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Review Paper

Nickel as a Pollutant and its Management

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Abstract

Nickel is naturally occurring in soil and surface water but some actives like industrialization, sewage, use of chemical fertilizer, pesticides etc. increase the concentration in environment. There many techniques are available for management of nickel pollution (Phytoremediation, Chemical remediation, remediation using nanoparticles). In this study we find out the effect of nickel on plant, human and microorganisms. The object of this paper is overview of the occurrence and sources of nickel in environment, as well as effect of nickel on human, plant and microorganism and how to manage the nickel pollution.

Keywords: Management, nickel pollution, toxic, human, plant.

Introduction

Nickel is one of many trace metals widely distribute in the environment. It is present in the soil, water and air in deferent form. Nickel is essential element for plant in low concentration but high concentration is toxic. It is also toxic for human health. Nickel occurs predominantly as the ion $Ni(H_2O)_6^{2+}$ in natural waters at pH 5-9[1].

Sources of nickel

Nickel is occurring naturally in soil and surface water with concentration lower than 100 and 0.005 ppm, respectively[2,3]. Nickel usually has two valence electrons, but oxidation states of +1, +3, or +4 may also exist. Several nickel salts, like the acetate, chloride, sulfate and nitrate are soluble in water, whereas hydroxides and carbonates are less soluble and disulfides, sulfides, sub sulfides and oxides are practically insoluble in water. Nickel is used in the production of stainless steels and other uses of nickel and its salts are in as a catalyst, electroplating, nickel-cadmium batteries, coins and electronic products[4]. Nickel is mainly used as a raw material in the metallurgical, electroplating industries and food industry[5]. The primary source of nickel in drinking water is leaching from metals which are in contact with drinking water, such as pipes and nickel may also be present in some ground water as a consequence of dissolution from nickel ore bearing rocks. Nickel is also released into the environment from various anthropogenic activities, like smelting, metal mining, vehicle emissions, fossil fuel burning, disposal of house-hold, municipal and industrial wastes, application of fertilizer and organic manures[6,7].

Nickel contaminated area

In recent years, Ni pollution has been reported from across the world, including Asia[8,9]. Nickel concentrations in groundwater depend on the soil, pH and depth of sampling. Increased nickel concentrations in groundwater and municipal tap water (100-2500mg L^{-1}) in polluted areas have been reported[10]. Concentration of nickel in water boiled in electric kettles may, depending on the material of the heating element, be noticeably increased, especially in the case of new or newly decalcified kettles. Nickel concentrations in the range 100-400 mg L-1, with extreme values over 1000 mg L^{-1}, have been reported[11, 12]. Levels of nickel in a selection of bottled mineral waters were below the detection limit of 25 mg L^{-1} [13].

In India, Raman *et al.,* found the nickel level in ground water was 0.029 to .154 mg L^{-1} in Joy nagar near the pallavaram solid waste dumpsite area in Chennai[14]. Also found the nickel concentration is 10mg kg^{-1} to 18.1mg kg^{-1} in soil of industrial area of Mysore city[15]. The Ni content found in soil of polluted area of Ratlam and Nagda (M.P.) was 39-129 mg kg^{-1} respectively[16]. Panwar *et al.,* 2010 found the Ni concentration in surface water and ground water of industrial area of Patancharu, Medak district 4.7-57.4 µg L^{-1} 3.9-26.4 µg L^{-1}, respectively and Ni content also found of kharmora village (M.P.) was 0.007-0.162 mg L^{-1} [17].

Nickel toxicity for Human

No safe level can be recommended for nickel in water because nickel is carcinogenic. There is agreement that nickel refinery workers exposed by inhalation to various nickel compounds in the past are at a significantly higher risk for cancer of the lungs and the nasal cavity than the non-occupationally exposed population. Laryngeal cancer, kidney cancer and prostate cancer have also been found in nickel workers[18]. Oral intake of nickel average 170 mg/day of which approximately 5% is absorbed (8.5 mg/day). Inhalation of nickel average 0.4mg/day for urban dwellers and 0.2 mg/day for rural dwellers, of which 35% is retained (0.007 to 0.014 mg/day). This assessment of nickel metabolism involves the assumption that 70% of absorbed nickel is promptly excreted by the kidneys and the remaining 30% is deposited in the tissues with a mean retention time of 200 days. Percutaneous absorption of nickel is important in view of the dermopathological effects (Contact dermatitis) in the context of nickel sensitivity. Absorbed nickel is transported via blood bound to albumin. There is little evidence of accumulation of nickel by tissues. Presumably there must be an as yet unelucidated mechanism in the animal body to control excessive intake, absorption and accumulation of nickel. The reactivity and protein binding properties of nickel compounds are related to their surface properties and crystalline nature. The numerous industrial uses of nickel in addition to production and refining suggest that many workers can be exposed to nickel in their occupations. There are many toxic effects like embryo toxic effect, allergic reactions, nephrotoxic effects and contact dermatitis due to nickel pollution

Nickel toxicity for plant

Nickel is essential for plants, but the concentration in the majority of plant species is very low (0.05-10 mg kg^{-1} dry weight)[19, 20]. Increasing Ni pollution, excess Ni rather than a deficiency is more commonly found in plants. It is recognized that relatively low concentrations of nickel are toxic to a wide variety of plants. Nickel is usually absorbed in the ionic form (Ni^{++}), from the soil or the culture solution. There are a number of reports that nickel is easily absorbed by the plants when supplied in the ionic form and is not as strongly absorbed when chelated[21, 22]. In tomatoes, absorption of nickel predominately damaged the roots, causing a reduction in the subsequent absorption and translocation of all major nutrient elements [23]. The absorption of nickel by plants is depending on the total amount of nickel present in the soil[24-26], and the properties of the soil, soil pH and the organic matter content[27]. This accelerated rate of nickel absorption actually does not depend on the net amount of nickel present, but on the amount of exchangeable nickel present in the soil. For this reason plants grown in soils rich in exchangeable nickel have a high content of nickel in their tissues. Addition of simple nickel salts in soil increases the exchangeable nickel content of the soil and thereby accelerates its absorption. The pH values of soil below 5.6 seem to favor the absorption of nickel, while values above 5.6 do not. This is largely due to the fact that the exchangeable nickel content of the soil increases with the increasing soil acidity [28]. Application of lime to the acidic soil reduces the absorption of nickel by the plants by increasing the soil pH [29]. The concentration of nickel in plants and its absorption are increased by increasing the phosphate content of the soil [30]. It is usually recognized that relatively low concentrations of nickel are toxic to a wide variety of plants. Some study have shown that in nutrient solution 5 ppm to wheat[31], around 2-60 ppm to buckwheat[32], approximately 5 ppm to oat[33], 15-30 ppm to sugar beet, tomato, potato[34,35]. These data show that at different concentrations nickel is toxic to different plants. The toxic symptoms produced by several heavy metals, including nickel, have usually chlorosis. Chlorosis is one of the main toxic symptoms produced by nickel is the usually followed by necrosis. Other toxic symptoms of nickel include stunted growth of root and shoot, deformation of various plant parts, unusual spotting and a host of other growth abnormalities. At extreme cases nickel may cause the death of the whole plant. Kucharski *et al.,* found that the soil contamination with nickel had a negative impact on the activity of soil enzymes [36].

Management of Ni contaminated area, Remediation using nanoparticles

In recent year, nanoparticle is use for management of nickel and other pollutant in the environment. Nanotechnology offers the possibility of an efficient removal of pollutants. Zero valent iron nanopartcles was used for removing of nickel from soil[37]. Jin *et al.,* investigated that the removal efficiencies of Ni^{2+} were 95.15% and 94.68% at a metal to solution ratio of 20 g L^{-1} for commercial iron powder and the steel manufacturing byproducts in 60 min at room temperature, respectively[38]. The removal efficiency reached 98.20% when the metal to solution ratio was 40 g L^{-1} for commercial iron powder. Rathor *et al.,* investigated that Ni concentration was reduced to 75-92% in the nickel polluted soil when the soil was treated with nanoparticle (250mg/10g of soil) while nickel decontamination in water was reduced to 99.6% after treatment of carbon nanoparticle (500mg/20 ml of polluted water)[39].

Phytoremediation of nickel

Phytoremediation of metal contaminated soil offers a low cost method for soil remediation. Because cost of growing a crop is minimal compared to those of using in soil removal and replacement, so the use of plants to remediate the polluted soils was seen to be having great promise. Phytoremediation is the use of plants to make soil contaminants non-toxic and is also often referred to as botanical bioremediation, bioremediation and green remediation. Use of rare plants which hyper accumulate metals to selectively remove and recycle excessive soil metals was introduced in 1983 [40]. Syed *et al.,* (2010) used to *Eichhornia crassipes* (water hyacinth) for phytoremediation of Ni^{++}contaminated soil and water, results showed the removal of (Ni) 24.23 μg g^{-1} dry weight of plant and large level calculations show removal of 3449.76 kg ha^{-1} of soil, equivalent to 25 μg g^{-1} of the added Ni^{++} [41]. Phytoremoval of $Ni^{++}$from soil and water, water hyacinth plant and its ash showed quality. The desorbed Ni^{++} can be used in the industries e.g. in Ni plating. Balasubramanian *et al.,* (1996) investigated that the use of powdered leaves of *Azadirachta indica*, treated by heating at 50°C with a mixture of aqueous formaldehyde and dilute sulfuric acid for 2 h, followed by filtering and washing the residue with water until a pH of 4 was attained, and then air drying[42]. The efficiency of a grassy vegetation mixture to absorb nickel from soil, the soil was most rapidly decontaminated from nickel in 7 years[43].

Chemical remediation of nickel

Chemical remediation technique is the most common technique for nickel from polluted area. The insoluble polyacrylate polymer could be used to remediate a sandy soil contaminated with 50 mg Ni kg^{-1} of soil[44]. The $CaCl_2$ solution was used to remove a certain % of Cd and Ni in soil. The adsorption of Cd and Ni by the soils was dramatically decreased and their transport through the soils was significantly enhanced in the presence of Ca. These effects were accredited to the competition between Ca and those metals for exchange sites on the soil surfaces[45]. Chompoonut investigated that the efficiency of the "ferrite process" for decontamination of copper, nickel and zinc from synthetic wastewater and chemical laboratory wastewater. The percentage of removed Cu, Ni and Zn from synthetic wastewater containing those three heavy metals was > 99.7 %. The percentage of removed Cu Ni and Zn from chemical laboratory wastewater was 88.92%, 87.29% and 98.68% respectively[46]. The comprising chemical coagulation, sedimentation and filtration, can applied to 35-80% for removal of nickel[47]. The powdered activated carbon can be used to enhance nickel removal from soil[48], Stetter *et al.,* studied that in the case of ground water; effective removal of nickel can be achieved using chelating ion exchange resins[49]. Electro-refining technology was successfully developed for decontamination of radioactively contaminated nickel and a laser-cutting demonstration of the barrier nickel drums was accomplished. Also, stainless steel from contaminated barrier nickel was successfully produced, and a new process to make sanitary drums from RSM was developed[50]. The magnetic alginate microcapsules were used to removal of nickel ions from the aqueous solution. They have found that the sorption capacity for nickel removal were increased by increasing the pH of the solution and the maximum uptake capacity was found to be around 0.42 mmol g kg^{-1} at the pH of 8[51].

Conclusion

Present study concludes that nickel pollution is a very dangerous issue for environment. That pollution not only affects the human health but also the quality of soil, air and water. This study also gives some information about, how to control nickel pollution and management. Today, there is need to making people aware, so that we can save our environment.

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