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REVIEW ARTICLE

Heavy Metals in Sewage Treated Effluents: Pollution and Microbial Bioremediation from Arid Regions

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Abstract: Not all heavy metals are toxic. Some at lower concentrations are essential to the physiological status of the organism. Under certain conditions, induced toxicity occurs when the heavy metals are in the form of cations which tends to bind to certain biomolecules, thus becoming toxic to organisms. In many industries, toxic heavy metals such as As, Cd, Cr, Cu, Hg, Pb and Zn, are released mainly in sewage effluents causing major environmental pollution. Several of the heavy metal contaminations resulted from industrial wastes, along with the mining and burning of fossil fuels, leading to water and soil contamination which causes serious health problems. Rapid population growth plus a steady increase in agriculture and industry are the main cause of environmental pollution. The most common sources of heavy metals are fuel combustion, mining, metallurgical industries, corrosion and waste disposal which infiltrates the soil and underground water. When present at certain levels in the human, metals can cause certain diseases. Most of conventional technologies are inefficient to remove heavy metal contaminants. Microbial bioremediation is a potential method for the removal of heavy metal pollution in sewage effluents before being discharged into the environment. However, further research is needed for isolation and identification of microbes resistant to heavy metals. Industrial regulatory standards must be established to regulate the spread of non-essential metals in the environment. The regulations must be rigidly enforced. The rest of the essential metals must also be regulated since an increase over the physiological limit can also be harmful.

Keywords: Arid regions, Heavy metals, Microbial bioremediation, Pollution, Sewage, Toxicity.

INTRODUCTION

Heavy metals are generally classified into three groups: basic metals, metalloids and transition metals. The metallic group has properties in atomic mass less than 20 [1]. The majority of heavy metals are transition metals. Whether metalloids or light metals, their toxicity varies according to the metal oxidation state and the concentration. Some heavy metals at specific oxidation state are trace elements, while in another oxidation state they become highly toxic. Therefore, not all heavy metals are toxic to organisms [2]. Some heavy metals at a lower concentration are essential elements and become toxic with concentration increase [3]. However, there are some heavy metals, such as Pb and Hg, which are highly toxic even at a low concentration. Toxicity of some heavy metals exists when they are in a specific form. For example, in soluble form, some heavy metals become toxic, affecting the physiologic state of organisms. The toxicity occurs when heavy metals are in the form of cations which enable them to bind to proteins and other biomolecules. Therefore, accumulation of non-essential heavy metal in organism tissue was used as bioindicators of environmental pollution [4].

Most heavy metals are used in light and heavy industries. In manufacturing, many of the heavy metals are released with sewage effluents causing environmental pollution. Since they cannot be destroyed, they accumulate in the environment affecting organisms, leading to toxicity and illnesses with diarrhea, vomiting, abdominal pain, nausea, heart problems and anemia, while some heavy metals are known mutagens causing cancer [5, 6].

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Many of the industrialized nations have serious environmental problems and challenges in controlling, heavy metal pollution along with health related issues, with only partial success avoiding heavy metal pollution in the environment. This is a major problem in the developing countries [7, 8]. Several major sources of heavy metal contamination which include consumer use of heavy metals, industrial waste, mining, and burning of fossil fuels leads to accumulation in soil, sediments, water and the food chain [9, 10].

To minimize heavy metal pollution, it is essential to have an effective monitoring system controlling industrial sewage effluents before they are released to the environment [11].

Heavy metal toxicity has been spreading rapidly in association with industrialization and increased release of pollutants to terrestrial and aquatic environments, causing threats to public health and has become common in many parts of the world [11 - 16]. Heavy metal pollution was reported to contaminate domestic animals, crops, and affect humans when consumed [3, 4, 17 - 22].

Several studies reported that heavy metal pollution was one of the main factors in declining populations in different habitats [17, 21]. It is well established that heavy metals lead to chronic diseases when excessively accumulated in organisms [23, 24]. A gradual bioaccumulation will ultimately become fatal [3].

So far, there are no sufficient technologies to detoxify heavy metal pollutants. The objectives of this article are to provide report on the economic importance of the heavy metals and type of heavy metals in relation to its adverse effects on environment and public health. Also, this paper will give an overview on microbial bioremediation of heavy metals in contaminated effluents.

GLOBAL METAL RESOURCES

Minerals and metals have played an important role in economy throughout the world. In general, minerals and metals are used in roads, general construction, and industries involving electronic devices, such as computers, telephones, semiconductors and other electric devices. Mineral resources are classified into two groups, metallic and non-metallic. The non-metallic minerals include dimension stone, gravel, uranium, gypsum and halite. The metallic minerals include aluminum, chromium, copper, gold, iron, lead, nickel, silver, tin, and zinc. The most abundant metal is aluminum followed by iron, titanium, chromium, zinc, copper, silver, platinum, gold and uranium [25]. Based on biological importance heavy metals are classified into essential metals with many biological functions (Ca, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, V, W, Zn), toxic metals (Ag, Al, Au, Cd, Hg, Pb, Sn, Ti), none essential nontoxic metals (Cs, Rb, Sr, T) and metalloids (As, Ge, Sb, Se) [2]. Economically, metals are classified into four categories: industrial, precious, critical and additional metals [26] (Table **1**).

Table 1. Economical classification of metals [26].

Industrial	Precious	Critical				Additional		
Al	Ag	Be	Pd	Ce	Ho	Li	Cr	Te
Fe	Pt	Mg	In	Pr	Er	B	Mn	Ba
Cu	Au	Co	Sb	Nd	Tm	Na	Ni	Re
Zn		Ga	Ta	Sm	Yb	Si	As	Tl
Sn		Ge	W	Eu	Lu	K	Sr	Bi
Hg		Nb	Os	Gd		Ca	Y	
Pb		Ru	Ir	Tb		Ti	Zr	
		Rh	La	Dy		V	Mo	

Metals and mineral resources are usually not renewable. Those minerals are not distributed evenly throughout the world. Some countries are mineral-rich while others are mineral-poor [25]. The share of the global metal industry varies among the producing countries with China taking the lead with a share of 27% followed by Australia (4%), Russia, USA, and Chile (3%) each, Canada (2%), while Brazil, DRC, India, Japan, Kazakhstan, Mexico, Peru, South Africa, Rwanda and Turkey (1%) [26]. The rest of the countries fall below those values. However, China has been seriously environmentally impacted with the rapid modernization in all aspects of industries, mainly depending on steel and other metals. For example, red alert of severe air pollution was issued in ten major cities in China in December 2015. Such magnitude of air pollution affecting a wide area due to industrialization rarely occurs. The smog pollution affected 30 other smaller cities, including Beijing. Pollution was caused by many industry sectors throughout China [7]. The Organization for Economic Co-operation and Development (OECD) [27] reported that the highest mortality rate from

outdoor pollution between 2005-2010 was China followed by India with an estimated cost of USD 3.5 trillion a year. Number of mortalities in outdoor air pollution exceeded the rest of the world (GBD 2014) [28]. The Pearl River delta in south China and the Yangtze delta in east China were the most polluted regions due to industries and mining. The two regions are heavily polluted with arsenic, cadmium, lead and mercury. It was reported that about 12 million tons per year of food produced in China is contaminated with toxic heavy metals. China has introduced soil-heavy-metals-remediation project with the estimated cost of more than 4 billion USD [8]. These conditions have led China to environmental disasters coupled with serious public health related issues which may also heavily impact their economy.

There is a major global concern on the management of metals in industry and recycling. The increased demand for metals will lead to significant global deficiency, specifically the platinum group [29]. Recycling of metals is therefore a wise practice. With the current technologies and challenges, it was reported that the current recycling process of metals does not meet the demand of most metals used in various industries [26]. Only 1% of most metals mentioned in Table **1** can be recycled as indicated in Table **2**. Most of the low-recycled metals are involved in many high-tech industries such solar PV, microchips, and consumer electronics. For example, sixty elements may be involved in manufacturing circuit boards and microprocessors, some of which are impossible to recycle due to technical limits or as a result of oxidation in the smelting slag [29]. If the current situation of metal loss continues, most of the current technologies will be facing a tremendous shortage. On the other hand, it was reported that it is not likely that there will be a complete depletion of useful mineral resources. However, he stressed that if the current economical supply deposits are depleted, and the cost will increase dramatically and the concentration factor will also increase [25].

Table 2. Metal recycling percentages [29].

< 1%				1-10%	>10-25%	>25-50%	>50%	
Be	Pr	Tm	Zr	Hg	Ru	Mg	Al	Co
Ga	Nd	Yb	Ba	Sb	W	Ir	Fe	Nb
Ge	Sm	Lu	Tl			Mo	Cu	Rh
In	Eu	Li	Ti				Zn	Pd
Ta	Gd	B					Sn	Ti
Te	Tb	V					Pb	Cr
Os	Dy	As					Ag	Mn
La	Ho	Sr					Pt	Ni
Ce	Er	Y					Au	Re

The most recycled metals are aluminum and steel [30]. The plentiful metals such as Al, Cu, Ni, Pb, and Zn with recycling rates of more than 50% due to their existence in pure forms (Table **2**). The rest of the metals are lost, causing accumulation in the environment. The other precious metals are at low-recovery rate. Some of unrecovered metals are highly toxic to organisms [29].

Heavy metal pollution should be dealt jointly in a global effort by setting up international regulatory standards to minimize its impact on the environment which directly affects public health. Several international organizations have established regulatory heavy metals standards. However, these standards are not unified [31 - 37] and have deficiencies in many elements mentioned in Tables **1** and **2**. Also, most of the metals are not recycled, leading to their accumulation in the environment causing pollution [29].

Environmental Pollution & Health

Due to excessive industrialization accompanied by rapid global population growth and increase in agricultural practices, heavy metals As, Cd, Cr, Cu, Hg, Pb, and Zn are the most common environmental pollutants [1, 38]. Generally, the sources of heavy metal pollution are mining, smelting, metallurgical industries, corrosion, waste disposal, fossil fuel combustion agriculture and forestry [5, 38 - 48]. As a result, the contaminants spread through air and accumulate in soil infiltrating underground water. Consequently, this causes severe ecosystem damages, entering the food chain through contaminated soil and water [1, 3, 4, 11 - 15, 49, 50]. More than ten million polluted sites were reported across the globe. Most of the polluted sites are contaminated with heavy metals and metalloids causing more than ten billion USD annually [1]. It was reported in 2009, Belgium has the maximum heavy metal pollution in Europe, followed by Greece. In 2012, Poland exceeded Belgium followed by Romania, while Greece decreased to lower levels [51].

Almost all mercury emission is from fossil fuel (46%) combustion, followed by gold production (24%), metal and

cement production (10% each) and waste incineration (6%). The major source of mercury air emissions from the US industrial sources and power plants is estimated at about more than half of anthropogenic emission. About 33 tons of mercury are released from power plants annually [52].

In addition to natural process, as anthropogenic activities are the main sources of pollution, which include fossil fuel combustion, smelting, waste disposal, mining, farming and corrosion [1]. Some of the toxic metals (As, Cd, Hg, Pb, and Se) residence time in the atmosphere, land, ocean and sediments differs significantly. In general, metal residence time in sediments ranges between year 90.8×10^6 for Hg to 99.8×10^6 for As and Cd, while the least residence time in atmosphere ranges between years. 1.0×10^{-1} for Hg to 3.0×10^{-2} As and Se [53].

Toxicity of heavy metals in human health and various organisms has been reported by many investigators (Table **3**). The effects range from low to severe cases with degenerative effects by interfering with specific cellular metabolic processes reducing natural detoxification mechanisms. For example, lead, mercury, and cadmium prevent glutathione S-transferase from liver peroxidase activity [43]. Other heavy metals mimic essential elements reducing co-factor activity at molecular level of cellular metabolism. Several factors are involved in heavy metal toxicity. These factors include route of exposure, type of metal and age.

Table 3. Metal sources relative to toxicities and human diseases.

Metal	Source	Effect in humans	References
Aluminum	Abundant metal in the earth's crust, found in food and water, cosmetics	Alzheimer, Parkinson, senility, prehensile dementia,	[39, 42, 44, 54]
Arsenic	Natural existence in inorganic and organic forms. Organic form commonly found in seafood, pesticides, coal combustion, metal smelters, mine leachate, wood preservative, tobacco smoke, cosmetics	Non-essential element, trivalent arsenic is more toxic than pentavalent, cumulative poison, carcinogen, abdominal pain, black foot disease, hepatoxicity, birth defects, cardiovascular mortality, gastrointestinal damage, vomiting and diarrhea	[38 - 40, 54, 67, 68]
Beryllium	Volcanic dust, coal, rock, soil aerospace industries, ceramic manufacturing, X-ray transmission windows, nuclear reactor, navigational systems, audio components, fluorescent lamps, computers components, dental labs, microwave devices, telecommunication devices, cosmetics	Non-essential element, carcinogen, chronic beryllium disease (CBD); lungs and respiratory diseases, skin diseases. conjunctivitis, rhinitis, infidelity of DNA replication	[54, 69 - 72]
Cadmium	Marine environment, mining, electroplating industry, PVC industry, Ni-Cd Batteries, plastics, paints, fertilizers, pesticides, anticorrosive agent, voltaic devices, TV industries, cosmetics, Textiles	Non-essential element, highly toxic & fatal, DNA damage, carcinogen, embryotoxic, placental abnormalities, nephrotoxicity, hypertension, hepatoxicity, renal dysfunction, pancreas toxicity, placental abnormalities, apoptosis in testis, bones softening, blood pressure, osteoporosis	[5, 6, 38, 43, 46, 48, 54, 67, 73, 74, 38]
Chromium	Element of earth crust, soil, water, lather and tanning industries, paper and pulp manufacturing, mineral resources, mines, cosmetics	Essential element (chromium III), lung damage, hepatoxicity, carcinogen, renal tubular necrosis, skin and stomach ulceration, hematological toxicity, weakened immune system, central nervous system	[54, 67, 68, 74]
Cobalt	Alloy manufacture, corrosion resistant alloys, petroleum and chemical industries, paint drying agent, medical treatment, food preservation, ceramic and porcelain production, nuclear power plants	Essential element, weakening human health, reactive oxygen species	[38, 75]
Copper	Utensil manufacturing, pipes, bronze, electrical wires, mining, chemical industry, pesticide production, metal piping	Essential element, DNA damage and carcinogen, embryotoxic, stomach and kidney damages, diarrhea, vomiting, loss of strength	[48, 54, 68, 74]
Iron	Most common metal, drinking water, cosmetics	Essential element, affecting melanin and causing grey or bronze skin color pigmentation, kdney, hepatoxicity, heart failure, joint diseases, acute toxicity to newborn babies and young children	[38, 39, 41, 45]
Lead	Painted items with led paint, water pipes, children toys and some cosmetic, industrial discharges, electronic solders, sewage effluent, fossil fuels burning, roofing industry, ceramic industry, battery manufacturing, textiles	Non-essential element, DNA damage, carcinogen, embryotoxic, most frequent toxic metal, metabolic toxicity, joint disease, kidney toxicity, reproductive system, abnormal circulatory system, central nervous system and gastrointestinal tract, affects hemoglobin synthesis. neurotoxicity, osteoporosis, breaks blood-brain barrier, decrease sperm count and motility	[38 - 40, 48, 54, 59, 60, 67, 73, 74]
Manganese	Drinking water, cosmetics	Essential element, hemoglobin synthesis, gastrointestinal tract, cells functions,, neurological disturbances, muscle dysfunction,	[54, 74]

(Table 5) contd.....

Metal	Source	Effect in humans	References
Nickle	Cosmetics, stainless steel, corrosion-resistant alloys, desalination plant tubing, coins, armor plates and burglar-proof vaults,	Essential element, cancer, nervous system damage, lung, cardiovascular system, liver, kidney toxicities, cellular damage and reduction in cell growth, decrease body weight	[54, 74]
Mercury	Volcanic eruption, rock weathering, Natural fires, cosmetics, folk medicines, dental amalgams, vaccines, mercury mining, fossil fuels, coal power plants, municipal waste, cement production, batteries; pesticides, paper industry, Cosmetics	Non-essential element, DNA damage, carcinogen, embryotoxic, joint disease, kidney, lung, abnormal circulatory system, neurological disorders, physiologica stress, fetotoxic, skin rashes, tiredness, central nervous system, mental retardation, headaches, blindness, sperm damage, miscarriage, calcium homeostasis, behavioral abnormalities, learning disabilities, estrogen mimic, abortion, tremor	[48, 54, 62 - 68]
Zinc	Most abundant in earth crust, battery manufacturing, roofing building construction, paints, cosmetics, photocopier papers, wall papers, inks, rubber production, metal plating, brass manufacture, plumbing, refineries, cosmetics, textiles	Essential element, DNA damage, carcinogen, hemotoxicity, fatigue, decrease test and smell, skin sores, stomach cramps, nausea and vomiting, respiratory diseases, eye irritation, pancreatic damage, birth defects.	[38, 48, 54, 73, 68]

Many heavy metals are used in traditional and international cosmetic brands, such as eyeliners, eyeshadows, lipsticks and powders. Most women use cosmetics daily without being aware of their contents and the health effects. The traditional known brands such as henna and kohol eyeliner are very common in many nations in the Middle East, Africa and India. Al-Dayel *et al.* [54] analyzed twenty-seven heavy metals and related elements from nine traditional and international brands from Bahrain, Bulgaria, India, Mauritania, Morocco, Nigeria, Oman, Pakistan, Saudi Arabia, the United Arab Emirates, the United Kingdom and the United States. They reported that the cosmetics contained different concentrations of Al, Ag, As, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Na, Ni, Pb, Rb, Sb, Se, Sn, Sr, U, V and Zn. Some with high concentrations of those element, suggesting that thorough investigation and evaluation of such products are needed for their safety.

Traditional remedies and medicines from China, India, Middle East, and Pakistan were also reported to contain heavy metals. In Oman and the United Arab Emirates, the traditional medicine "bint al dhahab" contained Cd, Pb and Sb [55]. Some Asian herbal remedies were found to contain toxic heavy metals [56]. Saper *et al.* [57], reported that Ayurvedic herbal medicinal products contained As, Hg, Pb and that Pb was the main constituent of Indian traditional remedies. Most of herbal medicines are not regulated and are easily accessible to the public. On the other hand, in Pakistan, occurrence of Pb, Cd, Cu, Cr, Co, Fe, Ni and Zn contaminants due to environmental pollution was reported in herbal plants. These plants include *Cuminum cyminum*, *Coriandrum sativum*, *Foeniculum vulgare*, *Glycyrrhiza glabra*, *Onosma bracteatum*, *Viola odorata*, and *Zingiber officinalis* which is evident that a health risk is associated with the use of such herbal drugs [58].

Aluminum is commonly found in food and water. This element was reported in the brains of patients suffering with Alzheimer's [42, 44].

Arsenic is found naturally in inorganic and organic forms. Arsenic intoxication is most commonly reported in cases with much toxic inorganic form. Seafood, for example, contains the highest concentration of As in an organic form [40].

Chronic Cd toxicity is rare but fatal and has no metabolic benefit in humans and other animals. It is mainly found in a marine environment. When ingested it affects internal organs, including spleen, kidney, liver and pancreas, while mimicking the zinc function in metabolic processes [46]. It is also reported to be carcinogenic [5, 6].

Toxicity due to iron is most common, affecting melanin and causing grey or bronze skin color pigmentation, damaging the liver, causing heart failure and joint diseases [41, 45].

The most frequent toxic metal reported is lead exposure from painted items, water pipes, children toys and some cosmetic items, such as mascara eyeliners [40]. It is one of the non-essential elements with no role in human metabolism, with children being more affected than adults [59]. Lead replaces calcium in bones and weakens bone structure and replaces Zn, blocking oxygen exchange in red blood cells. It is also interfering with some enzymes where magnesium is a co-factor affecting nucleotide synthesis [60].

The effects of mercury were reported by many researchers [61 - 65]. SaÌˆllsten *et al.* [66] reported that exhalation in low-level-mercury-exposed humans is treated with small doses of ethanol.

ROLE OF SEWAGE EFFLUENT POLLUTION IN ARID ZONE REGIONS

Rainfall scarcity in arid zone region is a common problem. Many countries with seacoast depend on seawater desalination plants for household and industrial uses. The produced sewage effluents are treated and recycled. The reclaimed water is used in agriculture, industries and public gardens [13, 50]. Some of the reclaimed water is disposed to sea or injected to aquifers [49]. However, aquifer recharging is an expensive process [76].

Oman and the rest of the Gulf Corporation Countries (GCC) are in the arid regions with severe lack of rain, depending mainly on desalinated water and recycling of sewage effluents [50]. Many studies in Oman have reported heavy metals in well water, soil, crops and marine habitats of fish and marine turtles [15, 50]. Some industrial applications of heavy metals (Y, Yb, Te and Zr) were detected in marine green turtle eggs (*Chelonia mydas*) at Ras Al-Hadd Turtle Reserve, Oman, suggesting that marine habitats are contaminated with industrial polluted effluents [14]. Treated sewage effluents were found to be the main source of such contamination. It is clearly indicated that the current technologies used in treating sewage effluents are not sufficient for removal of heavy metals and pathogenic microbes which are resistant to many antibiotics. The microbes were found to resist chlorination and were also found in well water, fish and marine turtles [14, 15 - 50]. For example, some researchers reported that microbes resistant to antibiotics are also resistant to heavy metals. Probably these microbes use the same mechanisms of resistance [77]. Such microbes were found in heavily polluted sewage effluents where they can be potentially used for bioremediation of heavy metals and solve the downsides of conventional methods which produce harmful secondary products.

Treatment of sewage effluent mainly relies on biological functions of microbes. Such microbes play an important role in bioremediation by breaking down toxic compounds under aerobic and anaerobic conditions where each microbial population plays a specific function. However, researchers reported that elimination of heavy metals from sewage effluent is inefficient [15, 73]. Probably the existence and interaction of appropriate microbial population at appropriate environmental conditions could be a key. Hence, isolation and identification of the right microbes to remove heavy metal toxicity are highly essential [78].

MICROBIAL BIOREMEDIATION

Heavy metal pollution continues to be one of the most important global threats. Out of twenty classified toxic heavy metals, half of them are released at higher concentrations with high potential to human health and the environment [78]. One of the main sources of water pollution is the discharge of industrial contaminated sewage effluents with heavy metals, such as Ag, As, Au, Cd, Co, Cr, Cu, Hg, Ni, Pb, Pd, Pt, Rd, Sn, Th, U and Zn. Continuous discharge of heavy metals into the environment and their accumulation cause adverse effects on terrestrial and aquatic environments as well as the population.

Well established physicochemical technologies to remove heavy metals and other contaminants from sewage effluents already exist. These include cementation, ion exchange, precipitation, electrocoagulation and electrowinning [73, 78]. However, these technologies are not cost-effective and needs skilled personnel for operation, generation of hazardous by-products and are inefficient for detoxifying low heavy metal concentrations [73, 79, 80]. Compared to conventional technologies, bioremediation is easy to operate, low metal concentration can be detoxified with high efficiency, self-sustaining system where the right microbes grow depending on the availability of the contaminant, harmful products are not produced and it can be operated in combination with conventional technologies [78, 79, 81]. The isolation and identification of heavy metal resistant bacteria in sewage effluent may contribute to efficient technologies to remove heavy metal pollutants from sewage effluents before being discharged to environment.

Microorganisms convert many toxic heavy metals through the process of metabolism into other non-toxic useful forms [82]. Microorganisms bioremediate heavy metals by several methods including bioleaching, enzyme-catalyzed transformation, biomineralization, biosorption and intracellular accumulation [83]. Most of heavy metal bioremediation occurs through the biosorption mechanisms [84]. However, ideal environmental conditions have to be met for the efficient bioremediation process.

In metal sulfide ores, ideal environmental conditions for maximum rates of bleaching at mining sites was reported at an optimum elevated temperature where high yields of metal extraction were achieved [85]. It was reported that the addition of appropriate nutrients enhances oxygen demand for *Pseudomonas* species and hence the active uptake of metals [86]. On the other hand, at optimum anaerobic conditions, *Klebsiella pneumonia* was reported to bioaccumulate high concentrations (15 mM) of heavy metals [87].

Basha and Rajaganesh [73], reported that *Bacillus licheniformis*, *Pseudomonas fluorescence*, *Salmonella typhi* and

Escherichia coli, isolated from textile industry effluents were used effectively to bioremediate zinc, lead, cadmium, other toxic chemicals. Both free or complex ionic forms of zinc, lead and cadmium are discharged by various industries, such as textile industries [88].

The main disadvantage of microbial bioremediation appropriate conditions to achieve maximum detoxification of pollutants [78, 86 - 88].

CONCLUSION

Heavy metals are found in the earth's crust. They cannot be degraded or destroyed. They enter the body via food, water and air. The majority of the metals are non-essential. Heavy metals can bioaccumulate gradually in the organism and stored in the body faster than they can be metabolized. Heavy metals can enter water such as rivers, lakes, seas and underground water. The most dangerous heavy metals in the environment are lead, cadmium and mercury. These can cause several serious diseases. Heavy metals can be found in wide environmental distribution such as soil, underground water, marine and fresh water habitats. Heavy metal detoxification in contaminated effluents is a global challenge. Current technologies are not efficient. Cheaper and efficient technologies are needed. Microbial bioremediation may be an alternative solution. However, further research is essential to understand microbial bioremediation of heavy metal pollutants before discharging contaminated effluents into the environment. International regulatory standards must be established to prevent the spread of non-essential metals in the environment such as arsenic, beryllium, cadmium, lead and mercury. The rest of the essential metals must also be regulated since an increase over the physiological limit can also be harmful. These regulations must be rigidly enforced.

CONFILICT OF INTERST

The authors confirm that this article content has no conflict of interest.

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