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Remediation of Heavy Metals in the Environment by Microorganisms

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Abstract: *Heavy metal pollution poses a serious threat to all kinds of life in the environment because of the harmful effects of long-term environmental contamination. These metals can accumulate in food webs and are particularly sensitive to low quantities, which poses a serious risk to the public's health. Different organic pollutants and metals are not biodegradable and remain in the environment for a very long time. Traditional physical and chemical cleanup techniques are wasteful and generate a ton of chemical waste. The balance of hazardous metals has drawn more and more attention over time to environmentally friendly and economical biosensor bacteria. Microbes have a variety of mechanisms for sequestering metals as a result, which gives them greater capacity for metal biosorption. We conclude by making suggestions based on microbiological tools for extracting and recovering metals and metalloids from solutions utilizing either living or dead biomass or its constituent parts.*

Keywords: Bioremediation; Microorganisms, Heavy metals, Pollution

1. INTRODUCTION

The rapid growth of the human population, as well as the growing demand for industrial facilities to support human requirements, has resulted in issues such as overuse of available resources and rising pollution in the land, air, and water environments. Heavy metal is a big business in the industrial world, and it's also becoming a big environmental issue all around the world (Igiri *et al*., 2018). Heavy metal pollution in the environment has become a severe concern to ecosystem living beings (Okolo *et al*., 2016; Siddiquee *et al*., 2015).

As public awareness has grown, a slew of new ways based on cutting-edge scientific technologies have emerged to assess and address this pervasive global problem. Bioremediation is a generally established method for decontaminating a polluted environment in an environmentally benign and long-term manner (Raghunandan *et al*., 2018). Chemical pollutants are used as an energy source by microorganisms throughout the microbiological process. Excessive concentrations of inorganic nutrients in soil, on the other hand, restrict microbial activity (Ahirwar *et al*., 2016). Microorganisms, in particular, can breakdown, detoxify, and even accumulate hazardous organic and inorganic substances (Medfu Tarekegn *et al*., 2020). Natural, agricultural, industrial solid waste, inland effluent, atmospheric sources and others are all sources of heavy metals in the environment.

Heavy metal (HM) pollution is a serious environmental issue that affects crop yield and food quality as a result of overuse of agricultural inputs such as fertilizers, pesticides, and mulch, which has resulted in heavy metal contamination of soils (Su, 2014). Metals, unlike organic pollutants, do not degrade and hence persist in the environment for a long time; when present in high amounts, metals can disrupt plant metabolism (Ferraz *et al*., 2012). Heavy metal ions must be removed from soil, water bodies, and wastewater using novel treatment technologies (Medfu Tarekegn *et al*., 2020). Various bacteria have been offered as efficient and cost-effective heavy metal removal options in soil and water (Ahirwar *et al*., 2016).

The bacteria' biochemical makeup will be determined, as will their ability to withstand heavy metals like zinc and copper. Recent improvements in bioremediation techniques have occurred in the last two decades, with the ultimate goal of effectively restoring damaged areas in an environmentally acceptable and cost-effective manner (Medfu Tarekegn *et al*., 2020). Different bioremediation approaches have been created and studied by researchers; however, due to the nature and/or kind of contaminant, there is no one bioremediation technique that can restore damaged habitats as a "silver bullet" (Medfu Tarekegn *et al*., 2020).

Most of the issues related with biodegradation and bioremediation of polluting substances can be solved by autochthonous (indigenous) microorganisms found in polluted settings (Azubuike *et al*., 2016), provided that environmental conditions are adequate for their growth and metabolism. Bioremediation has a number of advantages over chemical and physical remediation approaches, including environmental friendliness and economic savings. Nonetheless, the terms biodegradation and bioremediation are sometimes used interchangeably; the former is a phrase that refers to a process that falls under the latter (Medfu Tarekegn *et al*., 2020).

The nature of the pollutant, which might include agrochemicals, chlorinated compounds, dyes, greenhouse gases, heavy metals, hydrocarbons, nuclear waste, plastics, and sewage, determines the pollutant removal procedure (Medfu Tarekegn *et al*., 2020). Apparently, bioremediation techniques can be classified as ex-situ or in-situ depending on the application site. The type of pollutant, the depth and degree of contamination, the type of environment, the location, the cost, and environmental policies are all factors to consider when selecting a bioremediation technique (Smith *et al*., 2015).

Apart from selection criteria, performance criteria (oxygen and nutrient concentrations, temperature, pH, and other abiotic parameters) that impact the success of bioremediation procedures are also taken into account before the project begins. Microbial remediation introduces novel approaches to resolving the problem of heavy metal pollution in the environment, and it has become a focus of modern bioremediation research and development (Medfu Tarekegn *et al*., 2020). Microbes are being exploited as a tool for bioremediation of heavy metals in the environment, according to this review.

2. HEAVY METAL

Heavy metals are classified based on three factors: density, atomic number, and chemical characteristics. Heavy metals are important in industry and have now become a major environmental issue around the world (Igiri *et al*., 2018; Siddiquee *et al*., 2015). Heavy metal pollution has become a severe concern to living creatures in ecosystems, and it is dependent on heavy metal bioavailability and absorbed dose (Okolo *et al*., 2016; Siddiquee *et al*., 2015).

Heavy metal toxicity is caused by a number of methods, including the disruption of deadly enzymatic processes, functioning as redox catalysts in the generation of reactive oxygen species (ROS), destroying ion control, and directly disrupting DNA and protein development (Gauthier *et al*., 2014). The presence of heavy metals can change the physiological and biochemical features of microorganisms (Medfu Tarekegn *et al*., 2020). Various bacteria have been offered as efficient and cost-effective heavy metal removal options in soil and water (Ahirwar *et al*., 2016).

2.1. Heavy metal pollution in the environment

The ecology has been directly impacted as a result of rapid industrialization and urbanization. The resulting environmental degradation and contamination has become a huge hazard to all living things on the planet, including humans. Some water sources, such as rivers, lakes, oceans, and groundwater, have experienced the most serious water contamination. Furthermore, a large number of materials might alter the water's qualities and pollute it, rendering it unfit for its intended purpose (Medfu Tarekegn *et al*., 2020). Single identified localized sources of water pollution are referred to as point sources of pollution. When dangerous compounds are discharged directly into water bodies, this can happen. Polluted runoff from agricultural regions pouring into rivers and ocean waters are examples of non-point source pollution that affects the water body (Medfu Tarekegn *et al*., 2020). Furthermore, nonpoint source pollution originates from a variety of sources, making it difficult to develop a precise method to reduce pollution.

2.2. Heavy metal toxicity

Copper is a known metal that contributes to heavy metal pollution and contamination. Copper (Cu) is primarily found deep within the earth's crust. It's an uncommon element that can be found in nature in its pure form as well as in ores like chalcopyrite (Igiri *et al*., 2018). When eaten in high proportions, copper pollution can cause severe damage to the kidneys, liver, and even death. Cu accumulation in organs and toxicity inside bodies rose as zinc element and sulfate ions decreased (Lee, 2003), posing a hazard to the fish population.

Nickel, in addition to copper, is a major contaminant of the environment. It could be clastogenic, poisonous, or carcinogenic. Nickel compounds have varying carcinogenic potentials depending on their solubilities. Insoluble Ni_3S_2 or NiO are severe carcinogens, according to Rani (Rani, 2017), whereas soluble nickel salts are mild. Nickel is a common airborne contaminant that enters the body through the respiratory system in the form of nickel carbonyl $Ni(CO)_4$, an intermediate product of nickel refining activity.

The accumulation of several heavy metals (e.g., Pb, Cd, Cu, Ni, Zn, and Mn) in saltwater affected not only the water but also the soil. It has an impact on drinking water sources and increases the hazardous concentration of heavy metals in cereals and vegetables (Siddiquee *et al*., 2015).

A high concentration of mercury is dumped into the sea as wastewater, which has an impact on marine food chains such as shellfish and other seafood, which can accumulate a high concentration of mercury and become dangerous to those who consume it (Siddiquee *et al*., 2015). Heavy metal concentrations in the environment are steadily rising, posing a substantial human health risk through disrupting food chains (Siddiquee *et al*., 2015).

3. BIOREMEDIATION

Bioremediation is a process that uses natural biological activity in the environment to remove or render harmless a variety of pollutants (Siddiquee *et al*., 2015). Bacteria, fungi, or plants use it to breakdown or detoxify potentially harmful substances to human health (Qazilbash, 2004) Bioremediation is defined as the biological degradation or transformation of organic or inorganic waste into harmless materials. The process can run on its own or be aided by the addition of an electron acceptor, nutrition, or other variables. As a result, it employs low-cost, low-technology approaches that are often well-received by the public and may frequently be performed on-site (Su, 2014).

Bioremediation is a fascinating method for removing toxins from the environment. Microorganisms such as fungi, yeast, and bacteria have long been thought to be superior organisms for pollutant detoxification (Abou Seeda *et al*., 2017). It ensures a low-cost, straightforward, and environmentally friendly cleanup approach. Microorganisms have the ability to adapt to harsh environmental circumstances and are nutritionally versatile. They also have a variety of intracellular and extracellular enzymes that use complicated contaminants to transform them into carbon and energy (Thakur *et al*., 2019). They also go through a rapid genetic metamorphosis that allows them to gain new metabolic pathways for xenobiotic degradation (Igiri *et al*., 2018).

Microorganisms must enzymatically attack contaminants and transform them to harmless compounds for bioremediation to be effective. Because bioremediation is only effective when environmental conditions allow for microbial growth and activity, it is frequently used to manipulate environmental factors to speed up microbial growth and degradation (Su, 2014). The microorganisms could be isolated and applied to the polluted location from an indigenous contaminated area or from elsewhere. Living organisms change contaminant materials through reactions that occur as part of their metabolic activities (Siddiquee *et al*., 2015).

3.1 In-situ bioremediation and Ex-situ bioremediation

Bioremediation has been classified into in-situ bioremediation and ex-situ bioremediation (Hatzinger *et al*., 2002). Pollutants in the environment (soils and groundwater) are removed via in-situ bioremediation (Menendez-Vega *et al*., 2007). This method is popular since it is inexpensive, saves money on transportation, and reduces chemical pollutants by using harmless microorganisms (Science & Sharma, 2012). There are two kinds of in-situ bioremediation: Intrinsic bioremediation: This in-situ bioremediation is carried out without direct microbial amendment and by improving ventilation and nutrition conditions, and the second in-situ bioremediation is engineered in-situ bioremediation, which is carried out by applying a specific microorganism to a contamination environment (soil or water), in which nitrogen and phosphorous are used to grow up the development (Hunkeler *et al*., 2002).

Ex-situ bioremediation is the second type of bioremediation. This bioremediation procedure takes place away from polluted soil or water, and contaminated materials must be transported by pumping (water) and other soil transportation methods. Solid-phase bioremediation and slurry-phase bioremediation are the two types of ex-situ bioremediation. The solid phase system is utilized to produce organic waste and bioremediation for residential issues (Rosanti *et al*., 2020). Industrial waste, sewage sludge, and municipal concrete waste are all removed via bioremediation (Loehr *et al*., 2001). Soil bio-pilling, land-farming, and composting are three ex-situ bioremediation techniques. Slurry phase systems are the second type of ex-situ bioremediation; they promote solid-liquid suspensions in bioreactors. This method is a relatively rapid process than other treatment processes (Venkata Mohan *et al*., 2009).

3.2 Microbial Bioremediation

Ex-situ or in-situ microbial bioremediation methods are available. Ex-situ treatments involve transferring pollutants from polluted locations to another location for treatment, whereas in-situ techniques treat pollutants on the spot. Many studies do not recommend ex-situ remediation because of its limitations. It may or may not be profitable at specific locations, and it's possible that microorganisms that helped clean up contaminants in vitro don't do so efficiently in vivo (Barupal *et al*., 2019a, b).

Microbial bioremediation solutions rely on a wide group of organisms that are native to the polluted area and have enormous metabolic power. Isolating and purifying such native microorganisms provides insight into microbial metabolites and degradation pathways. Because the bulk of microorganisms in the environment are non-culturable under in-vitro conditions, the approach for accessing the microbial world remains baffling. Only a small percentage of microorganisms from various environmental samples are easily culturable, making them unavailable for basic study (Bursle and Robson, 2016; Awasthi *et al*., 2020).

4. ENVIRONMENTAL IMPACTS OF HEAVY METALS

Heavy metals are environmentally hazardous pollutants that can be found in soil and water (Wibowo *et al*., 2019; Wibowo & Naswir, 2019). Heavy metals contaminated soil and water, and acid mine drainage refers to heavy metals tainted in water around coal mines. Several locations in Indonesia have been contaminated with heavy metals, such the Grasberg Mine in Papua and the Bukit Asam coal mining firm; nevertheless, this situation is not exclusive to Indonesia. Unfortunately, heavy metal contamination of water does not occur in Indonesia, Susquehanna River, Pennsylvania, United States of America. Heavy metals in stream sediments have been discovered in Rodalquilar, Spain's environment. Groundwater resources in Queensland, Australia, were also contaminated by Mount Morgan.

Heavy metals from waste rock and tailings have been found in high concentrations in surface water, river sediments, groundwater, tailings, and soil in the Yuxi Basin, Hunan, China (Werner *et al*., 2019). Heavy metals can also be found in the home (for example, lead from paint) (Wilson, 2006). Heavy metals can also be found in anthropogenic operations such as smelting, mining, agricultural fertilizer and pesticide application, electroplating, and electronic production. Heavy metals in the aquatic environment have been impacted by all of these activities (Chen *et al.*, 2017)

Heavy metals were found to be contaminated in the world's southernmost mussel farm, Beagle Channel, Argentina, according to a recent study. Five heavy metals in sediment, as well as the gills and digestive glands of mussels, were investigated in Argentina to assess the possible damage to human health. The authors stated in their research that this location has considerable metal bioaccumulation, including Zn, Fe, Cu, Cd, and Pb. The authors of this study took sand samples and measured them in the lab. Using an air–acetylene flame and deuterium background correction, the heavy metals were measured using a Perkin Elmer AA-2380 atomic absorption spectrophotometer (D2BGC). Metal bioaccumulation was also discovered in mussel tissues from Argentina, with metal concentrations ranging from 91 to 103 percent and low metal contamination, such as Cu, Zn, Fe, and Pb (Channel *et al.*, 2010).

Chromium (Cr), a metal ion having valence states ranging from 0 to IV, is one of the metals with a high toxicity. Cr(III) and Cr(IV) are examples of high valence states that are more stable in the environment. Cr(III) and Cr(IV) have completely distinct characteristics in the soil. Cr(III) is found mostly in Cr^{3+}, $Cr(OH)^{2+}$, $Cr(OH)^{2+}$, $Cr(OH)_2$, $Cr(OH)_3$, $Cr(OH)_5^{2-}$, and $Cr(OH)_4^{2-}$. (Mendoza *et al*., 2007) Cr(IV) is more poisonous than Cr(IV) and is found mostly in CrO42-, Cr2O72-, and HCrO4- (III). These elements have a high solubility in the environment, making it easier for them to travel through pore water (Mendoza *et al*., 2007).

Heavy metals in the environment are also produced from sulfide oxidation. This process generated wastewater called acid mine drainage. Acid mine drainage has high heavy metals contamination such as Fe, Mn, Mg, Al, Ag, etc. (Wibowo and Naswir, 2019; Wibowo and Syarifuddin, 2018).

Heavy metals have also been discovered in Beijing's dust road. Chong Men reported on geographical variance and heavy metals source detection in Beijing's dust road. They identified and analyzed the risk index using the Nemerow Integrated Risk Index (NIRI). Heavy metals (i.e., Cd, As, Cu, Cr, Ni, Mn, and Pb) have a significant tendency to accumulate and are easily transported through the food chain, according to the authors of this research. Dust road was collected in the China Plain's northwest area, around 115.70-117.40 E, 39.40-41.60 N. According to this study, 22 percent of the population is at danger during the spring; fuel burning is the leading source of heavy metals (34.21 percent) (Men *et al*., 2019).

According to a recent study, 168 rivers and 71 lakes were polluted between 1972 and 2017. Researchers looked at 12 heavy metals (Cd, Pb, Cr, Hg, Zn, Cu, Ni, Al, Fe, Mn, As, and Co) in rivers and lakes for this study. Heavy metal evolved from single metal pollution to mixed metal pollution between 1972 and 2017. Heavy metals in water bodies around the world come from mining and manufacturing industries over time (Zhou et al., 2020); in 2004, heavy metal concentrations in Nigeria river water were 30 g.L-1 for Pb, 50 g.L-1 for Cd, 2080 g.L-1 for Cr, and 780 g.L-1 for Ni. Heavy metals are also founded in the environment, such as contaminated soil caused by petroleum, oil, and gas activity (Zhang *et al*., 2019).

5. HEAVY METAL BIOREMEDIATION ABILITY OF MICROORGANISMS

Heavy metals are taken up by microbes through bioaccumulation, an active process, and/or adsorption, a passive process. Several microorganisms, such as bacteria, fungi, and algae, have been used to clean up heavy metal-contaminated environments, with the application of metal-resistant strains in single, consortium, and immobilized forms for heavy metal remediation yielding effective results, while the immobilized form may have more chemisorption sites to adsorb heavy metals.

5.1. Heavy metal's bacterial repurposing ability

Microbial biomass contains a variety of biosorptive properties that range greatly amongst microorganisms. However, each microbial cell's biosorption ability is influenced by its pretreatment and experimental settings. To improve biosorption, microbial cells must respond to changes in physical, chemical, and bioreactor architecture (Ayangbenro & Babalola, 2017). Bacteria are essential biosorbents because of their widespread distribution, size, capacity to thrive in controlled environments, and resistance to environmental conditions (Srivastava *et al*., 2015).

Bacterial species such as Flavobacterium, Pseudomonas, Enterobacter, Bacillus, and Micrococcus sp. have been used to test a variety of heavy metals. Their high surface-to-volume ratios and possible active chemisorption sites (teichoic acid) on the cell wall contribute to their strong biosorption capabilities (Mosa *et al*., 2016). Abioye and colleagues (Abioye *et al*., 2018) used Bacillus subtilis, Bacillus megaterium, Aspergillus niger, and Penicillium sp. to evaluate the biosorption of Pb, Cr, and Cd in tannery effluent. Pb reduction was greatest in B. megaterium (2.13 to 0.03 mg/L), followed by B. subtilis (2.13–0.04 mg/L). After 20 days, A. niger had the best ability to reduce Cr concentrations (1.38–0.08 mg/L), followed by Penicillium sp. (1.38–0.13 mg/L), while B. subtilis had the best ability to reduce Cd concentrations (0.4–0.03 mg/L), followed by B. megaterium (0.04–0.06 mg/L).

Kim and his coauthors (Kim *et al*., 2015) developed a batch system that removed Cr^{6+}, Cu, and Ni with removal efficiencies of 99.8%, 98.2%, and 90.1 percent, respectively, utilizing zeolite-immobilized Desulfovibrio desulfuricans. Abbas *et al*. (2014) found that bacterial consortia efficiently removed chromium, zinc, cadmium, lead, copper, and cobalt at a rate of 75 to 85 percent in less than 2 hours of contact time.

5.2. Heavy metal's fungi remediation capability

Fungi are commonly utilized as biosorbents for the removal of hazardous metals because of their high metal absorption and recovery capacities (Fu *et al*., 2012). The ability of *Coprinopsis atramentaria* to bioaccumulate 76 percent of Cd^{2+} at a concentration of 1 mg/L Cd^{2+} and 94.7 percent of Pb^{2+} at a concentration of 800 mg/L Pb^{2+} was investigated. As a result, it has been proven to be an excellent heavy metal ion accumulator for mycoremediation (Lakkireddy & Kues, 2017). Luna *et al*. (2016) also discovered that Candida sphaerica produces biosurfactants with Fe, Zn, and Pb removal rates of 95%, 90%, and 79%, respectively.

5.3. Heavy metal removal using biofilm

There are several reports on the application of biofilms for the removal of heavy metals. Biofilm acts as a proficient bioremediation tool as well as biological stabilization agent. Biofilms have a very high tolerance against toxic inorganic elements even at lethal concentrations that are lethal. It was revealed in a study conducted on Rhodotorula mucilaginosa that metal removal efficiency was from 4.79% to 10.25% for planktonic cells and from 91.71% to 95.39% for biofilm cells (Goher *et al*., 2016).

5.4. Heavy metal's algae-remediation ability

In comparison to other microbial biosorbents, algae are autotrophic, meaning they consume few nutrients and produce a large amount of biomass. These biosorbents have also been utilized to remove heavy metals from the environment due to their high sorption ability (Abbas *et al*., 2014). Adsorption or integration of algae biomass into cells is employed for bioremediation of heavy metal-polluted wastewater.

Phycoremediation is the employment of several forms of algae and cyanobacteria to remove or degrade toxicants in order to remediate heavy metals (Chabukdhara *et al*., 2017). Algae have chemical moieties on their surface that act as metalbinding sites, such as hydroxyl, carboxyl, phosphate, and amide (Abbas *et al*., 2014).

Dead chlorella vulgaris cells were utilized by Hussian and Napiorkowska-Krzebietke et al. (Abbas *et al*., 2014) to remove Cd2+, Cu2+, and Pb2+ ions from aqueous solutions under various pH, biosorbent dosage, and contact time conditions. These findings reveal that the biomass of C. vulgaris is an exceptionally efficient biosorbent for the removal of Cd2+, Cu2+, and Pb2+ from a mixed solution containing 50 mg/dm-3 of each metal ion, with removal rates of 95.5 percent, 97.7%, and 99.4%, respectively, from a mixed solution.

6. EFFECT OF HEAVY METAL

The presence of heavy metals in the environment will have certain harmful consequences. According to a recent study, heavy metals from mining operations have an impact on the quality of mining tailing leachate. The effects of heavy metals from mining operations were studied in batch and column leaching tests, and the findings revealed that Cr, Cu, Ni, Zn, As, Cd, and Pb had an impact on soil quality. These metals pose a significant environmental threat. This study also revealed that tainted heavy metals from mining operations could affect surface water and land that is irrigated by local surface water (Wang *et al.,* 2019).

Heavy metals are well known for their harmful effects on human health due to their toxicity, even at low doses. The quality of groundwater in Punjab, India, was recently documented in a study. Physicochemical features, water quality, heavy metals concentration (Cd, Co, Cr, Pb, Zn), and impacts on adults and children over the winter and summer seasons were all investigated at the 18 sites. They took 18 samples in the summer (9 and 7) and 18 and 8 samples in the winter. Cobalt's non-cancer risk quotients average 5.09-7.63, or more than 1. All heavy metals pose a total risk of 6.00-10.11, with >1. Ropar Wetland, Punjab, India, has an increased incidence of non-cancerous health problems as a result of these findings. According to this study, groundwater in Punjab, India, contains a high level of heavy metal contamination. Due to heavy metals from bioconcentration in food crops farmed in certain locations, this condition may pose a serious health danger to humans via drinking water and irrigation of agricultural fields (Sharma *et al*., 2019).

Heavy metal pollution, such as that found in the soils surrounding an electronics manufacturing site, is linked to human health hazards. This research was conducted in Xiangyang, Hubei Province, Central China, which has a total area of 19.774 km2 and a population of around 5.5 million people. Heavy metals such as Cr, Cu, Zn, As, Cd, Pb, and Ni are highly concentrated in this state. The carcinogenic and non-carcinogenic effects of several heavy metals have been linked. Children (more than 86 percent) and adults (50 percent) have a higher non-carcinogenic influence (Sun et al., 2018). Heavy metals can affect human health in two ways: through ingestion (eating and drinking) and inhalation (breathing). Arsenic, barium, lead, cadmium, chromium, mercury, silver, and selenium are metal ions that provide a high danger of contamination.

One of the metal ions is arsenic. Volcanic activity, rocky erosion, forest fires, and human activity all have the potential to release enormous amounts of arsenic. Arsenic can be found in paints, metals, dyes, pharmaceuticals, semi-conductors, and soaps in the United States. Arsenic is toxic to humans. This metal has been linked to skin, bladder, liver, and lung cancer. Long-term low-level exposure can cause a darkening of small corns' appearance, decreased white and red blood cell production, ingestion of high contaminated can result in death, and long-term low-level exposure can cause a darkening of small corns' appearance, warts on the palms, torso, and soles, and skin irritation. The EPA (Environmental Protection Agency) has set regulation limits for arsenic in drinking water (0.01 ppm), and OSHA (Occupational Safety and Health Administration) has set a limit of 10 micrograms per cubic meter of working air in 10.m-3 for eight-hour shifts and forty-hour work weeks (Adriano, 2001).

Barium is one of the most abundant metals. This metal is found in nature and is used in the manufacturing industry. Barium-nickel alloys are a type of barium compound that is employed as a drying and oxygen-removing agent in spark-plug electrodes and vacuum tubes. Cancer is one of barium's health impacts. Vomiting, diarrhea, abdominal cramps, breathing difficulty, low blood pressure, numbness around the face, and muscle weakness are all symptoms of short-term barium exposure. Large levels of tainted barium can cause excessive blood pressure, cardiac rhythm changes, and paralysis, leading to death. The Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) are international bodies that regulate barium limits.

For eight hours of work per day and a 40-hour workweek, the EPA has set barium pollutants limits of 2.0 ppm in drinking water and 0.5 milligrams of soluble barium compounds per cubic meter of the workplace. According to a recent study, barium is widely known. Inhalation and ingestion of a substance containing barium can lead to barium contamination in humans (BaCl2). Since 1940, this molecule has been identified as a human toxic, causing diarrhea, vomiting, cardiac arrhythmia, renal failure, liver failure, tremors (nervous system problems), brain edema, and paralysis (Kravchenko *et al*., 2014).

7. ADVANTAGES AND PROBLEMS OF BIOREMEDIATION

The capacity to remove heavy metals by microbial treatment has several advantages, including adaptability: self-reproductivity, bioproduct recycling, and environmental friendliness. Several laws have been enacted in Indonesia to encourage the use of bioremediation for environmental remediation. Since 1994, an international oil and gas corporation has been working on bioremediation. To begin, microbial remediation was tested in a lab setting and was successful. Nine bioremediation facilities have a waste capacity of 42,000 m3. In 2002, this technology was put to its full potential. This circumstance demonstrated that bioremediation is not limited to the laboratory.

Bacillus strain H9, *Aspergillus terreus* for Cd, Pseudomonas aeruginosa, and Aspergillusniger for Cr, Pseudomonas aeruginosa PU21 (Rip64), and Aspergillusnige for Pb were reported to minimize contaminants from wastewater. Pseudomonas spp., and Candida spp. could reduce Cu and Ni utilizing Thiobacillus ferrooxidans and Schizosaccharomyces pombe (Banik *et al*., 2014), and much of the microbiological has not been established as a wastewater remediation agent.

The possibilities for this procedure are far greater than for other methods. Adsorption is a low-cost and simple method for dealing with heavy metal contamination. Many studies have been written about this approach of removing heavy metal contamination. Even so, when the adsorbent absorbs the metals, the adsorbent transforms into hazardous waste (due to metals contamination). Another technology is required to address this problem. As a result, we will have to pay more to reduce the amount of metals tainted by the adsorbent. This strategy, on the other hand, is too unique. When the metals can't detect them, the microbes will die. Metals are food for microbial consortia; nevertheless, bioremediation employing microbial requires a far higher cost to generate than adsorption.

The pollutants must be bioavailable in order for biological contaminant degradation to work properly. It is necessary to maximize the effectiveness of contact between bacteria and pollutants. Microorganisms physically assimilate pollutants in the liquid phase. It is difficult to breakdown pollutants from a denser and hydrophobic phase (NAPLs) such that they can be absorbed and dispersed out of nanopores. In such instances, the degree of diffusion, desorption, or solubility can be used to influence the rate of biodegradation. More polar (water-soluble) pollutants are now available. Increased interaction between bacteria and contaminants, particularly in hydrophobic pollutants, is also required, requiring the inclusion of surface-active chemicals (surfactants). Bioavailability includes the influence of all physical and chemical parameters that ultimately determine the potential utilization of microbes in utilizing these contaminant compounds.

Co-remediation techniques including permeable reactive barriers, electrokinetic systems, microbial electrochemical technologies, and others may help with heavy metal bioremediation. Many coupling methods have a lot of promise for reducing heavy metals and other pollutants in wastewater. The quest for a suitable coupling technology that may greatly reduce pollutants while maintaining low operational and investment costs is still ongoing in this field.

8. CONCLUSIONS

The biotechnological potential of microbes in removing and/or recovering metals has piqued interest in methods involving heavy metal uptake by microorganisms in recent years, according to this review. The enormous threat posed to the environment by manmade activity has prompted researchers to consider novel decontamination and cleanup solutions. Realizing and discovering the relationship between microbial communities in contaminated environments is difficult.

The review focuses on the most important information for using bioremediation for environmental remediation. In-situ and ex-situ bioremediation are the two types of bioremediation. Ex-situ bioremediation techniques are divided into solid-phase system and slurry phase system, and in-situ bioremediation techniques are divided into intrinsic bioremediation and engineered in-situ bioremediation. Heavy metals are a hazardous substance in the environment. These materials are also hazardous, with detrimental consequences for the environment and human health. The effects of heavy metals on human health and the environment have been discussed. These compounds may cause cancer, skin illness, poisoning, and other negative consequences.

Researchers in the area should look into new species that have a lot of potential in the future. Competition with biological agents, insufficient supply of vital nutrients, unpleasant external abiotic conditions (aeration, moisture, pH, temperature), and limited bioavailability of the pollutant all influence the rate of undesirable waste item decomposition. Bioremediation is only effective when environmental circumstances allow for microbial growth and activity, and it is a highly safe and accommodating method because it relies on bacteria that naturally occur in the soil and pose no risk to the environment or the people who live there.

Bacteria are one of the most important microbiological options for bioremediation; nevertheless, only a few studies have been conducted in this field, and more comprehensive and comprehensive investigations are needed to get the most out of bacterial systems as "heavy-metal pollution alleviators." More research is needed, however, to determine the precise and unambiguous mechanisms involved in heavy metal removal by bacteria, fungi, and algae.

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