Investigation of Cadmium Biodegradation by Bacteria and Comparison with Other Biodegradable Materials

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

With the development of release of heavy metals into the environment is increasing. The abundant use and increase the level of concern is serious. Biotechnology, bioremoval heavy metals from industrial wastewater by using microorganisms' ability to be an efficient, environmentally friendly and developing effective. Identify bacteria resistant to toxic metals that have the potential in this area are technically complex and useful. The use of halophilic bacteria due to having special features, high power stability important in biological cleaning of metal compounds in natural environments play. Biological removal of toxic metal cadmium with high, environmental movement as an important field of biotechnology. Optimization of environmental conditions whose removal increases the efficiency should be considered further. The aim of this study reviews the removal of cadmium by biodispersion. And the impact of environmental factors on biological uptake of heavy and compare them with other bioabsorbents.

Keywords: Biological removal; heavy metals; halophilic bacteria; bioabsorbents; biotechnology.

1. INTRODUCTION

Heavy metals such as lead, copper, cadmium, zinc and nickel are among the most common pollutants found in industrial wastewater, even at very low concentrations, can also be toxic to living organisms, including humans [1]. The world’s largest soil contamination is linked to industrial activities. Human industrial activities such as mines and industries of animal production are the main sources of pollution in the transportation and disposal of metals [2]. Different methods of removing heavy metals from industrial wastewaters are mainly physical,
2. SOURCES OF HEAVY METALS

Natural processes and human activities are two main sources of heavy metals entering the environment [10]. Natural processes such as erosion of rocks and volcanic activity, which have a significant role in the introduction of water resources [12]. Human activities such as industry, agriculture, mining, and urban development can contribute to the transfer of pollutants to the water [13]. Pollution of heavy metals, and in particular of toxic metal cadmium, has been reported due to the excessive use of chemical fertilizers or the use of sewage sludge in the soil of agricultural areas of the world [14]. Among heavy metals, cadmium is widely used in industry, has a high toxicity level and is toxic in low amounts [15]. This metal is widely used in metal plating and plastic tightening in the industry. [16]. Cadmium is naturally found in crude oil and therefore in its derivatives such as mazut and gasoline. Flowing water from streets after rainfall will contain large amounts of cadmium [17]. Contact in humans is more likely to result from respiratory and edema as a result of environmental and occupational conditions. Smoking can also be a major source of contamination with cadmium. However, the accumulation of cadmium in non-smokers who have no occupational exposure is primarily due to food intake [18]. This Metal is relatively common in all types of foods with different concentrations. Vegetable foods have the highest concentrations of cadmium compared to meat, eggs, dairy and fish [19]. Effects of Heavy Metals on the Environment Heavy metals destroy DNA and RNA, inhibit protein synthesis, inhibit enzymatic processes, and inhibit cell division and cellular processes [20]. Cadmium causes acute and chronic diseases such as cancer, kidney disease, pulmonary disorder, weight loss, kidney damage, gastrointestinal and bone discomfort [21]. Cadmium absorption has the same mechanism of calcium and iron absorption and, therefore, replaces an essential element thereby increasing the iron content [22]. The permitted amount in drinking water is 300 mg/l [23]. Some heavy metals exist in the structure of enzymes and proteins, such as iron in the structure of the group in cytochromes, manganese in photosynthetic reactions associated with water oxidation, and in many dehydrogenases and superoxide dismutase (SOD), copper in cytochrome oxidase, Plastocynin in catalases and other oxidases, zinc metal is often combined with dehydrogenase, in particular, superoxide dismutase (SOD) and proteins bound to nucleic acid (zinc finger), molybdenum involved in the enzymes responsible for the metabolism of nitrogen (Denitrogenase and nitrate reductase) And cobalamin plays an important role [24]. Vegetative growth has been observed due to the use of heavy metals such as cadmium and copper in beans [25]. Cadmium has a positive twofold and competes with elements such as magnesium (Mg++) in chlorophyll and also with iron ions (Fe++), which are bivalent. It replaces these ions and eliminates the chlorophyll molecule in the plant [7]. Cadmium toxicity mechanisms are still not fully understood. Generally, cadmium interferes with the plant's absorption, transfer and use of calcium, magnesium, phosphorus, potassium and water. Cadmium reduces nitrate absorption and transferring it from roots to the limb by inhibiting nitrites reductase enzyme activity [26].

3. HEAVY METAL REMOVAL METHODS

Conventional methods for the removal of heavy metals from the environment, including chemical sequestration, ion exchange method, electrolytic
Table 1. Advantages and disadvantages of some heavy metals treatment methods

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Advantages</th>
<th>The purification process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mud production, operation cost and Very high sludge</td>
<td>Low initial investment cost, easy operation, short sedimentation time, sludgy sedimentation</td>
<td>Chemical treatment and filtration</td>
</tr>
<tr>
<td>Further refinements are needed to improve the removal efficiency of metals</td>
<td>Low hydraulic time, low cost production, low required time</td>
<td>Float with soluble air</td>
</tr>
<tr>
<td>High cost of investment</td>
<td>Low cost of operation, high efficiency</td>
<td>Ionic exchange</td>
</tr>
<tr>
<td>The number of resins is not enough to remove all metals</td>
<td>Little waste is produced.</td>
<td>Biodegradation processes</td>
</tr>
<tr>
<td>The need for specific types of germs, specific environmental conditions,</td>
<td>The required operating space is low.</td>
<td></td>
</tr>
<tr>
<td>requires specific substrates for microorganisms.</td>
<td>There is a possibility of metal removal.</td>
<td></td>
</tr>
<tr>
<td>High cost of investment and operations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

purification methods, adsorption method, reverse osmosis, electrodealization, evaporation, biodegradation, solvent extraction, clotting, continuous separation process, etc. [27]. Physicochemical methods can not be adapted to environmental standards, since it is often inefficient and uneconomical when the concentration of heavy and toxic metal in contaminated environments in the range of 10-100 ppm [28]. In Table 1, the advantages and disadvantages of some of the methods for treating heavy metals are shown in the table [29].

4. BIOAVAILABLE BIO HISTORY

The use of repeat mechanisms to absorb heavy metals in the early 18th and 19th centuries began to be investigated in removal of heavy metals in water solutions [30]. Mills and colleagues worked in 1973 for the first time on biological wastewater treatment [31]. Bioavailability is a process in which cellular components or metabolic activities of microorganisms can be used to remove toxic substances from the environment and convert them into non-toxic and harmless substances [32]. Bioavailable biofuels are used from microorganisms such as algae, fungi, yeast, protozoa, and bacteria to remove heavy metals from industrial wastewater [33]. The use of microorganisms and plants as effective biological solutions for the removal of heavy metals from the environment, because it is environmentally friendly, has the lowest cost economically, is called Bioremediation. If the plants are used to clean the environment, they are called Phytoremediation [30]. Benefits of Bioavailability

The main advantages of using environmental safety, high efficiency and low costs can be mentioned. Microorganisms have a large surface area. Therefore, they create a lot of contact for interaction with metals, and they are part of the functional group. Because of their negative charge, these groups are the main positions for the absorption of metal cations [34].

5. BIOAVAILABLE DISADVANTAGES

Due to current constraints, the use of this technology at present is not feasible due to its ability to adapt and biofuel efficiency of microorganisms for practical application. Biofuel mechanisms still seem to need more understanding. Mechanisms that facilitate the function of bioplastics by valuable germs can enable us to use them effectively [29].

6. BIOAVAILABLE MECHANISM

In the bioavailable method, metal cations on the functional groups with negative charge in the cell wall of the microorganism are believed to be exhausted [35]. The biological elimination method is biologic: Bioavailability and bioaccumulation. In biodegradation, heavy metals are stabilized for living and non-living biological agents without causing harm to biological agents. Removal of heavy metals through intracellular through prolonged contact with living matter is called a bio-accumulation bioaccumulation solution [36]. Different mechanisms of microbial resistance to metals include bioengineering, bioavailability, bioavailability, bioconversion and bioengineering [37,38]. Biological absorption is subdivided into two categories: a) Biological Absorption of Metabolism: Absorption, Physical Absorption, Ionic Exchange, Formation of Complex; b) Biological Absorption Depending on Metabolism: Transition from Cellular Membrane Surface (accumulation). Absorption is independent of the
metabolism of metal absorption by the physicochemical interaction between the metal present at the cell surface and does not require a living cell. Independent absorption of the metabolism on the cell wall and its outer surface is the only mechanism available for non-viable biomes. This type of absorption is fast and reversible. Biological recovery is one of the mechanisms independent of metabolism, which is carried out by the presence of the forces of van der Waals [39]. The colleagues showed that the biological absorption of thorium and uranium to Rhizopus arrhizus is based on the absorption of cell wall chitin. Volosky's biological absorption of uranium, cadmium, copper, zinc and cobalt into dead microbial mass and the result of electrostatic interactions between metal ions in solution and cell wall [40]. Cellular ion exchange: In this mechanism, metal ions dissolved in iodine ions are exchanged in polysaccharides [15]. Microorganisms are polysaccharide, and bivalent ions can be exchanged in polysaccharides with their ions. Cell wall Microorganisms contain polysaccharides and two-volume metal ions that can be replaced by other ions. For example, seaweed alginates are in the form of sodium, potassium, calcium, magnesium salts. These ions can be exchanged with ions such as cobalt, zinc, copper, and cadmium. The bioavailability of copper by the niger Aspergillus fungus is done in this way [40]. Formation of the complex: The absorption of metal from solutions may be accomplished through a complex on the cell wall through an interaction between metal and active groups. Cadmium accumulation in Pseudomonas syringaceus occurs through the formation of the complex [15]. In all biochemical adsorbents, all metal ions must pass through the cell wall before access to the plasma membrane and cytoplasm. Since the cell wall contains polysaccharides and proteins, they can be coupled with metal ions [41]. This process can be either dependent or independent of metabolism. If the microorganism produces compounds that lead to metal deposition, in this case, the mechanism is dependent on cellular metabolism. However, if the sedimentation occurs after the chemical reaction between the metal and the cell surface, it will be independent of cellular metabolism. Treatment: An independent metabolism is caused by a cross-reaction between the metal and the cell surface. The bioavailability of cadmium to the algae mass is accomplished by this mechanism [39]. Depending on metabolism: these mechanisms vary depending on the type of metal and its compounds. Metals can enter the cell through natural transmission processes or through competition to form bands. The living biomass has a metal adsorption potential inwardly. Intracellular absorption improves total capacity and stability of the metal [40]. Transition from the surface of the cell membrane: One of the mechanisms that is dependent on metabolism is the heavy metal ions, such as on the muscle, accumulate in the cell. Biological absorption has been reported in the metabolism of metals: copper, cadmium, nickel, manganese, zinc, cobalt in fungi and yeasts [42].

**Bacteria:** Gordon et al. (1990) observed in a study comparing the cadmium biomass uptake by gram positive bacteria with gram negative bacteria that the cadmium uptake in the gram-positive bacterium was 20 times higher than that of gram negative bacteria. The presence of peptidoglan on the exterior of the gram-positive bacterium Potentially, sites attach more to cadmium than phospholipids and lipopolysaccharide in the exterior of the cell wall of the gram-negative bacterium. This is because the gram-positive bacteria are more absorbent [43]. A number of cadmium-resistant microorganisms have been identified, including E.coli, Alcaligenes eutrophus, Bacillus subtilis, Pseudomonos putida, Listeria species, some cyanobacteria, fungi and algae. If gram-positive bacteria use an ATP-dependent transmission pump to resist cadmium, gram-negative bacteria use a double-sided chemo-osmotic pump [44]. Bioactive factors excretion of metal cations by microorganisms depends on environmental factors such as pH, temperature, metal concentration, biomass, and also the time of equilibrium [45]. Under optimum conditions, in terms of growth indices, the bacteria have maximum growth and multiplication and unfavorable environments can lead to a decrease in their growth [46]. Effect of pH on bioavailability: pH is the most important bioabsorption parameter that depends on the chemical solubility, the activity of functional groups in biomass and ionic competition. In general, absorption of metal ions is pH dependent [47]. The possibility of an extremely acidic or alkaline pH has an effect on absorption and reduces absorption. This can be due to the structural and chemical changes of the macromolecule and the reduction of metal binding sites [39]. It has been determined that the absorption of metal is dependent on pH in almost all biomass, including bacteria, cyanobacteria, algae and fungi. The competition between cation and proton shows that the absorption of metals such as copper, cadmium,
nickel, cobalt and zinc at a low pH decreases. Due to the increase of the positive charge density at the binding sites, the amount of metal ion access to these sites decreases [47].

7. EFFECT OF TEMPERATURE ON BIOAVAILABILITY

Temperature is an important environmental factor that contributes to the growth of microorganisms, each microorganism is capable of growth at a certain temperature range. Increasing temperatures above 50 °C can have adverse effects on the growth of most microorganisms and can affect bacteria. By increasing the temperature, the enzymes that affect the bacterial growth are degraded, which disrupts the cell metabolism [48]. Absorption reactions are naturally thermosensitive, so the ability to absorb bioavailability decreases with temperature. When the temperature is very high, the metal absorption decreases due to the shrinkage of some metal binding sites at the cell surface [49]. Studies of the effect on the bioavailability of metals show different results. Some studies increase temperature by increasing the activity of metal ions in the solution and, as a result, easily connect to the cell surface. But the adsorption process is not usually used at high temperatures because it costs [50]. Effect of primary metal concentration in bioavailability: The amount of metal adsorbed by biomass has a direct correlation with the initial concentration of metals. Thus, metal adsorption increases with increasing metal concentration [51]. The initial concentration on the propulsion force plays a role in overcoming the transfer mass of the ion between the adsorbent and the liquid phase. The higher initial concentrations increase the velocity of the mass transfer mechanism, thus increasing the absorption [52]. Similar studies by Patel et al. 2006 in cadmium-resistant Halomonas seurlhalina bacteria, which absorbed at high levels, reduced cadmium concentrations [53]. In the year 1390 in Iran, Akhavat and Mousavi considered effective in reducing arsenic, chromium and cadmium in Iran [54].

8. EFFECT OF COMPOSITION OF CULTURE MEDIUM ON BIOAVAILABILITY

Impact of carbon source: Glucose is a carbon source widely used in the combination of the culture medium and also acts as a source of energy. Glucose will increase the growth of living cells and facilitate metal absorption. Some studies on the glucose uptake of heavy metals such as cadmium, chromium, copper, zinc and nickel from aqueous electroplating by Saccharomyces cerevisiae cells have shown that pretreatment of yeast cells with glucose results in an increase in metal recovery [50].

9. EFFECT OF NITROGEN AND PHOSPHORUS

Adding enriched culture enhances the logarithmic increase of the microbial population and, as a result, increases the amount of enzyme synthesized and ultimately increases the efficiency. Research shows that microorganisms will have the best growth in optimum ratios. Tomas et al., From Carbon to N, have an optimal ratio of C: N: P to optimum growth of microorganisms [51]. Sendstatein et al. (1976) argued that the addition of nitrogen and mineral phosphate accelerates the biodegradation process, but does not affect the amount of biodegradation [55].

10. EFFECT OF SODIUM CHLORIDE CONCENTRATION

High concentration of salt in the environment leads to cell membrane degradation and inactivation of enzymes, and these conditions can be destructive for microorganisms that remove contaminants from the environment [56]. The effect of salinity concentration on the toxicity of heavy metals was studied. In general, salinity reduction resulted in increased sensitivity to cadmium. However, salinity increased cadmium toxicity, the dependence on salinity in cadmium-resistant species in Pseudomonas was confirmed [57]. With increasing salt concentration, the amount of phospholipids is increased in comparison with neutral phospholipids. The amount of neutral phosphoric acid ethanolamine decreased and, by contrast, the level of phosphatidyglycerol or diphosphatidyl glycerol increased, resulting in a decrease in bacterial growth. In fact, with the increase in salt concentration, the growth of the bacterium is reduced [6].

11. EFFECT OF BIOMASS CONCENTRATION IN BIOAVAILABILITY

If the concentration of biomass is lower in the solution, the specific absorption rate is higher because the increase in the concentration of
biomass causes interference and overlapping of the graft sites. Gad 1988 concluded that increased concentrations of biomass would interfere with and overlap the graft sites [42].

12. THE EFFECT OF THE PRESENCE OF OTHER METAL IONS

The presence of other metal ions sometimes reduces the absorption and sometimes does not affect the absorption rate, which is due to rival links that occur with the surface [39].

13. OPTIMIZATION OF ENVIRONMENTAL FACTORS BY TAGUCHI METHOD

Since the 1980 Taguchi method has been used in biology studies as a quality control methodology to optimize the test process. The purpose of the Taguchi method is to design, determine the effective parameters of the relationship between the meta-data. In this method, Qualitek-4 software is used to analyze the data. Analysis of variance (ANOVA) is done to calculate the error variance and the relative importance of each of the factors. In addition, the degree of freedom, the sum of squares, the relative optimal conditions of the factors affecting biological absorption, and the interaction of effective factors [58].

14. ESTIMATION OF BIOAVAILABILITY

The ability of bacteria to remove metal from a metal solution with a fraction of the metal content measured by the atomic absorption system was obtained from the initial concentration of metal according to the following relation. The adsorption rate was calculated in mg / l and was calculated as a percentage.

\[ R = \left[1 - \left(\frac{C_p}{C_f}\right)\right] \times 100 \]

Where:
- \( R \) - the rate of metal adsorption by the biomass
- \( C_p \) - concentration of metal measured by atomic absorption device
- \( C_f \) - initial concentration of metal

The isotherm of absorption is one of the important factors in the design of absorption systems, according to the following equation [5]. The values (Q) of the absorption capacity, V is the volume of solution, Ci is the initial concentration of the metal, Ce is the secondary concentration of metal M in the absorbent mass.

\[ q = \frac{V \left(C_i - C_e\right)}{M} \]

15. COMPARISON OF BIOLOGICAL ADSORBENTS BACTERIA

Due to the high surface-to-volume ratio, which is responsible for the large metal exposure to existing sites and the frequency of presence in different environments, the ability to grow under controlled conditions is used as an effective biological absorbent [5]. The absorption process varies in gram-positive and gram-negative bacteria. The cell membrane is relatively simple in gram-positive cells and consists of two layers of germs, while in gram-negative bacteria, this coating is very complex and multi-layered. The outer membrane of the gram-negative bacteria has a lipid nature that keeps the hydrophilic molecules away from it. Gram-positive bacteria are better candidates for biological treatment of heavy metals [59].

16. THE MECHANISM OF BACTERIA

Transition of active metal to microorganism outside. In the process of resistance to the toxic effects of heavy metals, various systems are involved in which the P-type ATPase group system is one of the largest systems of resistance to metals, and is in fact a group of membrane transferring proteins that has 8 superfamilies and ions. Contrary to the concentration gradient, they transfer energy released from ATP [60].

17. EXTRACELLULAR SEQUESTRATION OF METALS

Metal separation is accomplished by the formation of complex on the surface of the cell. Carboxyl and hydroxyl groups play an important role, for example, the sedimentation of cadmium by Klebsiella aerogenase is a mechanism of this kind [35]. Carboxyl and hydroxyl groups play an important role, for example, the sedimentation of cadmium by the Klebsiella aerogenase of this type of mechanism [39]. Exellular material, anionic agent band on the cell surface with a wide range of cationic metals such as cadmium, lead, zinc and iron. For example, lead fixation has been observed by several extracellular bridge cells such as Staphylococcus aureus, Micrococcus luteus and Azotobacter [61].
18. INTRACELLULAR SEQUESTRATION OF METALS BY BINDING TO PROTEINS

The mechanism by which the metal enters the cytosote and is either immediately ejected or deactivated from the deactivation of metal enzymes or structural proteins [62]. The expansion of heavy metals in cytosol is another mechanism for removing metal poisoning. Heavy. The calciner contains amino acids, organic acids and a group of peptides including methalytonins and glutathione [63].

19. SULFURIZATION IN SULFATE REDUCING BACTERIA

One of the models is the bacterial reduction method of sulfate, so that the sulfate reducing bacteria oxidize organic compounds such as methanol and ethanol using sulfate and bicarbonate and hydrogen sulfide. Hydrogen sulfide precipitates with heavy metal ions and depletes insoluble sulfides in the form of dense sludge. Certain anaerobic microorganisms and bacteria have the ability to convert metal ions into sulfides [64].

20. ANTIOXIDANT PRODUCTION

Identifying and detecting ways of biological degradation of contaminants by microorganisms and their enzymatic systems are the starting point for environmental applications of biotechnology. Among the various enzyme systems, cytochrome P450 enzymes have a special place to purify bio-contaminants [65].

21. GENETIC DETERMINANTS OF CADMIUM RESISTANCE

Often, heavy metal resistance relates to the presence of plasmids that carry genes that are resistant to transmitting these genetic elements to other strains (e.g., the presence of the cad A plasmid gene in some of the cadmium-resistant bacteria). Occasionally these resistors have chromosomal origin. Algae, Cyanobacteria have some advantages over other microorganisms, which include their greater glaze content, along with the high binding density, large cross-sections and nutrients needed, can easily be cultured on large-scale cyanobacteria in the laboratory and The low biomass provided for the absorption process [67]. The absorption of cadmium ion by various types of biological absorbers including brown algae vesiculosus and Fucus has a cadmium uptake of 0.56 at 0.55 [42]. In a study on cyanobacter *Spirulina platensis* as a cadmium adsorbent in aqueous solution at pH 8, 26°C and 160 mg cadmium after 90 minutes of contact time [68,66].

In the cell wall of fungi, phosphate and carboxyl groups take part in the absorption of metals, biological absorption by fungi occurs in two steps, rapid absorption of the surface at first and intracellular diffusion in the second 2 hours, which occurs slowly. Families of *Penicillium*, *Aspergillus* and *Rhizospus* have been widely studied for the removal of heavy metals from aqueous environments [69].

Table 2. Comparison of maximum bioavailability of cadmium by various bioactive adsorbents

<table>
<thead>
<tr>
<th>pH</th>
<th>Metal</th>
<th>Max absorption capacity mg/g</th>
<th>reference</th>
<th>Biological absorbent</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/5</td>
<td>Cd</td>
<td>66</td>
<td>[74]</td>
<td><em>Sargassum filipendula</em></td>
</tr>
<tr>
<td>5/5</td>
<td>Cd</td>
<td>85</td>
<td>[75]</td>
<td><em>Fucus serratus</em></td>
</tr>
<tr>
<td>3/5</td>
<td>Cd</td>
<td>56</td>
<td>[42]</td>
<td><em>Fucus vesiculosus</em></td>
</tr>
<tr>
<td>6</td>
<td>Cd</td>
<td>38</td>
<td>[76]</td>
<td><em>Pseudomonas aeruginosa</em></td>
</tr>
<tr>
<td>3-9</td>
<td>Cd</td>
<td>1/27</td>
<td>[77]</td>
<td><em>Bacillus licheniformis</em></td>
</tr>
<tr>
<td>7</td>
<td>Cd</td>
<td>45</td>
<td>[75]</td>
<td><em>Bacillus sp.</em></td>
</tr>
<tr>
<td>8</td>
<td>Cd</td>
<td>12/02</td>
<td>[78]</td>
<td><em>Halomonas BVR 1</em></td>
</tr>
<tr>
<td>6</td>
<td>Cd</td>
<td>20</td>
<td>[79]</td>
<td><em>Spirogra insignis</em></td>
</tr>
<tr>
<td>2/8</td>
<td>Cd</td>
<td>16</td>
<td>[80]</td>
<td>Modified Banana Shell</td>
</tr>
<tr>
<td>5</td>
<td>Cd</td>
<td>43/4</td>
<td>[81]</td>
<td><em>Halomonas Strain D</em></td>
</tr>
<tr>
<td>6</td>
<td>Cd</td>
<td>19</td>
<td>[82]</td>
<td><em>Chondros criopus</em></td>
</tr>
<tr>
<td>6/5-7</td>
<td>Cd</td>
<td>40</td>
<td>[83]</td>
<td><em>Palmaria palmata</em></td>
</tr>
<tr>
<td>3-10</td>
<td>Cd</td>
<td>14/77</td>
<td>[4]</td>
<td><em>Calcareous granules</em></td>
</tr>
</tbody>
</table>
22. YEASTS

Yeasts are preferred to remove heavy metals because of the survival and growth in places infected with heavy metals and the high capacity of metal binding to the cell wall and high intracellular absorption rates[70]. Lu et al. (1996) isolated the copper, cadmium and zinc ions from the solution using the Saccharomyces cervisiae yeast stabilization in alginate [71].

These biodegradable materials are, on the one hand, very popular and available, and on the other hand they are not particularly used. Studies by Larson et al. 1981, in which straw activated carbon was used to remove cadmium [72]. Cesar et al. 2004 studied the use of modified rice bran carbon was used to remove cadmium [72]. Cesar et al. 2004 studied the use of modified rice bran carbon was used to remove cadmium [72].

The maximum Bioavailability of Cadmium is Compared with Biochemicals: Table (2) was shown that algae have a maximum bioavailability of heavy metals and are the best absorbent to other adsorbents.

23. CONCLUSION

Deletion of heavy metals into the environment is one of the serious concerns in recent years. Removal of heavy metals from aqueous solution in a conventional way has many disadvantages, such as expensive equipment, sludge production and other toxic waste materials, which require high energy. One of the effective methods for treating waste from heavy metals is the use of bacteria that can lead to a more successful purification of heavy metals from the environment. There are challenges to using the ability of microorganisms. High concentrations of metals can be toxic to microorganisms and provide undesirable acidic conditions for growth. In order to overcome these challenges, the use of indigenous microorganisms adapted to the conditions or use of genetically modified microorganisms or dead biomes of microorganisms that meet existing conditions is needed. It is [84].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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