Mycoremediation is a Potential Strategy for Environmental Clean-up of Heavy Metal: A Review

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Abstract

Living organisms are under serious threat from environmental contamination as because of the recent growth of industry. Heavy metals are dumped into the water body by many enterprises. Heavy metals can be harmful to humans, cause various diseases and endanger the aquatic ecosystem. Hence, removing heavy metals from wastewater is a difficult task. Because to its low cost, high biomass, and environmentally beneficial nature, mycoremediation—the biosorption of heavy metals using fungi is a commonly utilized method. Comparing fungal biomass to other biosorbents, it can be found more easily as an industrial waste product and offers benefits economically. The majority of fungi used to remove heavy metals don’t show pathogenicity and can be utilized with no problems regarding safety. A number of factors, including pH, metal ion concentration, biomass content, and temperature, have a significant impact on fungal biosorption. In addition to providing information on biosorption techniques and a functional group of fungi involved in the removal of various heavy metals, this review study focused on facts obtained and disseminated on numerous fungal adsorbents that are essential for heavy metal removal.

Keywords: Biosorption · Fungi · Heavy metals · Mycoremediation · Functionalgroups

1. INTRODUCTION

The environment is made up of numerous complicated variables, such as land, water, and air. The existence of humans alongside other living organisms, such as plants, animals, and bacteria, is based on their beneficial relationship. Although air, soil, and water are thought as essential components of life forms, knowledge and technological advancements in current civilizations have significantly contributed to environmental risk. Growing human population, urbanization and quick mechanizations are acknowledged as significant obstacles to managing groundwater supplies in emerging nations (Selvi et al. 2019).

Heavy metal pollution poses serious risks to the health of ecosystems due to its varied levels of accumulation and toxicity (Tangahu et al. 2011). Biological sorption has emerged as a promising alternative to the expensive methods currently in use despite the fact that there are numerous heavy metal reclamation techniques. It has several benefits including low cost, environmental friendliness, ease of operation, safety, and the idea of green chemistry (Sharma et al. 2018). The most well-known biological sources for the utilisation of heavy metal sorption techniques are plants, fungi, bacteria, and algae (Kaur et al. 2019). The fungal biomass has been considered to have the highest capacity for heavy metals sorption on polluted environments due to the composition of their cell walls, which are composed of 80–90% polysaccharide, protein, and lipids with numerous significant functional groups that could be used in metal binding (Dhankhar and Hooda 2011). They usually have outstanding tolerance to metals as well as to other harsh conditions, like low pH (Simonescu and Ferdeş 2012).

Fungal biomass has received a lot of interest as a biosorbent due to its high concentration of cell wall material, which increases the variety of functional groups involved in heavy metal binding and thus boosts the potential of organisms to sequester metals (Dhankhar and Hooda 2011). However, because this technology is not yet extensively used, much more focus and effort must be placed into it. Therefore, the current review's main focus was on different features of heavy metal removal using different fungal, factor, and biosorption approaches along with functional groups responsible for biosorption.

2. MYCOREMEDIATION

Mycoremediation, a type of bioremediation, uses fungi to heal and restore damaged habitats (Mani and Kumar 2013; Asiriuwa et al. 2013; Hamba and Tamiru 2016). Mycoremediation is the process of employing fungi to clean up environmental toxins. These funguses develop long threads (hyphae), which join with the earth, rocks, and tree roots to form a filamentous body. According to Aly et al. (2018), these fungi are known to be resistant to heavy metals and several adverse environmental factors, such as high pH, high temperature, low nutrient accessibility, and low nutrient availability. By moving heavy metals from the contaminated environment to the fruit bodies, this innovative technique may be able to remove heavy metal contamination (Okhuoya 2011; Deshmukh et al. 2016). Mycoremediation requires the selection of the best fungus species to chelate, adsorb, accumulate, or transform a certain pollutant (Thenmozhi et al. 2013; Hamba and Tamiru 2016). According to Hoshino and Morimoto (2008) and Harms et al. (2011), fungi, which make up the majority of living organisms in soil, are routinely used to clean up environments that have been contaminated with metal. Due to the aforementioned factors, such as the uniqueness of its biomass, hyphal network, and longer lifecycle, fungi have an advantage over bacteria for the bioremediation of polluted environments. In extreme circumstances, metal-resistant fungi also compete with common bacteria (Sun et al. 2012). Due to their more widespread metabolic competency, fungi have a variety of benefits in the elimination of various contaminants. The primary components of fungi's cell walls are polysaccharides and proteins having carboxyl, hydroxyl, sulphate, phosphate, and amino groups for binding metal ions (Maheswari and Murugesan

2009). To attract and hold metals in the biomass, these functional groups provide the ligand atoms needed to form complexes with metal ions. The right site-specific bioremediation can be achieved through the selection of metal-tolerant fungus from a polluted environment, screening them for their capacity to remove metal, and further bioaugmentation of promising soil fungi local to the metal-contaminated soil. Several researchers have also recommended looking into wild-type fungal strains that can survive high metal concentrations, remove metal from the environment, and provide an effective bioremediation process (Gentry et al. 2004; Mukherjee et al. 2010).

3. IMPORTANT FACTORS AFFECTING BIOSORPTION OF HEAVY METALS USING FUNGI

Numerous factors that affect the biosorption mechanisms have an impact on the biosorption process. The main factors affecting the removal of metal ions are the pH, initial heavy metal concentration, amount of biomass, temperature, and period of contact (Veglio and Beolchini 1997).

3.1 The role of pH

One of the key elements influencing the absorption of heavy metals is the environment's pH. At an acidic pH, the majority of heavy metal reduction and uptake by fungal species was beneficial. Because heavy metals prefer to generate free ionic species at lower pH levels, there are more protons available to saturate metal-binding sites. This demonstrates that when hydrogen ion concentrations increase, the adsorbent surface becomes more positively charged. A lower pH enhances the rate of biosorption because it creates a large number of free binding sites and speeds up metal uptake (Dwivedi 2012). Bhainsa and D'Souza (2009) assert that pH 4 is the pH at which Aspergillus fumigatus may fully eliminate metal ions.

3.2. The role of Heavy Metal Concentration

The molecular mass transfer resistances from molecules to sorbent are greatly influenced by the heavy metal's starting concentration (Khataee et al. 2013). Chromium [Cr (III)/Cr

(VI)] starting values ranging from 0 to 500 mgL-1 are used to examine how much the initial concentration affects metal ion biosorption. In addition to fungal biomass and contact duration, the reduction of Cr (IV) to Cr (III) was seen above 200 mgL-1 starting concentration, underscoring the importance of beginning concentration (Kim et al. 2011). In the investigation conducted by Aksu et al. (2007), chromium absorption was measured at a range of 2.34 mgL-1, and early levels of 15–30 mgL-1 of *Trichoderma versicolor* fungal biomass were observed for chromium (VI) biosorption.

3.3. The Role of Temperature

Temperature, which can also ionize chemical molecules, is known to have an impact on the structure and stiffness of the cell wall. Less heavy metal removal might be the result of these variables' combined effects on the binding sites on isolated fungus species (Congeevaram et al. 2007). According to Kabbout and Taha (2014), temperature influences how strongly fungus attaches to heavy metals. The bulk of studies utilising various fungi species to study the biosorption of heavy metals functioned best between 20 and 30 °C.

3.4. The role of Contact Time

The contact time indicates how long the fungus has been a part of the contamination. It also contributes greatly to fungal biosorption, demonstrating the efficiency of biosorbent in cleaning up polluted environments. The effectiveness of the dead mass metal adsorption by Aspergillus niger, as well as the speedy removal of metal ions on the exchange in the functional groups present on the fungal cell surface at the initial reaction period, and further reduction into metal ion adsorption due to intracellular aggregation of the metal particles, were evaluated. After 180 minutes, the experiment attained equilibrium. The majority of the adsorption took place in the first 10 minutes of contact (Vale et al. 2016).

3.5. The role of Biomass Dosage

Heavy metal contamination in terrestrial and aquatic habitats can be removed using fungus biomass. The efficiency of ion biosorption rises with biomass mass, reaching a value of 0.013 g (0.1 g of wet mass), according to a study by Godlewska-Ykiewicz et al. (2019). The fact that the biosorbent's surface has more binding sites is most likely what is to blame. The biosorption efficiency remained constant between 0.013 and 0.066 g of biomass dosage, showing the development of equilibrium between the ions bound to the biosorbent and those remaining in the solution. The amount of copper (II) uptake by Aspergillus tamarii NRC 3 biomass rose as the starting amount of biomass grew, according to a study by Saad et al. (2019). Additionally, the absorption of Cu+2 in a medium containing 5 g of wet weight biomass was recoded (92.40%).

3.5. The Underlying Mechanisms of Biosorption of Heavy Metals Using Fungi

Microorganisms develop defense mechanism against the metal contaminants as a result of frequent exposure to heavy metal stress. Several criteria are routinely used to group biosorption-related mechanisms: Three types of biosorption exist: intracellular accumulation, cell surface sorption/precipitation, and extracellular accumulation/precipitation (Fig. 1). According to Bellion et al. (2006), Vankar and Bajpai (2008), Dhankhar and Hooda (2011), Thakur et al. (2015), Shakya et al. (2015), Siddiquee et al. (2015), and Bahobil et al. (2017), there are two types of cell metabolism: metabolism-dependent and non-metabolism-dependent.

There are two main strategies that have been suggested to overcome the heavy metal resistance of fungus. Both external (chelation and attachment to cell membranes) and internal (physical sequestration of metal by binding to proteins or other ligands) processes are used to protect metal-sensitive biological targets from metal. Accordingly, intracellular sequestration systems are meant to lessen metal stress within the cytosol, whereas extracellular mechanisms are primarily used to avoid metal invasion (Baldrian 2003; Anahid et al. 2011). In order to chelate metal ions, the extracellular mechanism of the fungal cell entails the evacuation of a number of organic molecules from the cell membrane matrix. "Biosorption" is the term for "binding to a fungus' cell membrane" (Fawzy et al. 2017). A range of polysaccharides, proteins, and lipids with different functional moieties, such as hydroxyl, amine, carboxyl, and phosphates, can be found in the cell wall of fungal biomass. This permits the binding or sequestering of metal (Ahemad and Kibret 2013).

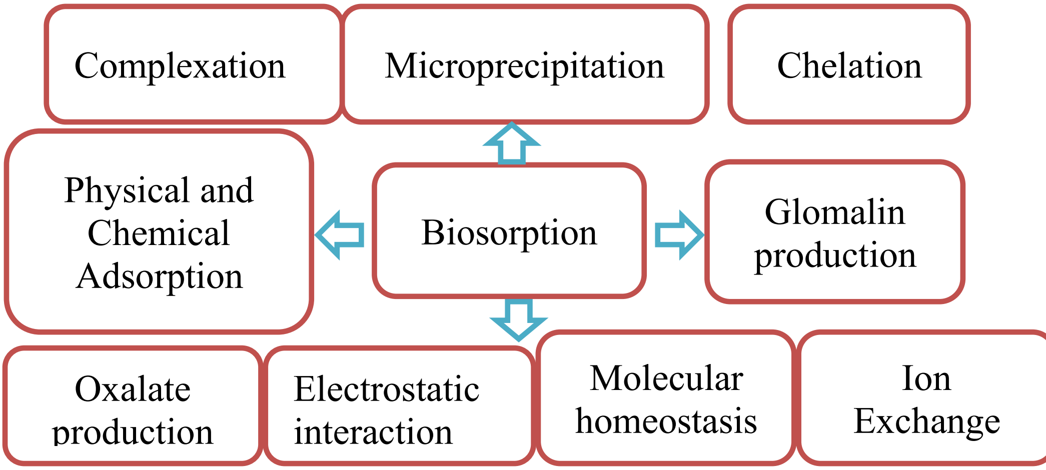

Fig. 1 Different mechanisms involved in biosorption phenomena. (Asgher 2012; Kumar et al. 2019)

CONCLUSION

The use of fungal biomass for the removal of heavy metal ions has been thoroughly discussed in the current review paper. The elimination of metal ions over a reasonably broad temperature and pH range is one of the process's many alluring characteristics. The biosorption capacity of numerous fungal biosorbents has been investigated, and the findings offer compelling arguments in favour of adopting biosorption technology to remove heavy metals from solutions and comprehend the biosorption mechanism. Numerous factors, including pH, initial concentration, contact time, temperature, and biomass dosage, affect how well heavy metals are removed by fungus. It has been discovered that biomass is a natural resource with a variety of functional sites that can adsorb metal ions. Selective adsorption is still challenging due to the diversity of the fungal cell surface. To further understand the biosorption processes used to remove heavy metals, more study needs to be done.

FUTURE SCOPE

The usage of fungus in heavy metal cleanup is sustainable and environmentally friendly. Chemical treatment can change how a heavy metal interacts with the surface of a fungal cell wall which could increase metal adsorption. This approach may be utilized sustainably to largely improve the cleanup of metal.

Conflict of Interest

The authors have no conflict of interest.

Author contributions:

DB, AC, AS, SS, SP, MK collected the information in various literatures. SS1, BG, SG contributed in data input and analysis. SS2 conceived the idea and wrote the paper

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