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Assessment of Eco-Toxicological Risk and Study of Fish Culture Systems for Specific Metal Bioremediation

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ABSTRACT

The problem of heavy metal contamination of aquatic resources has been extensively studied over the last 20 years in many parts of the world (Guhathakurta and Kaviraj, 2000; Kumar et al., 2012; Ma et al., 2013; Tang et al., 2014, Alinnor et al., 2016). Heavy metals are thought to be more hazardous than other toxic compounds that infiltrate aquatic environments because they are non-degradable, quickly enter the bodies of aquatic organisms, and many of them are very poisonous. The progressive increase in heavy metal concentrations in freshwater ecosystems over the past 20 years has become a major health problem for people due to the fact that heavy metals are polluting drinking water and aquatic food sources (Nawaz et al., 2010; Islam et al., 2016). The bioavailability and method of entrance of metals into aquatic species determine their toxicity. Numerous physical, chemical, and biological mechanisms that regulate the speciation of metals in water also affect the bioavailability of metals to aquatic species (Brown and Markich, 2000; Paquin et al., 2000, 2002). The dissolved organic stuff in water easily forms compounds with heavy metals.

KEYWORD: Bioremediation, Cu, Ni, Ni, Bioaccumulation and toxicity, Essential micronutrient

INTRODUCTION

Two heavy metals that are commonly found in freshwater environments are copper (Cu) and nickel (Ni), which are the subject of the current study. Cu levels in freshwater lakes and rivers typically vary from 0.20 to 30 µg/l; however, in water bodies contaminated by mining and industrial effluents, Cu concentrations can surpass 1000 µg/L (Craig et al., 2007). However, there is little data about the impact of nickel (Ni) pollution on aquatic life. Nonetheless, the metal commonly finds its way into natural waterways through the effluents released by a variety of industries, including electroplating, batteries, coal combustion, alloys, and ore refinement (WHO, 2005; Cempel and Nikel, 2006; Munoz and Costa, 2012), among many more man-made ones.

India's status regarding heavy metal contamination

In India, as industry and urbanization have grown, so too has the amount of heavy metal contamination of freshwater environments. Heavy metal pollution is a major problem for India's principal rivers, including the Ganga (Beg and Ali, 2008; Bhattacharya et al., 2008), Yamuna (Kaushik et al., 2009; Shegal et al., 2012), Cauvery (Raju et al., 2012), Godavari (Ghorade et al., 2014), as well as their tributaries (Sanyal et al., 2015; Maurya and Malik, 2016), and canals (Javed and Usmani, 2013). The main sources of heavy metals in these Indian water bodies are home sewage from big cities and industrial effluents from a variety of enterprises. In these aquatic bodies, moderate to high levels of heavy metal deposition are also caused by road and agricultural runoff (Negi and Mayura, 2015). Records also show that heavy metal pollution occurs in freshwater ponds that are not contaminated by industry (Roychowdhury et al., 2008). Fish raised in ponds supplied by household sewage have a significant potential for heavy metal accumulation (Adhikari et al., 2009; Kumar et al., 2011; Mastan, 2014). Cu is often found in river water in India, ranging in concentration from low (0.43 ppb) to high (1.4 mg/L) (Singh et al., 2012; Kumar et al., 2012; Ghorade et al., 2014). In India, the average content of Ni in water varies from 2.58 to 11.87 µg/L (Anonymous, 2014), but internationally, it varies from 1.0 to 10.0 µg/L, with polluted water potentially containing as much as 1000 µg/L (Eisler, 1998; Zhou et al., 2016).

Copper's toxicity and bioaccumulation

Common metallic pollutants in water, copper (Cu) is extremely hazardous to aquatic invertebrates and fish (Ebrahimpour et al., 2010; Ezeonyejiaku et al., 2011). (Brown et al., 2004; Shuhaimi-Othman et al., 2012). Anthropogenic Cu fluxes in water have a negative impact on aquatic biodiversity (Kinsella, 2016). There is a lack of sufficient literature linking the ambient concentration of copper in water or the concentration at which the metal is released into water from various sources to aquatic life toxicity.

Ni bioaccumulation and toxicity

Ni is regarded as an essential micronutrient, yet it is unclear how important the element is to aquatic life (Muyssen et al., 2004). Accordingly, aquatic creatures may be at risk by Ni presence, even at low concentrations. There is little evidence of Ni toxicity to aquatic life (Hoang et al., 2004). According to a few published studies on the acute and long-term toxicity of nickel to fish and aquatic invertebrates, certain freshwater fish have 96-hour LC50 values of nickel that range from 19.3 to 61.2 mg/L (Svecevicius, 2010). Fish toxicity to nickel may vary depending on the physico-chemical characteristics of the water, such as pH, hardness, alkalinity, and dissolved solids (Pyle et al., 2002, Hoang et al., 2004). According to Luca et al. (2007). Therefore, the presence of Ni, even at low concentrations, may have a negative impact on aquatic life. In both invertebrates and vertebrates, nickel has been shown to cause nephrotoxicity, hepatotoxicity, and teratogenesis (Hobe et al., 2000; Denkhaus and Salnikow, 2002; Vijayavel et al., 2009; De Forest and Schlekat, 2013). The carp fish Hypophthalmicthys molitrix suffered significant harm to its gill histology after being exposed to 5.7 mg/L nickel for a duration of 10 to 30 days (Athikesavan et al., 2006). According to research, marine crustaceans are extremely susceptible to nickel (Buttino et al., 2011; Mohammed et al., 2010). At 0.4 mg Ni/L, almost 94% of the naupli of the calanoid copepod Acartia tonsa perished (Zhou et al., 2016).

Bioremediation

According to Sood et al. (2012), bioremediation has demonstrated its efficacy and affordability as a natural water treatment method when compared to more expensive and traditional technologies such as ion exchange, reverse osmosis, chemical precipitation, ultrafiltration, chemical oxidation and reduction, and coagulation-flocculation. Numerous floating aquatic weeds, including Azolla (Sood et al., 2012; Debi et al., 2014), Lemna minor (Hou et al., 2007; Boule et al., 2009), Eichhornia crassipes, Pistia stratiotes, and Spirodela polyrrhiza (Mishra and Tripathy, 2008; Akinbile et al., 2012; Das et al., 2014; Sanyal et al., 2015), Lemna minor (Hou et al., 2007; Boule et al., 2009), and Spirodela polyrrhiza (Mishra and Tripathy, 2008; Akinbile et al., 2012; Azolla). Metal buildup occurs mostly in the roots of these aquatic macrophytes (Odjegba and Fasisdi, 2004; Das et al., 2014; Sanyal et al.

Review of Literature

India's fast industrialization and urbanization in recent years has resulted in a massive increase in the country's heavy metal contamination of the aquatic environment (Javed and Usmani, 2013). Large lakes, reservoirs, and even freshwater ponds without a direct source of effluent discharge are also contaminated by heavy metals, although major rivers are the primary recipients of heavy metals discharged through metallic effluents from industries (Aktar et al., 2010; Sanyal et al., 2015; Mayura and Malik, 2016; Tables 2.2 & 2.4). (Negi and Maurya, 2015). Because fish obtained from these sites frequently exhibit extremely high concentrations of heavy metals, there is grave worry about the implications to human health (Islam et al., 2016; Javed and Usmani, 2016).

Reviews of Cu and Ni Levels in the Environment

Environmental Cu concentrations

Copper is frequently found in the biota and the environment at concentrations well over the allowable limit set by the majority of international regulatory agencies. As a result, scientists are keen to record the amounts of Cu in the environment as well as its manner of bioaccumulation and toxicity to aquatic life.

Worldwide Scenario

In recent decades, the processes of urbanization and industrialization have led to a concerning level of heavy metal contamination in aquatic environments. Natural geochemical processes, mining, industrial applications, the manufacture of fungicides, fertilizer additives, antifouling coatings, and many other products have all contributed to pollution (Ellingsen et al., 2007;

Tchounwou et al. 2014). Cu is typically found in freshwater bodies due to industrial wastes. Nonetheless, moderate to trace amounts of Cu are found in freshwater bodies such as rivers, lakes, and marshes across Africa and the Arab world . The only place in Nigeria where Cu concentrations in water were discovered to be significantly higher (10.5 mg/L) than the WHO/FEPA threshold (1.0 mg/L) was the Ogun River.

Environmental Ni Concentrations

Recent releases from mine runoffs, industrial effluents, and urban and agricultural sewage have raised the amount of nickel (Ni) in various environmental strata. Ni pollution of water is also caused by geologic weathering of rocks and soil (Bradl, 2005 and Cempel et al., 2006).

Worldwide Scenario

Effluents from a variety of sectors, including alloys, electroplating, batteries, coal combustion, and ore processing, among many other human sources, commonly introduce nickel into natural bodies of water (WHO, 2005; Cempel and Nikel, 2006; Munoz and Costa, 2012). Because of this, there is a progressive increase in the amount of Ni pollution in water, which exposes more living things to this metal (Munoz and Costa, 2012). Worldwide, the content of Ni varies from 1.0 to 10.0 µg/L, with polluted water potentially containing as much as 1000 µg/L (Eisler, 1998; Zhou et al., 2016). According to Emeka et al. (2014), there is between 0.084 and 0.259 mg/L of nickel in the water of Oguta Lake in the Nigerian state of Imo.

Indian Scenario

In India, average Ni contents in water range from 2.58 to 11.87 µg/L (Anonymous, 2014). According to this research, the levels of nickel contamination in the Baitarni, Ganga, Gomti, Hasdeo, Mahanadi, Narmada, Purna, Seonath, Subarnarekha, Tel, Wainganga, and Wardha rivers are higher than the permissible limit (20µg/L). In the Ganga river near Kolkata, Wasim-Akhtar et al. (2010) discovered Ni in the range of 0.045 – 0.24 mg/L between November 2005 and October 2006. According to Malik et al. (2010), the average concentration of nickel in the freshwater lake of Bhopal, India, was found to be 0.17 mg/L. 0.12 mg/L was found in the river water that received waste water from the Harduaganj thermal power plant in Kashimpur, Aligarh, India (Javed et al., 2013). The majority of heavy metals are ultimately sucked down by sediment (Duzzin et al., 1988; Rajendran et al., 1992). After examining the recently deposited silt from the shallow water of 12 sites along the Narmada River in 2008 for various metal pollution, Jain et al. discovered that the content of Ni varied between 250 and 300 µg/g. According to Dhanakumar et al. (2013), the average Ni concentration in the surface sediment varied between 9 µg/g during the dry season and 18 µg/g during the rainy season, based on data from 10 sample locations along the Cauvery River. The quantity of nickel ranged from 12.10 to 21.3 mg/kg in sludge samples from Telangana state's "Sai Cheruvu" freshwater pond supplied by a tannery (Baig et al., 2014).

CONCLUSION

Aquatic environments are more susceptible to heavy metal contamination compared to other ecosystems, and heavy metal pollution is a global issue. Globally, freshwater habitats have seen an alarming rise in the concentration of certain hazardous heavy metals in recent years. Aquatic creatures quickly collect heavy metals, and many of these metals have a tendency to biomagnify along the food chain. Heavy metals are more harmful than other contaminants because they do not degrade and because many of them are extremely poisonous. The two heavy metals under investigation in this study are copper (Cu) and nickel (Ni). In every living system, Cu plays specialized biological tasks, whereas Ni's biological significance is questionable. However, fish and other aquatic species become poisonous when exposed to high concentrations of these metals. In surface water from various freshwater habitats in India, the concentrations of Cu and Ni range from undetectable to 1.12 mg/L and 0.05 to 0.24 mg/L, respectively. Cu and Ni deposits in water follow distinct patterns. Ni undergoes a relatively sluggish process of removal from water, whereas Cu is swiftly removed and deposited over the bottom. The inference is that because Ni is significantly more persistent in water than Cu, pelagic creatures would be more vulnerable to Ni than Cu. The best time to remove Cu or Ni from water may be found using regression analysis and classical optimization. The bioavailability of the metals and the test organisms' capacity to control the levels of the metals inside their bodies determine the lethality of Cu and Ni to those species. The best explanation for the variation in the sensitivity of Cyprinus carpio, Branchiura sowerbyi, and Diaptomus forbesi to Cu and Ni over time is found in linear and power regression for Cu and Ni, respectively.

Cu has a higher overall lethality than Ni does to D. forbesi, B. sowerbyi, and C. carpio. However, because nickel has a longer half-life in water than other metals, it poses an inherent risk to pelagic animals such crustacean zooplankton. Cu and Ni are absorbed by sediment, and B. sowerbyi, a bottom-dwelling worm, tends to amass the most Cu and Ni in its body. The way that Cu and Ni build up in the body of the fish C. carpio varies depending on the metal. Fish muscle had traces of copper, while the liver had the highest concentration of Cu accumulation, followed by the stomach, gills, and kidney. This pattern of accumulation suggests that C. carpio mostly acquired Cu from diet. On the other hand, in C. carpio, the gills and stomach were the only places where Ni accumulated. Ni concentration in the stomach was trace levels.

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