refineries.
4.	Lead	Automobile batteries, Petrol based materials, pesticides , Paints
5.	Nickel	Metal refining, galvanization, paint and powder, batteries processing units, and super phosphate fertilizers.
6.	Zinc	Rubber industries, paints, dyes, wood preservatives and ointments.
7.	Mercury	Emissions from industries producing caustic soda, Thermometers, adhesives, paints, light bulb industry, wood preservatives, leather tanning, ointments producing industry
8.	Iron	From metal refining, galvanization engine parts.
9.	Arsenic	Semiconductors, petroleum refining, wood preservatives, animal feed additives, coal power plants Automobile exhaust, industrial dust and dyes.

Table 1: Some of the common industrial units releasing toxic heavy metals into environment are listed below [29].

Metal ion	Bacterial species	Biosorption capacity (mg/g^{-1})	pH	References
Zinc (Zn)	*Pseudomonas putida*	17.7	5	
	Bacillus jeotgali	222.2	7	[30]
Copper Cu(ii)	*Enterobacter sp.* J1	32.5	5	[31]
	Arthrobacter sp.	17.87	5	[32]
Chromium Cr(vi)	*Pseudomonas fluorescence*	40.8	2	[33]
	Pseudomonas sp	95	4	[34]
Nickel Ni(ii)	*E. coli*	6.9	2.7-3.6	[35]
	Pseudomonas fluorescence	40.8	2	[33]
Cadmium Cd(ii)	*Enterobacter sp.* J1	46.2	6	[35]

Table 2: Bacterial species used for the removal of different heavy metals.

Metal removed	Algal species	Biosorption capacity (mg/g)	References
Lead	*Spirogyra* sp.	140	[36]
Zinc	*Sargassum muticum*	34.10	[37]
Cadmium	*Ulva lactuca* sp.	43.02	[38]
Lead		181.82	[38]
Cadmium	*Sargassum* sp.	84.7	[39]
Chromium	*Chlorella miniata*	34.60	[40]
Cupper	*Spirulina platensis*	67.93	[41]

Table 3: Different species algae and their biosorption capacity.

Fungal species	Metal ion	Biosorption capacity (mg/g)	References
Aspergillus niger	Pb	34.4	[42]
	Cu	28.7	[43]
Penicillium simpliccium	Cd	52.50	[44,45]
	Zn	65.60	[44,46]
Saccharomyces cerevisiae	Pb	270	[14,47]
	Hg	64.2	
Penicillium chrysogenum	Ni	260	[48,49]
	Pb	204	
	Cu	92.0	[50]
Penicillium purpurogenum	Cr(Vi)	36.5	[50-53]

Table 4: Fungal species used and their biosorption capacity.

Conclusion

Microbial biomass is one of the low-cost and efficient biosorbents of heavy metals removal from solutions. The process of biosorption has many attractive features including removal of metals ion over relatively broad range of pH and temperature. Many researchers studied biosorption performance of different microbial biosorbents which provide decent arguments for the implementation of biosorption technologies for heavy metal removal from solutions and also to understand the mechanism responsible for biosorption. Consequently, through unrelenting effort and research, above all full-scale on pilot and biosorption process, the situation is expected to change in the near future, with biosorption technology becoming more beneficial and eye-catching than currently used physicochemical technologies of heavy metal removal.

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