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Sequestering of Heavy Metals by Bio-sorption

Veeresh Halemane[1] and Dr. Vijayakumar Durg[2]

Assistant Professor, Department of Chemistry, Government First Grade Degree College, Humnabad, Karnataka, India[1]

Professor, Department of Chemistry, Bheemanna Khandre Institute of Technology, Bhalki, Karnataka, India[2]

veereshhalemanechem@gmail.com and vijayakumardurg@gmail.com

Abstract: *Fresh water represents 3% of water assets on the Earth. Human and mechanical exercises produce and release squanders containing overwhelming metals into the water assets making them inaccessible and undermining human wellbeing and the environment. Regular strategies for the evacuation of metal particles, for example, compound precipitation and layer filtration are very costly while treating a lot of water, wasteful at low groupings of metal (inadequate metal expulsion) and create enormous amounts of slop and other dangerous items that require cautious removal. Bio-sorption and bioaccumulation are ecofriendly options. These elective strategies have points of interest over customary techniques. Plentiful characteristic materials like microbial biomass, agro-squanders, and modern results have been recommended as potential biosorbents for overwhelming metal evacuation because of the nearness of metal-restricting practical gatherings. Biosorption is affected by different procedure parameters, for example, pH, temperature, beginning grouping of the metal particles, biosorbent portion, and speed of fomentation. Likewise, the biomass can be adjusted by physical and substance treatment before use. The procedure can be made affordable by recovering and reusing the biosorbent in the wake of expelling the overwhelming metals. Different bioreactors can be utilized in biosorption for the expulsion of metal particles from enormous volumes of water or effluents. The ongoing improvements and the future degree for biosorption as a wastewater treatment alternative are talked about.*

Keywords: Bio-sorption , heavy metal, isotherm, bioreactors

I. INTRODUCTION

Water assumes a significant job on the planet economy. Dominant part (71%) of the Earth's surface is secured by water, yet crisp water comprises a miniscule division (3%) of the aggregate. Water fit for human utilization is acquired from the crisp water bodies. Around, 70% of the crisp water goes to horticulture. This regular asset is getting rare at numerous spots and its inaccessibility is a significant social and financial concern [1]. In spite of the fact that entrance to safe drinking water has improved throughout the most recent couple of decades, it is assessed that 5,000,000 passings for each year are caused because of utilization of dirtied drinking water or dry spell. In many creating nations, 90% of all wastewater despite everything goes untreated into the crisp water bodies making it unfit for human utilization, which either prompts shortage or influences the human populace [2]. The worry to ensure new water bodies for a sound populace is a test as of late.

Industrialization to a bigger degree is answerable for the sullying of condition particularly water where lakes and streams are overpowered with an enormous number of dangerous substances. Overwhelming metals are arriving at dangerous levels when contrasted and the other lethal substances [3]. Overwhelming metals are a remarkable gathering of normally happening mixes. Their persistent discharge prompts overconsumption and collection. Subsequently, individuals around the world are presented to unfavorable outcomes of these substantial metals. Numerous businesses (manures, metallurgy, cowhide, aviation, photography, mining, electroplating, pesticide, surface completing, iron and steel, vitality and fuel creation, electrolysis, metal surface treating, electro-assimilation, and apparatus producing) release squander containing substantial metals either straightforwardly or by implication into the water assets [4]. Lethal substantial metals, which are of concern, are chromium (Cr), lead (Pb), zinc (Zn), arsenic (As), copper (Cu), nickel (Ni), cobalt (Co), cadmium (Cd), mercury (Hg, etc. As these metals are not biodegradable, they will in general amass in the living creatures and lead to different infections and clutters which eventually undermine human life. They can cause sick wellbeing, in any event, when present in the scope of parts per billion (ppb) [5]. Biosorption has developed as an appealing choice over ordinary techniques for the expulsion of overwhelming metal particles from effluents released from different businesses which at last reach and dirty crisp water bodies. This section reports the poisonous quality of substantial metals, the benefits of biosorption, different biosorbents utilized for the expulsion of metal particles, impact of immobilization and changes of biosorbents, different variables influencing the procedure of biosorption, diverse bioreactors utilized in biosorption, and the use of biosorption for the expulsion of metal particles from different wastewaters like mechanical effluents and debased water assets. The ongoing advances, current status, and eventual fate of the procedure are talked about.

Toxicity of heavy metals

The pathway of presentation for overwhelming metals is predominantly through inward breath, dermal contact, and ingestion. The individual metal shows its own particular indications of poisonous quality [6]. The seriousness of wellbeing impacts is reliant on schedule and portion, the sort of overwhelming metal, and its compound structure. The idea of impact might be dangerous, mutagenic, neurotoxic, teratogenic, or cancer-causing [6]. Numerous examinations detailed that substantial metals influence cell organelles and interface with cell parts causing cell harm and apoptosis. Indeed, even at a low degree of introduction, they actuate different organ harm. Inebriation of substantial metals additionally prompts harm to the significant frameworks in the body and may prompt an expanded hazard in creating diseases [7]. Metal particle contamination is exceptionally determined, and the vast majority of them are nonbiodegradable. The nearness of different overwhelming metals, for example, chromium (Cr), lead (Pb), zinc (Zn), arsenic (As), copper (Cu), nickel (Ni), cobalt (Co), cadmium (Cd), and mercury (Hg) causes unsettling influences in circulatory, gastrointestinal, and sensory systems. They likewise influence different organs and lead to visual deficiency, deafness, mind harm, loss of fruitfulness, malignant growth, and numerous other extreme medical issues that at last reason demise of the person.

Bio-accumulation and bio-sorption

In view of the disadvantages associated with conventional methods for metal removal, there is a need for alternative, cost-effective technologies. In recent years, biosorption/bioaccumulation processes have been considered as novel, economic, efficient, and eco-friendly alternative treatment technologies for the removal of heavy metals from contaminated wastewaters generated from various industries.

Bio-accumulation

Bioaccumulation is a metabolism-mediated active process in which the metal ions accumulate the biosorbent intracellularly in the living cells. The process occurs in two steps: the first step is the adsorption of metal ions onto cells, which is quick and identical to biosorption, and the later step is slower which includes the transport of metal species inside the cells by active transport [25]. Unlike biosorption, it is an irreversible, complex process which depends on the metabolism of the cells. The process of bioaccumulation occurs by cultivating the biomass of a microorganism in the vicinity of the metal to be accumulated. Since the solution contains the growth medium, the organism begins its metabolic processes and activates the intracellular transport systems for the accumulation of the sorbate. However, the major limitation of the process is that the nutritive medium for growth of the microorganism contains organic carbon sources [26, 27]. Bioaccumulation is an active process which requires a living biosorbent and is mediated by the metabolism of the microorganism used. The process operates by cultivating the microbe in the presence of a metal ion which has to be removed. Part of the biosorbate accumulates inside the cell which enables the biomass to increase and bind greater amounts of metal ions. The organisms which are capable of resisting high loads of metal ions are best suited for accumulating metal species. They do not possess any mechanisms for hindering the accumulation of metal ions in large quantities [28]. They may possess special mechanisms for synthesizing special intracellular binding regions rich in thiol groups as a response to metal ions in their surviving environment. It was found that morphology and physiology of the cell changes upon increase in concentration of the metal ion to be accumulated [29]. Efficient bioaccumulation can be achieved by selecting the microbes that are screened from polluted environments [30]. Pichia stipitis yeast was capable of bio-accumulating Cu (II) and Cr (III) with the maximum uptake capacity of 15.85 and 9.10 mg/g, respectively, from aqueous solutions with an initial concentration of 100 ppm at pH 4.5 [31]. Aspergillus

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niger was capable of removing Cu (II) and Pb (II) with the maximum uptake capacity of 15.6 and 34.4 mg/g, respectively [32]. Table 1 summarizes some more examples of biosorbents used for metal bioaccumulation.

Biosorbent type	Metal ion	Uptake capacitya (mg/g)	Reference
Pichia guilliermondii	Cu (II)	20	[1]
Aspergillus niger	Pb (II)	172.25	[2]
Aspergillus flavus	Cu (II)	93.65	
Bacillus circulans	Cr (VI)	34.5	[3]
Bacillus megaterium		32	
Saccharomyces cerevisiae	Cr (III) & (VI)	11.3, 3.3	[4]
Drepanomonas revolute	Zn (II), Cd (II), Cu (II)	22.1, 0.75, 0.2	[5]
Uronema nigricans	Zn (II), Cd (II), Cu (II)	24.3, 0.37, 0.95	
Euplotes sp.	Zn (II), Cd (II), Cu (II)	71.5, 0.83, 0.25	

Biosorption

Biosorption can be characterized as a basic metabolically latent physicochemical procedure engaged with the authoritative of metals particles (biosorbate) to the outside of the biosorbent which is of natural beginning [25]. Natural expulsion incorporates the utilization of microorganisms, plant-determined materials, farming or mechanical squanders, biopolymers, etc. It is a reversible quick procedure associated with authoritative of particles onto the practical gatherings present on the outside of the biosorbent in watery arrangements by methods for different cooperations as opposed to oxidation through vigorous or anaerobic digestion [37]. The benefits of this procedure incorporate are straightforward activity, no extra supplement prerequisite, low amount of ooze age, low operational cost, high proficiency, recovery of biosorbent, and no expansion in the synthetic oxygen request (COD) of water, which are in any case the significant confinements for a large portion of the regular methods [27]. Biosorption can expel contaminants even in weaken fixations and has uncommon importance regarding substantial metal expulsion inferable from lethality at ppb levels. Microorganisms (live and dead) and other mechanical and farming results can be utilized as biosorbents for the procedure of biosorption.

The primary stage in biosorption is that biosorbent ought to be suspended in the arrangement containing the biosorbate (metal particles). After hatching for a specific time interim, balance is achieved. At this stage, the metal-improved biosorbent would be isolated [27]. The procedure of biosorption is invaluable in light of the fact that it is reversible, doesn't require supplements, a solitary stage process, of fast range, has no risk of poisonous impacts and cell development, permits middle of the road harmony grouping of metal particles, and isn't constrained by digestion [26].

Biosorption limit (mg/g) of the biosorbent can be characterized as the measure of biosorbate (metal particles) biosorbed per unit weight of the biosorbent and can be communicated by utilizing the accompanying mass equalization condition:

$$qe=(Ci-Ce)V / m$$

The percent biosorption (R%) known as biosorption proficiency for the metal was assessed from the accompanying condition:

$$R\%=(Ci-Ce) / Ci \times 100$$

where qe is the measure of adsorbed metal particles of the adsorbent (mg g^{-1}), Ci is the underlying centralization of metal particle in the arrangement (mg L^{-1}), Ce is the balance grouping of metal particle in the arrangement (mg L^{-1}), V is the volume of the medium (L), and m is the measure of the biomass utilized in the adsorption procedure (g).

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II. MECHANISM OF BIOSORPTION

The mechanism of biosorption is a complex process which involves the binding of sorbate onto the biosorbent. Many natural materials can be used as biosorbents which involve the binding of metal ions by physical (electrostatic interaction or van der Waals forces) or chemical (displacement of either bound metal cations (ion exchange) or protons) binding, chelation, reduction, precipitation, and complexation (refer Figure 1). Biosorbents contain chemical/functional groups like amine, amide, imidazole, thioether, sulfonate, carbonyl, sulfhydryl, carboxyl, phosphodiester, phenolic, imine, and phosphate groups that can attract and sequester metal ions. The key factors controlling and characterizing these mechanisms are [38, 39]:

- the chemical, stereochemical, and coordination characteristics of metal ions like molecular weight, ionic radius, and oxidation state of the targeted metal species;
- properties of the biosorbent, that is, the structure and nature (in case of microorganism—living/non-living);
- type of the binding site (biological ligand)
- the process parameters like pH, temperature, concentration of sorbate and sorbent, and other competing metal ions; and availability of the binding sites.
- The combined effects of the above parameters influence the metal speciation (the formation of new forms of metal as a result of biosorption).
- Types of biosorbents
- Identification of biosorbents for the process of biosorption is a major challenge. It is desirable to develop/obtain biosorbents with the capacity to bind/uptake metal ions with greater affinities [56]. A wide variety of materials available in nature can be used as biosorbents for the removal of metals from contaminated water resources.
- high affinity for metals (biosorption capacity)
- low economic values (low cost)
- availability in large quantities
- easy desorption of the adsorbed metal ions and possible multiple reuse of the biosorbent.

Type of biosorbent	Source of biosorbent	Biosorbate	Biosorption capacity/efficiency (mg/g or %)	Isotherm model	Functional groups involved	Mechanism	Ref.
Tea industry waste	Local tea factory	Cr (VI)	54.65 mg/ga*	Langmuir	-OH, $-SO_3$, C-O, -CN		[6]
Sugar industry waste (bagasse)	Food canning processes	Cd (II), Fe (II)	96.4%, 93.8%a*				[7]
Peach and apricot stones	Juice and jam industry	Pb (II)	97.64%, 93%a*	Langmuir			[8]
Antibiotic waste	Antibiotic production complex	Cationic dye (Basic blue 41)	111 mg/ga*	Freundlich		Ion exchange or complexation	[9]
Sludge	Paper mill	Ni (II), Cu (II), Pb (II), Cd (II)	13.7, 13.9, 14.1, 14.8 mg/ga*	Freundlich		Ion exchange and physic-chemical adsorption	[10]

Type of biosorbent	Source of biosorbent	Biosorbate	Biosorption capacity/efficiency (mg/g or %)	Isotherm model	Functional groups involved	Mechanism	Ref.
Waste green sands	Iron foundry industry	Zn (II)	10.0 mg/ga*	Freundlich			[11]
Fly ash	Cement industry	Pb	22 mg/ga*			Precipitation	[12]

III. CONCLUSION

One advantage of biosorption is the removal of residual or minute concentrations of contaminants. Conventional water treatments may not completely remove contaminants. Hence, biosorption may be integrated downstream of other conventional water treatments. This is especially relevant in the case of pollutants like heavy metals whose effects are felt even at ppb levels.

The efficiency for the removal of specific metals is hindered by the presence of other contaminants. This may be important during the recovery of specific metals of economic value. In this regard, biosorption may be applied to wastes and effluents before it enters the sewage or natural discharge streams like rivers, seas and so on.

However, with the aim of treating effluent/remediating water resources of all/most contaminants, it may be an advantage to have all pollutants (metal or contaminants) removed simultaneously using a non-specific/non-selective biosorbent and reducing the number of operations/steps. Multiple biosorbents of different specificities/selectivities can also be used.

The strains or biomass used as the biosorbent should be of safe origin especially for water treated for human or animal consumption. Hence, pathogens and toxin-producing organisms need to be avoided. In this regard biomass from food-grade microorganisms like lactic acid bacteria and (wine/beer yeast) and agro-waste is of significance.

Regeneration and immobilization of biomass in order to reduce the cost of biomass involve the use of hazardous solvents which can lead to pollution. Hence, the use of harmless chemicals may be explored.

The existing waste can be classified as solid (degradable and non-degradable) and liquid in nature. A lot of solid non-biodegradable wastes (plastic) can be recycled to form chemically and mechanically robust and inert matrices to hold the biosorbent. Degradable wastes or biomass (agricultural/domestic/industrial) can be employed as biosorbents. A compatible biosorbent-matrix combination can then be employed to treat liquid discharge/effluents. This can make the waste treatment economical and sustainable while addressing the problems of solid and liquid effluents simultaneously.

REFERENCES

[1] de Silóniz Ma-I, Balsalobre L, Alba C, Valderrama Ma-J, Peinado JM. Feasibility of copper uptake by the yeast Pichia guilliermondii isolated from sewage sludge. Research in Microbiology. 2002;153:173-180

[2] Iram S, Shabbir R, Zafar H, Javaid M. Biosorption and bioaccumulation of copper and lead by heavy metal-resistant fungal isolates. Arabian Journal for Science and Engineering. 2015;40:1867-1873

[3] Srinath T, Verma T, Ramteke P, Garg S. Chromium (VI) biosorption and bioaccumulation by chromate resistant bacteria. Chemosphere. 2002;48:427-435

[4] Ksheminska H, Fedorovych D, Babyak L, Yanovych D, Kaszycki P, Koloczek H. Chromium (III) and (VI) tolerance and bioaccumulation in yeast: A survey of cellular chromium content in selected strains of representative genera. Process Biochemistry. 2005;40:1565-1572

[5] Martín-González A, Díaz S, Borniquel S, Gallego A, Gutiérrez JC. Cytotoxicity and bioaccumulation of heavy metals by ciliated protozoa isolated from urban wastewater treatment plants. Research in Microbiology. 2006;157:108-118

[6] Malkoc E, Nuhoglu Y. Potential of tea factory waste for chromium (VI) removal from aqueous solutions: thermodynamic and kinetic studies. Separation and Purification Technology. 2007;54:291-298 [60] Kumar A, Sahu O. Sugar industry waste as removal of toxic metals from waste water. World Journal of Chemical Education. 2013;1:17-20

[7] Rashed M. Fruit stones from industrial waste for the removal of lead ions from polluted water. Environmental Monitoring and Assessment. 2006;119:31-41

[8] Yeddou-Mezenner N. Kinetics and mechanism of dye biosorption onto an untreated antibiotic waste. Desalination. 2010;262:251-259

[9] Suryan S, Ahluwalia S. Biosorption of heavy metals by paper mill waste from aqueous solution. International Journal of Environmental Sciences. 2012;2:1331

[10] Lee T, Park J-W, Lee J-H. Waste green sands as reactive media for the removal of zinc from water. Chemosphere. 2004;56:571-581

[11] Alinnor I. Adsorption of heavy metal ions from aqueous solution by fly ash. Fuel. 2007;86:853-857

[12] Yeddou-Mezenner N. Kinetics and mechanism of dye biosorption onto an untreated antibiotic waste. Desalination. 2010;262:251-259