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Biomagnifications of Heavy Metals in Aquatic Inhabitants

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Abstract
The natural aquatic ecosystems are being significantly impacted by the discharge of wastewater containing harmful heavy metals from the industrial sector without proper treatment of contaminated water. As a result, harmful heavy metals collected in various aquatic animal organs, such as fish tissues or organ systems, disrupting their physiological pathways and lowering their rate of development and reproduction. Bioaccumulation is a sustainable method for addressing heavy metal toxicity in polluted aquatic environments. Additionally, by modifying the harmful effects of certain heavy metals, bioremediation aids in improving the physical conditions of fish. Additionally, it contributes to the productivity of aquatic ecosystems by using the proper bioremediation techniques, which can significantly recycle water to reduce water waste and significantly reduce bio-contaminants by decomposing organic matter and increasing environmental biosafety.

Keywords: Heavy metals, Fishes, Toxicity, Aquatic organisms

Introduction

A recent study shows contamination of heavy metals in the aquatic ecosystem have a tremendous impact on pisces members (Baje et al., 2005). In natural habitat, heavy metals exist in their raw form and however, their uncontrolled utilization in industries for solving numerous challenges has remarkably escalated its amount in ecosystem (Adebisi and A.A. 1991). Human practices such as farming, erosion, and waste disposal are the primary contributors of heavy metals in water.Heavy metals readily disintegrate in the water bodies on introduction, thus rapidly aggregating onto the bodies of different organisms including fish and thereafter into the consumer species. This biomagnification in the fish adversely affects its physiological functions and overall health (Buikema et al., 1982). Exposure of metal, duration of metal exposure and type of fish species, are the parameters of metal toxicity whether it is carcinogenic, teratogenic or mutagenic, from both water and the release of leachates percolating in the water body can be life threatening to the marine organisms (Ashraf 2005). The neural system of the fish suffers severe damage by heavy metal-mediated toxicity, hence impairing the fish interaction with their surroundings.Most of the organisms lack the ability to break these toxic compounds into non-toxic forms, they thereby have detrimental effect on human health and their uncontrolled consumption and buildup has become a significant health concern (Daka et al., 2008). Fishes heavily contaminated with heavy metals have shown lower gonadosomatic indexes (GSI), fecundities and fertilization rates, in result decreased the growth and reproductive activity (Doherty et al., 2010). Additionally, embryos and larvae stages of fish undergo abnormal growth and development due to toxicity of heavy metals. Some metals are essential but most are extremely hazardous, even in minimal quantities (Edem et al., 2009). These extremely toxic metals have the tendency to cause cancer and mutations. Metals such as nickel (Ni), cadmium (Cd), copper (Cu), zinc (Zn), chromium (Cr), lead (Pb), mercury (Hg), arsenic (As), selenium (Se), etc., are not deadlybut have shown the property of mutagens and carcinogens (Adeyeye et al., 1996) (Fig.1).

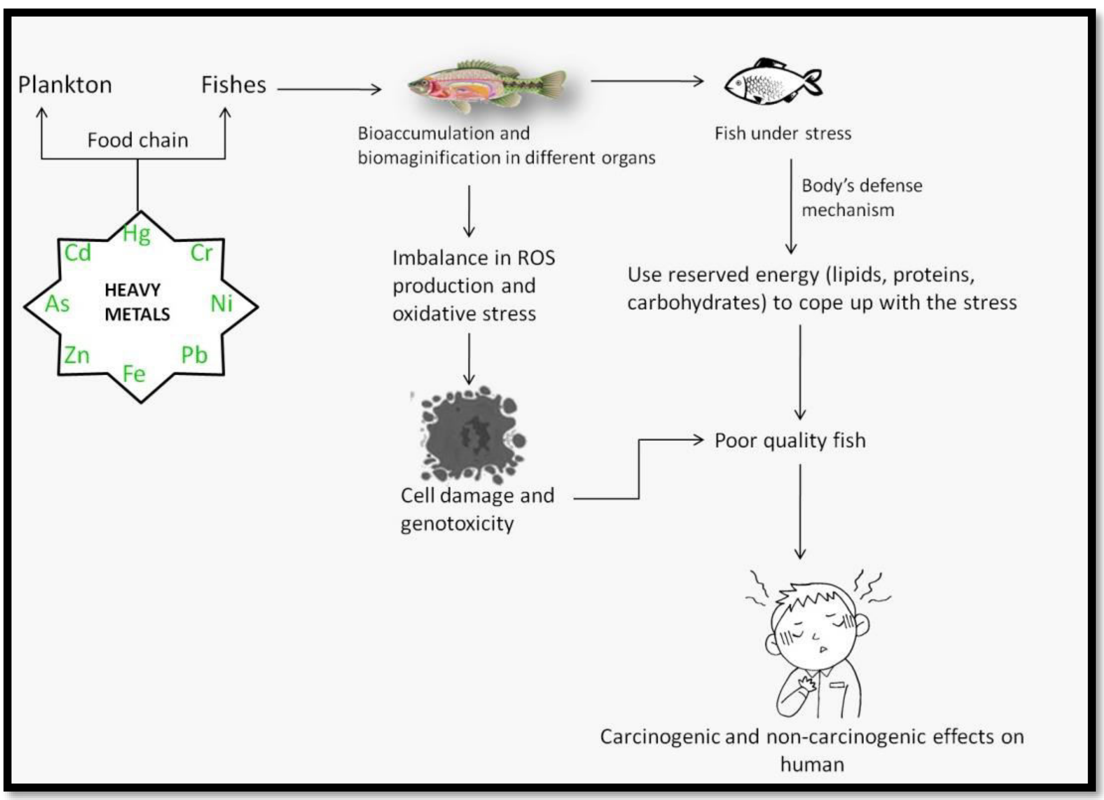

Fig.1: Bioaccumulation of heavy metals in fish metabolism

Despite,many physio-chemical advances in the depletion of these heavy metals, most of the associated technologies are not ideally considered with the concentration of heavy metal under than 100mg/L (Allen 1995). As many heavy metals show solubility with water but theirseparations via physical methods arechallenging (Hayat et al., 2007). Circumstantially biological methods such as bioremediation give a ray to overcome the contamination of heavy metal in marine system (Jaji et al., 2007). Bioremediation is the eco-friendly, cost-effective and sustainable method to bring down the level of harmful contaminants in aquatic system (Mansour and Sidky, 2002). Conventionally, bioremediation process is effective approach to reduce the lethality of theseheavy metals by making them in less reduce forms with the help of either microorganism or enzymes to decrease the heavy metal pollution (Novozamsky et al., 1983). Catabolic property of microorganism with the use of their enzymes and usage of biological surfactants are an ingenious approach to aid the remediation process.

Microorganisms have the capacity to form the metals in their metabolic pathway, and this way theyare considered as the green approach to treat the metal contamination (Obasohan et al., 2006). Different microorganisms such as bacteria, algae are used worldwide in wastewater treatment as they are capable of synthesizing nanomaterials,having property of efficiency to reduce and salvage them in their raw formfrom severely affectedmarine bodies without altering their stability (Shukla et al., 2007). For remediate the heavy metals from water bodies, several study shows that transgenic microorganisms could increase the adsorption property (Venugopal and Luckey, 1978). Through the association of various substances such as biosurfactants, water, minerals, compost and production of biochar can adds thepositive production in remediation process by microorganisms (Wiener and Giesy, 1979). In addition, many biotechnology approaches in microbial bioremediation such as nanotechnology, rhizoremediation and genetically modified organismshave been used vastly in bioremediation process to eliminate the toxicity of heavy metals from the nature (Nwani et al., 2010). Regardless of the bioaccumulation ofheavy metal in fish, no further significant data is present on the removal of heavy metal toxicity in marine bodies especially in fishes (Labonne et al., 2001). As a consequence the contemporary review concludes the direct guidance concerning the modern approaches inbioremedication strategy and bioaccumulation of heavy metal in fishes (Ishaq et al., 2010).

Bioaccumulation of Heavy Metals in Different Tissues of fishes

Estimation of bioaccumulation can possibly be managed by targeting the ecological pathway of heavy metals in the marine bodies (Nwani et al., 2010)..Lethality and oxidation of these transition metals are the parameters that indicate the type of metal and their respective forms. Predominantly in nature, Chromium (Cr) exists in six oxidation forms (+1 to +6) , among which chromate ion bearing hexavalency Cr (+6) forms disastrous effect in members belonging to the class Pisces (Ishaq et al., 2010).. Fishes are majorly prone to the heavy metal contamination in marine ecosystem as these chordates accumulate metals at tissue level in their body such as branchia, parenchymal of liver, kidney, epidermis, muscle, etc. Under stressed conditions, fishes obligate more energy from reserved biomolecules such as protein, fat, and carbohydrates to cope up with various conditions and to sustains the physiology of fishes heavymetals like Cd, Cr, Cu, Fe, Hg, Ni, Pb, Zn, As play an important role as they have high redox potentiality and upon reaction they tend to produce reactive oxygen species (ROS) (Kappus, 1987). ROS are the primaryindicators of oxidative stress that eventually reduce the metabolism of cells as they are involved in activation of inflammasomes and ultimately lead to degradation of proteins, lipids, and DNA. Bioaccumulation of heavy metals present in marine food chaincauses the serious threat to human health through the consumption of these contaminated fish (Kurland et al., 1960). Bioaccumulation of heavy metals in different fish is presented in Table 1.

Table 1:Bioaccumulation of heavy metals in different tissues and organs of fishes

Heavy metals	Fish	Bioaccumulation in tissue or organ	References
Nickel	Hyperopisusbebeoccidentalis	Kidney<Heart<Gills	Murtala et al., 2012
	Hydrocynusforskahlii	Heart<Muscle<Gills<Kidney	Murtala et al., 2012
	Coregonuslavaretus	Muscle<Gills<Liver<Kidney	Gashkina et al., 2018
	Clariasgariepinus	Brain<Skin<Muscle<Blood<Gills<Liver	Murtala et al., 2012
Chromium	Clariasgariepinus	Muscle<Heart<Gills<Kidney	Murtala et al., 2012
	Coregonuslavaretus	Muscle<Gills<Kidney<Liver	Gashkina et et al., 2020

	Pelteobagrusfulvidraco	Muscle<Intestine<Gills<Kidney<Liver	Rajeshkumar et al., 2018
	Hyperopisusbebeoccidentalis	Heart<Muscle<Gills<Kidney	Murtala et al., 2012
	Cyprinuscarpio	Liver<Kidney<Muscle<Gills	Rajeshkumar et al., 2018
	Hydrocynusforskahlii	Gills<Muscle<Heart<Kidney	Murtala et al., 2012
Copper	Pelteobagrusfulvidraco	Intestine<Gills<Muscle<Kidney<Liver	Rajeshkumar et al., 2018
	Coregonuslavaretus	Muscle<Gills<Liver<Kidney	Gashkine et al., 2020
	Cyprinuscarpio	Muscle<Liver<Kidney<Intestine<Gills	Rajeshkumar et al., 2018
Arsenic	Orechromisniloticus	Muscle<Gills<Liver<Stomach	Oliveira et al., 2017
	Clarias batrachus	Brain<Skin<Muscle<Blood<Gills<Liver	Kumar et al., 2012
Lead	Cyprinuscarpio	Intestine<Liver<Muscle<Kidney<Gills	Rajeshkumar et al., 2018
	Hyperopisusbebeoccidentalis	Muscle<Heart<Kidney<Gills	Murtala et al., 2012

	Coregonuslavaretus	Muscle<Kidney<Liver<Gills	Gashkine et al., 2020
	Hydrocynusforskahlii	Kidney<Heart<Muscle<Gills	Murtala et al., 2012
	Pelteobagrusfulvidraco	Muscle<Intestine<Gills<Liver<Kidney	Rajeshkumar et al., 2018
Cadmimum	Hyperopisusbebeoccidentalis	Muscle<Heart<Gills	Murtala et al., 2012

Arsenic (As)

As is considered as noxious naturally occurring metal which contaminates the marine ecosytem through the numerous natural and anthropogenic activites (Nwani et al., 2010).Arsenic is highly toxic in its inorganic form compared to its organic form and on evaluation it is mostly evident in different parts of fish at diverse rate (Hayat et al., 2007). Studies revealed that the accumulation of As in elevated amount seen in liver is 10.04 g/g, although the lowest amount seen in muscle is 3.74_3.38_g/g after 20 days of exposure by Oreochromisniloticus (Kurland et al., 1960). It has been reported that As exposure result into deleterious effect seen in the metabolism and production, reduction, hemato-biochemical alteration, hormonal dysfunction, histopathological abnormality, retardation in embroyonic and larval development and other concerning diseases in fishes (Filazi et al., 2003). Additionally, lethality of As also damage the immunology and hematology of fish. A strong concentration of Aseffects in over production of mucus, erratic swimming behavior, and loss of equilibrium in Anabas testudineus and Daniorerio. Arsenic toxicityresults in increasing the cell death, genotoxicity and various other cellular and nuclear anomalies in hemocytesin fish (Goodwin et al., 2003). In Oryziaslatipes commonly known as medaka, As also generates various type of cytotoxicites and genotoxicites. Likewise, contamination of As has negative influence on the reproduction pattern of fish by inhibiting the gametogeneis and leads to degrading the quality of sperm and ovum respectively along the quantity, fertilization and hatching process (Gosselin et al., 1984).

Chromium (Cr)

Cr is a pervasive metal that has destructive effects on the environment from different types of industries (Filazi et al., 2003). In fishes like Crypinuscarpio, O.aureus,Cirrhinusmrigalaand Carassiusauratus, shows the accumulation of Cr metal in different organs (Table 1). In fishes, Cr induces the anomalies in the physiological condition by overpowering the allergic response as well as the impairment in organ-system (Eralagere et al., 2008). Moreover, in Labeo rohita and C. mrigala Cr continues its toxic effect by changing the property of lipids, proteins and glycogen content in the muscle, liver and gills and leads to damage of hepatic sytem in C. auratus, disrupts the function of vital organs such as kidney, liver of Ctenopharyngodonidella . Cr toxicity also leads to endrocrinological anomalies in fishes found in fresh waste bodies. Additionally, in Pangasianodon hypothalamus Cr alters the hematological profile which results in the cellular and nuclear deformities (Kime et al., 1996). Study shows that the high amount of Cr in fishes notably minimize the growth and survival conditions of different fish species and persistent exposure of Cr causes complication in the reproduction pattern of fishes by decreasing the spawning rate, deforming testis, lowering sperm motility and interfering in oocytogenesis (Hayat et al., 2007).

Copper (Cu)

Cu is a substantial water pollutant that creates severe contamination in the aquatic system and greatly hinders the fish physiology and growth (Gosselin et al., 1984).. The bioaccumulation of Cu in different organs of fish species is exhibited in Table 1. In accordance to a number of studies, in fish the primary location of highest accumulation of Cu is liver relative to other organs. An excessive amount of copper in the fish's diet decreases their appetite thus impacting the development and utilization (Kime et al., 1996). Copper toxicity causes malformed reproductive organs as well as reduces the GSI, fecundity, fertilization and hatching rate in multiple fish species (Labonne et al., 2001).

Magnese (Mn)

Mn is covered a broad variety of habitats. Human activites cause Mn to dissolve in the water bodies (Hayat et al., 2007). Fish toxicity to Mn varies depending upon some parameters such as species, age and water quality Kurland et al., 1960). It has been observed that as water hardness increases, the toxicity of Mn decreases. In Argyrosomus japonicas, bioaccumulation of Mn in muscles, gills and liver disrupted the carbohydrate metabolisation and fluctuatethe ionic composition of blood (McCraken, 1987). It influences the fish behaviourby inducing lethality and fatality. In C. auratus, Mn causes oxidative stress. It causes the formation of free radicals and inhibits various enzymes having antioxidant capacity, which ultimately leads to neurogenetic issues (Labonne et al., 2001)..Mn harms the hepatocytes and triggers cell caspases leads to apoptosis in Grouper fish (Filazi et al., 2010).

Nickel (Ni)

Ni is utilized vigorously in various industries and is regarded as the main aquatic pollutant. In water bodies, Ni interacts with chemical compounds and generates nickel associated compounds (McCraken, 1987). These nickle compounds have the potential to interact with other substances (organic matter, minerals, sediments, or even biological organisms like algae or bacteria) and show several antagonistic and synergistic effects (Filazi et al., 2010).. The concentration of Ni, water quality and physiological features of a fish species determines the toxicity of nickel. According to the research, Ni aggregates in different regions of fish, specifically gills and causes complications in respiratory functions (Raoux et al., 1999). It is found that Ni builds up in the fish intestine, interferes with its functions and also alters its normal physiology causing death of various species (Shimuzu, 1972). Nickel causes histological gill abnormalities, such as hyperplasmia, hypertrophy and fusion of branchia lamellae in Orechromisniloticus. Furthermore, fish exposed to Ni toxicity have oxidative stress and impaired ion regulation (Romeo et al., 1999). There was no apparent effect on fish growth in two studies; however zebrafish and pulmonate snails had an affected growth (Wiener and Giesy, 1979).

Lead (Pb)

Another potent toxin that enters the aquatic system is Lead that goes into the creatures through feed and water(Shimuzu, 1972). It accumulates in organs like digestive tract, gills, liver, kidney and spleen and causes changes in plasma of fish that leads to infection in cell membrane and shedding of liver cell (Shukla et al., 2007). Different factors in fish body are affected such as weight, specific metabolism rate, and feed intake and these factors cause detrimental impact on fish growth and feed utility. In addition to its toxicity towards the reproductive system, Pb lowers the sperm and ovum quality, decreases rate of fertilization, hatching, embryo and larval survival, etc. (Wiener and Giesy, 1979).

Zinc (Zn)

Controlled amount of zinc has a notable role in metabolic and reproductive health in fishes, however excess exposure to this heavy metal can cause hazardous side effects (Olaifa et al., 2004). Zn contamination is common in ecosystem and mainly accumulates in the tissues of the liver and kidney (Odoemelan, 2005). The growth of fish, its reproduction, homeostasis, feed intake and osteogenesis are adversely damaged by the zinc toxicity (Nwani et al., 2008). The quality of water also deteriorates as enhanced zinc concentration promotes ammonia excretion which becomes a pressured condition for fish and this result in excess levels of AST (Aspartate amino-transferase) and ALT (Alanine amino-transferase) through the hepatocytes which damage the liver of fish. Additionally, zinc toxicity in fishes facilitates the abnormal oxidation of body lipids and proteins which leads in reduction of protein consumption (Wiener and Giesy, 1979) (Fig.2).

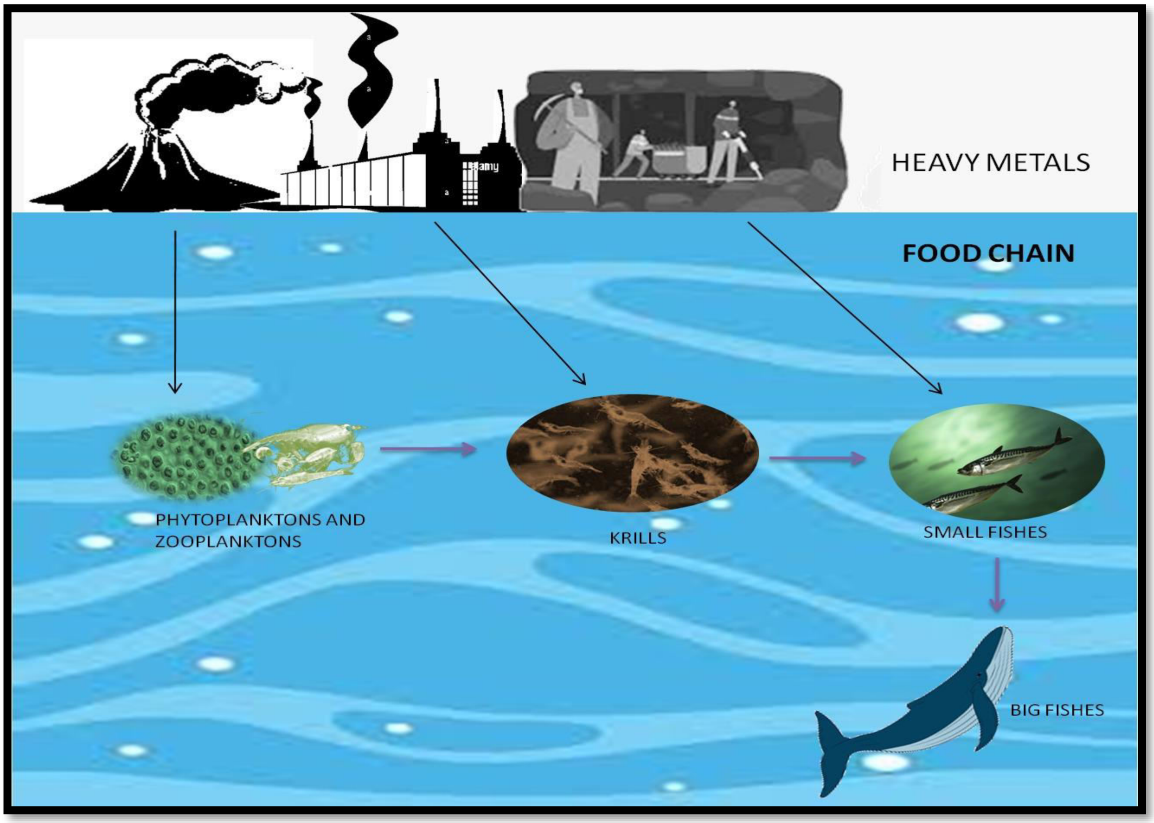

Fig.2: Graphical representation of heavy metal invasion in aquatic ecosystem

Bioremediation of Heavy Metals Toxicity in Fishes

Bioremediation is an advantageous as this is an environment friendly process and can be easily implement to reduce the concentration of toxic metals from the polluted environment. Through implementation of physio-biochemical mechanisms, molecular mechanisms and adsorptionbioremediation of toxicants can be easily executed. Various enzymes such as superoxide dismutase, SOD; catalase, CAT; glutathione S transferase, GST and non-enzymatic substance like reduced form of glutathione, GSH play a role as antioxidant bymaintaining the ROS balance through detoxification (Mansour and Sidky, 2002). SOD has the capacity to form hydrogen peroxide radicals from superoxide radicals that can efficiently convert into nontoxic oxygen and water using the catalase. In contrast, GST enzyme helps in detoxification process through the catalyzing electrophiles to GSH (Filazi et al., 2007). Additionally, the nonenzymatic oxidation of electrophilic compounds that includes free radicals and ROS are successfully transformed by the GSH. To minimize the pollutants from marine ecosystem several microorganisms are used. Majority of microbial enzymes plays a major role in transforming toxicants to nontoxicants chemicals via changing their chemical structure (Shukla et al., 2007). Lactobacillus spp. competently lowers the pH of environment i.e. acidic environment which helps in remediation of heavy metals from environment and also across via biosorption or leadsbinding of heavy metals to the lipid bilayer constitutents (Idowu and Ayoola, 2008). Microorganisms have various mechanisms against heavy metals like extracellular sequestration, intracellular sequestration, depletion of heavy metals ions by microbial cell and extracellular barriers(Shukla et al., 2007). To immaculate the environment microorganisms such as bacteria, fungi and algae are useful in detoxification of heavy metals. Moreover, in bioremediation of heavy metals wild microbes and various genetically transformedmicrobes mainly surface-engineered microorganisms, were developed having target specificity(Idowu and Ayoola, 2008).

Various studies shows that the genetically altered microbesare much more advantageous than the wild microbes for remediation of heavy metals or organic molecules under natural ecosystem conditions(Raoux et al., 1999).Perspective of genetic engineering deals with the nucleotide editing, metabolic enzyme pathway modification and alteration in gene sequence like coding and controlling, are majorly done to modify the genome of microbes and leads to production of genetically modified organisms(GMOs), which can remove a variety of heavy metals like Cd, Ni, Cu, Hg, As and Fe. Genomics, Proteomics, Metabolomics, Metagenomics and transcriptomics are several advanced genetic approaches that can be successfully used to enhance the mechanism in microbes to remediate heavy metals from contaminated environment (Barak and Mason, 1990). Genetically modified microbes such as Pseudomonas putida and Escherichia coli strain M109 have efficiency to remove the Hg from affected area. Using insertional mutation onmer gene in Deinococcusgeothemalis and Cupriavidusmetallidurans strain MSR33 has been found to decrease Hg amount in polluted area. Additionally, in bioremediation of these transistion metals the presence of transporters in membrane of microorganisms also shows the capability to renew the ecosystem (Allen, 1995). Studies revealed that probiotic microbe, Lactobacillus plantarum attenuates the toxicity of aluminum in tilapia (Barak and Mason, 1990).

A bioremediation technique which uses several plants and microorganisms to reduce contaminants from marine ecosystem is known as phytoremediation (Edem et al., 2002).

The application of Spirulinaplatensis and probiotics in diet, remarkably reduce the harmful effects of As toxicity in Oryziaslatipes (Ademoroti, 1996). Moreover, the addition of probiotics rich diet has been found to alter the adverse effects of Cd on the metabolism and hematopoeisis of Oreochromisniloticus (Barak and Mason, 1990). Regardless use of EDTA successfully reduced the Cd amount and result in ameliorating the hematology profile of Clariasgariepinus. Pomegranate peel and Lactococcuslactis have remediation property upon Hg toxicity in C. gariepinus (Cusimano et al., 1986). Addition of probiotic supplements in growth of Cyprinuscarpio reduces the harmful effect of Pb (Gosselin et al., 1986).

Application of Bacteria in Bio-remediation of toxins

As a consequence of bacterial distribution, size and capacity to grow in moderate and tough environments they play a major role in bioremediation. Studies revealed that 70% and 75% Cd is successfully eliminate by the P. aeruginosa and Alcaligenesfaecalisindependently and in comparison (Barak and Mason, 1990),Pb amount get reduced upto 87% and 88% by the action of Bacillus pumilus and Brevibacteriumiodinium and also by the Micrococcus luteus. B. cereus used to reduce the Cr amount upto 72% (Arabatzis and Kokkinakis, 2005). Some bacteria spp. such as B.megaterium, Aspergillusniger and B.subtilis have the extortionate capacity to eliminate the Pb, Cr and Cd, respectively. Elimination of Cr 99.8%, Cu 98.2% and Ni 90.1% via the action of Desulfovibriodesulfuricans. It has been reported that through the use of various different bacteria species able to extract, Zn, Co, Cd, Cr, Cu and Pb (Cusimano et al., 1986).

Application of Fungi inBio-remediation of toxins

Similar to bacteria, various species of fungi are extensively used because of their ability to both absorb and recover metals (Goodwin et al., 2003). Studies have revealed that live and dormant cells of fungal species can actively participate in absorbing metals. Aspergillus species effectively eliminate 85% of Cr according to the reports. It has been discovered that dormant cells of PenicilliumchrysogenumAspergillusniger, Saccharomyces cerevisiae and Rhizopusoryzae (Cusimano et al., 1986). have the ability to convert toxic Cr into less toxic forms. Coprinopsisatramentaria, another type of fungus is regarded an essential metal aggregator (Coughtrey and Throne, 1983). By producing biosurfactants, Candida sphaerica considerably reduces metal loads. Other species known to convert Cr into less toxic forms are Rhodotorula mucilage, Hansenulapolymorpha, Rhodotorulapilimanae, Yarrowialipolytica, Pichiaguilliermondii, and Saccharomyces cerevisiae (Goodwin et al., 2003).

Application of Algae in Bio-remediation of toxins

Algae possess a great ability of biosorption to extract toxic heavy metals. Variety of algal and cyanobacterial species are known to either eliminate or break down harmful metals (Filazi et al., 2010). The highly efficient photosynthetic ability allows algae to degrade heavy metals by dissolving considerable amount of oxygen in the water bodies, thus promoting aerobic degradation of several organic compounds along with metals (Goodwin et al., 2003). Moreover, the enzymes as well as metabolic processes of an algae's metabolism can also break down, detoxify or convert various heavy metals and other harmful compounds (Eralagere and Bhadravathi, 2008). The cell wall of algae contains crucial functional groups like fucoidan and alginate which helps in biosoprtion of these metals (Shukla et al., 2010). Algae also uses its extracellular and intracellular binding properties such as chelating complexation and physical absorbtion to bind to the heavy metals and either eliminate them or break them down into less toxic compounds (Goodwin et al., 2003).. Furthermore, in detoxification of heavy metals algae plays a major role as they needs post translational activation through the presence of heavy metals and they have the capacity to synthesize class III metallothioneins (phytochelatins) from phytochelatin synthase enzymes (Daka et al., 2008). Hydroxyl, carboxyl, phosphate, amide and many chemical compounds are present on the algal surface which have binding sides for heavy metals (Filazi et al., 2010). An important species of algae, Chlorella vulgaris produces dead cells which remove Cd, Cu and Pb in water bodies (Adebisi, 1981)

Conclusion

The release of effluent containing toxic heavy metals without appropriate management of polluted water from industry sector is negatively impact the natural aquatic ecosystems. As an outcome, toxic heavy metal accumulated in the different organs of aquatic animals such as seen in tissues or organ-system of fishes and disrupted their physiological channels, resulting in the decreasing growth rate and reproduction pattern. As a sustainable approach, bioaccumulation deals with the solution of toxicity of heavy metals in contaminated aquatic ecosystems. Furthermore, Bioremediation helps in fishes to enhance their physical conditions by changing the toxic impacts of various heavy metals. In addition to this, it also helps in the productivity of aquatic ecosystemsby the use of right approach of bioremediation can remarkably recycle the water that minimize the water wastage and decomposition of organic matter notably decrease the bio-contaminants that increase the biosafety of our environment.

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Contribution

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