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Effect of heavy metal (Ni) on plants and soil: A review

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Abstract
Nickel stands 24th in most abundant elements list in earth crust, and present as 3% of earth composition. By weight it is 5th most copious element after iron. In low concentration Ni is essential element, in natural form nickel occurring in soil and surface water and its concentration is less than 100 and 0.005 ppm. Plants need trace elements to perform their metabolic functions normally, when concentration of trace elements is more than required it will become hazardous and will interfere with plants physiological as well as biological processes ultimately hampered the crop production. The aim of this review was to evaluate the data about nickels functioning in metabolism of plant and its essentiality with its importance for agronomic crops and also contamination of soil with heavy metals.

Keywords: Nickel, elements, plants, soil, metabolism

1. Introduction

Now a day's industrial development is taking place worldwide and is out of control and causing air, soil and water pollution as a result of variety of chemical substances which are responsible for environmental pollution that is now worldwide problem. Nickel (Ni) is found very commonly in environment from anthropogenic and natural resources (WHO 1991) [39]. Microelements are found from these two main resources by activities of human and through natural and geochemical processes (Lazaro *et al*. 2006) [16]. Use of soil amendments for high production in agriculture resulted in heavy metal addition (Adriano 2001) [1]. Soil is contaminated with heavy metals and is a worldwide problem, causing reduction in agricultural yield and perilous health effects when became part of food chain. Many biochemical processes and physiological processes are affected in plants when nickel is up taken in toxic level. Chlorosis, inhibited photosynthesis and respiration are the most frequent symptoms (Fatemeh *et al*. 2012) [43]. In 1975 nickel was first discovered and was discovered as a urease enzymes component. That is present in many species of plants (Takishima *et al*. 1988) [37]. In the list of heavy metals in earth crust nickel has unique place. For plant growth it is an essential micronutrient and is a component of urease enzyme which is necessary in higher plants for nitrogen metabolism. In environment Ni concentration is increasing due to use of nickel and nickel compounds for commercial and industrial uses. In higher concentration Ni is phytotoxic (Satish *et al*., 2015).

Application of industrial waste to agricultural areas is contributing in mixing of trace elements in environment. Nickel level is increasing in soil due to this anthropogenic release and is responsible for collateral increase of nickel concentration in plants as well as in food chain. Ni is accumulated in seed and vegetative tissues and is a threat to human also (Boominathan and Doran 2002) [5]. Periodic table elements list Ni is at 28th with color of silver white in metallic form with several oxidation states. (Denkhaus and Salnikow 2002) [6]. Nickel from environment comes in different forms by sewage residues that have heavy metals in it and somehow by organic fertilizers, mineral fertilizers and pesticides that are contaminated with heavy metals (Orlov *et al*., 2002) [26]. Nutrients in soil are absorbed only in the form of soil solution phase and in soil solid phase these nutrients are not absorbed directly. Nutrients in soil, solid phase results in limited solubility to access micronutrients, which leads to restriction of microelements in soil solution.

Diffusion, mass flow and interception are the main ways of plant uptake from soil solution. The present review describes the uses and toxic effect of nickel in plants and soil.

2. Effect of heavy metal (Ni) on plants

Heavy metals are responsible for stomatal closure which is their primary effect and it causes reduction in transpiration. In result of loss in moisture content and stomatal closure it induces toxicity for photosynthesis (Seregin and Ivanor 2001) [31]. Nickel typically heap together at soil surface and collectively spreads uniformly through soil profile. Ni as micro-element is very essential for development of plant and has great importance in metabolism (Fargasova 2008) [42]. Its application in excess cause breakdown of food material stored in seed and inhibits the germination of seed (Pandey and Sharma 2002) [27]. On other hand excess uptake of nickel from groundwater effects aquatic life and also has damaging effect on human health, causing allergic reactions and respiratory problems and also responsible for nose and lungs cancer (Lakshmi *et al*. 2014) [15].

Contamination of soil with heavy metals is worldwide problem and results in low agricultural yield and harmful health affects by entering in food chain. Many physiological and biochemical processes are effected by Ni because of its essentiality and as toxic in toxic level. Respiration, chlorosis and inhibited photosynthesis are very common symptoms. Ghasemi *et al*. (2012) [10] concluded that, Ni causing damage of membrane and cell death, when concentration of nickel was increased to 100 µmol, the chlorophyll a contents increased at 200 µmol of Ni was decreased. But in chlorophyll b and in carotenoids contents no momentous changes were observed. By increase in concentration of nickel resulted in decrease of hill reaction rate because of chlorophyll a in $PSII_{680}$ reaction center to split water. K^+ efflux was increased by nickel different concentrations and also leakage of sugar from roots and responsible for root tips cell death. Ni has adverse effect on photosynthesis and has not such attributed to any factor and resulted in structural damage by treating with different levels effecting structure of chloroplast, photosynthetic proteins and chlorophyll content and has adverse effect in membrane properties.

Seregin *et al*. (2003) [32] carried out an experiment on plants affected by nickel specific aspects. It was found that nickel in high concentration in cells of pericycle and endoderm inhibited cell divisions. Due to blockage of cell division caused in pericycle resulted in root branching inhibition. Najafi *et al*. (2011) [21] reported that nickel had very strong and positive effect on Mn, Fe and concentration of nickel roots and leaves in comparison with control. However, rate of respiration was increased but photosynthetic rate inhibited and also resulted in decrease of RWC with all concentrations. Sharma and Dhman (2013) [34] concluded from their studies about role on nickel and cadmium. Ni considered as essential elements for plants and without these elements plant is unable to complete its life cycle, there is no other replacement of these elements. First nickel was considered as essential nutrient because it plays vital role in life cycle completion of plant. Ni is very important for plant because its deficiency causes decrease in plant capacity in viable development of seed, because it hinders growth of embryo. In plants Ni is up taken through root system by means of active transport and by passive diffusion. Within species active transport and passive transport ratio varies. Accumulation of heavy metals in food chain is responsible for human health and also a source of toxicity in plants.

Mukherjee *et al*. (2014) [20] concluded that yellow mustard (Brassica hirta) seeds that were inoculated by these test isolates of bacteria showed improvement in Plant Growth Promoting activities like root and shoot growth was enhanced and resulted in protection of plant from nickel's different phytotoxic effects. Bashmakov *et al*. (2005) [4] studied that Physiological doses and sub lethal doses of heavy metals lead, copper, nickel and zinc were used to test growth of seedling. 10–100 mM Physiological doses enhanced young plants growth, but 1–5 µM suppressed the growth processes and accumulation of biomass in roots and also caused leaf area reduction and dis-balance of water. Heavy metals concentration and nature of chemical is responsible for their effects. Melo *et al*. (2005) [18] concluded that nickel is already wondered as a plant nutrient, urease contains nickel as its component, when used in heavy concentration it causes toxicity to plants.

Baccouch *et al*. (2001) [3] investigated that Ni toxicity resulted in oxidative stress in roots and lipid per oxidation was enhanced that could be caused by primary effects of stress of nickel. Nouri *et al*. (2002) [25] documented that translocation and absorption of Ni in chemical form in maize leaves and its gross distribution, Ni63 nickel complexes were present in atomic form according to demonstration in leaves of maize. Chlorophyll was associated with Ni63 according to electrophoresis results. Pigment destruction was noted by application of sludge with high concentration of nickel. Concentration of nickel in plants is up taken in in-organic form and is influenced by sludge amount. Phytotoxic effects may be caused on crops by application of sludge in higher amount. It would be easy to monitor heavy metals and nickel concentration in sewage sludge. In soil plant system nickel amount was found to be changing with time like nickel complexes in plants. These are of importance and are of common interest to nutrition of animal and human. Cell wall has exceeded with content of Ni in protoplast without tissue and root region. Accumulation and penetration of Ni in endodermal barrier and pericycle was at maximum level. Root branching was restricted due to accumulation of Ni in the pericycle. Final cell length was not affected by Ni and resulted in inhibited growth of roots showing decreased cell division (Seregin *et al*., 2003) [32]. Ghani (2010) [9] reported that maize plants growth was effected toxically by heavy metals. Plants were affected more within those soils which were heavily dosed with heavy metals. Shar *et al*. (2003) [45] concluded that high concentrations of heavy metals including Ni were absorbed by maize varieties and investigated in 5 varieties. The value of these toxic and trace elements was below recommended value of WHO.

Bashmakov *et al*. (2005) [4] examined that young plants with physiological doses of 10-100 mM enhanced the young plants growth, on other hand 1-5 µM resulted negative effect on growth processes and also accumulation of biomass, mainly roots were affected and also responsible for suppression of leaf area and causing water misbalance. The effect of these heavy metals depends on their concentration and chemical nature on existing solution. Gondek *et al*. (2009) [11] described that fertilization of sewage sludge and its mixtures that were with peat and with farmyard manure have obtained higher yields in comparison to treatments that were fertilized especially with mineral salts. Rathor *et al*.

(2014) [44] stated that at low concentration nickel is essential for growth of maize plant and high concentration is toxic. Different toxicity levels of nickel on maize shoot length, on roots and dry biomass were compared with control. 10 mg kg^{-1} decreased the maize dry matter yield in solution culture of nickel on the other land; pot culture revealed that 50 mg kg^{-1} concentration of Ni caused reduced weight of dry matter and with above 100 mg kg^{-1} dose of Ni symptoms of chlorosis were observed. This study revealed that nickel reduces maize growth. Arunkumar *et al*. (2014) [2] reported that Physico-chemical parameters like adsorbent dosage, time of contact, initial concentration and ph. The result showed that Corn cob, is capable of good prospects as an adsorbent and has ability to remove Ni (II) which is a toxic heavy metal through industrial waste water. Ebru (2014) [7] concluded that cobalt and nickel showed particular effects at germination time. Low level of cobalt resulted in enhanced germination and nickel showed decreased germination. But there was a difference shown by maize germination percentage against treatment of cobalt and nickel. Radziemska and Mazur (2005) [28] stated that parts of maize which were above ground which were not applied with mineral fertilization and also with mineral fertilization of nitrogen showed the highest average crop yield in comparison with those which were not applied with mineral N-fertilization. Crop yield was recorded at maximum with compost including fish waste with straw and lignite addition and bark with lignite. Portion having lignite addition to mass of compost with mineral N fertilization showed stronger impact on Ni, Cd, Cr and Zn contents in maize aboveground parts.

Mohammed *et al*. (2012) [19] investigated that amount of nickel differ in soil samples which were collected from different sites with distribution of residual, oxides of Fe and Mn, oxide and carbonate (organically bound phases). The results indicated that concentration of nickel was higher than tolerance limit of 50 mg/kg in few sampling locations and there was a significant difference in concentration of nickel with several crops of maize. Similarly, there was also a significant difference in concentrations of nickel with several maize grown soils. Nasr (2013) [22] studied the toxic effect of aluminum and nickel toxicity on root, seedling length shoot and germination of seed and biomass of dry seedling of maize was compared with control values. It was observed that aluminum treatments have adverse effects on maize seedlings in comparison with nickel. It was concluded that treatment of nickel and aluminum at 200mg/L gave lowest tolerance percentage in maize seedlings when compared with control. Helal *et al*. (1998) [12] stated that heavy metals leaching in surface water and transfer of these heavy metals to food chain in those areas which are salt affected is greater than pretended. Ahmad *et al*. (2009) [41] reported that seed germination was promoted in result of low concentration of Ni and also growth was enhanced by using high concentration resulted in inhibited germination. 40mg/L was reported as nickel maximum tolerance level. Ahmad *et al*. (2010) [40] reported that nickel in high concentration resulted in low fresh weight of root and shoot but also caused decrease in concentration of Ca, Mn, and Fe. With increase of nickel level zinc, nitrogen, potassium and copper were decreased.

Singh and Agarwal (2010) [35] concluded that amendment of sewage sludge resulted in enhancement of soil physiological parameters and heavy metals availability was improved in soil also. Soil having excess of heavy metals contents resulted in decrease of root length. Also increase in shoot length, number of leaves and total biomass were observed. Shakier *et al*. (2010) [33] reported that nickel and lead's effect at two levels 5 and 25 µM on chlorophyll a and chlorophyll b with carotenoids in wheat (*Triticum aestivum* L) that was grown in laboratory conditions with nitrogen 5 mM presence or absence. Chlorophyll a and carotenoids were reduced less then chlorophyll b. On the other hand, nitrogen application resulted in increase of carotenoids content and chlorophyll.

Torresdey *et al*., (2011) [8] reported that concentration of nickel was high in roots then in leaves and in last was stem in which metals content was lowest. Concentration of Lead was also like nickel first roots then leave and in last stems, copper concentrations were also like nickel and lead. On the other hand, concentrations of cadmium and nickel were lower and have difference from 30 mg/Kg on roots, then 37 mg/Kg on leaves, and in last was 10 mg/Kg on stems was for cadmium, and nickel content investigated were varying from 27 mg/Kg on roots, then 23 mg/Kg on leaves, last was 10 mg/Kg on stems. In site 4 concentrations of soil were high for lead and copper, but concentrations of were cadmium and nickel were low. It was noticed that those section having heavy metals higher concentration resulted in higher uptake by plant also stated that *Larrea tridentate* has ability of up taking copper and lead, and cadmium and nickel to some extent, from soils that were contaminated with heavy metal. Kaverammal and Subramani (2013) [13] investigated that Different growth parameters of ground nut were reduced due to high concentration of nickel chloride ($NiCl_2$). Rajkumar *et al*. (2013) [30] observed that on the basis of morphological features, partial analysis of sequence of 16_S rDNA and biochemical characteristics *Bacillus megaterium* is identified and is a strain of Ni-resistant bacteria $SR_{28}C$ that was isolated from serpentine soil that was nickel rich. Tolerated concentrations of the strain $SR_{28}C$ of Ni L_1 were up to 1200 on a (LB) agar medium. Very high resistance was shown by different metals like copper, zinc, cadmium, lead and chromium and including various antibiotics like streptomycin, penicillin etc. were tested. In resting cells nickel was bounded by strain in considerable amount. Traits that are plant growth promoting were exhibited by strain, like phosphate solublization and IAA production in LB (Luriae Bertani) medium and Pikovskayas medium within or without presence of nickel. In various concentrations of nickel in soil were assessed and was interrogated accumulation of nickel and growth effected by $SR_{28}C$ of *L. cylindrical*, *B. juncea* and *S. halepense*. In test plants biomass was stimulated with $SR_{28}C$ Inoculation in soil contaminated with nickel and also in contaminated of stimulated the biomass of the test plants grown in both Ni contaminated and non-contaminated soils. $SR_{28}C$ showed that the harmful effects of Nickel were by minimized by reducing its uptake and also plant translocation. It was concluded that due to properties of PGPB inoculants on growth promotion and lowering the toxicity of Ni in those sites which are contaminated with nickel Ni could be gained for phyto-stabilization.

3. Effect of heavy metal (Ni) on soils

Nickel is 22^{nd} abundant element in earth crust holding a special place among other heavy metals. For growth of plant nickel contributes as essential micronutrient and it is a component of urease enzyme, in higher plants for metabolism of nitrogen urease is required. Nickel and compounds of nickel have many uses industrially and commercially, and the advancement of industries is influencing the environment by pollutants increased emission. Redistribution and absorbance of nickel in plants takes through cation and or with complex transport system of metal-ligand. Ni in higher concentration becomes strongly phytotoxic. Ni causes change in some plants antioxidant enzymes activity e.g. SOD (superoxide dismutase), APX (Ascorbate peroxides) and CAT (Catalase). toxicity of nickel is commonly identified by growth inhibition in plant, resulting in chlorosis, induces necrosis and causes wilting. Metabolic reaction is strongly effected in plants with Nickel and Reactive Oxygen Species (ROSs) are generated with it which might result in oxidative stress. Use of Ni in high levels resulting in suppression of root meristem cell division in plants which are non- tolerant and growth of plant is decreased. Conducted research showed that photosynthesis and respiration are affected negatively by nickel. In plant species of monocot and dicot Ni up taken in high level causes decrease in content of water. In plants Ni toxicity can be indicated by decline of water. There is not so much attention given to nickel because of its dual nature and complex electronic chemistry which results in obstruction to expose the mechanism of toxicity in plants. Conducted study was with the aim to know about sources, its essentiality, and uptake by plants and toxic effects on plants. Pollution of nickel is severe environmental concern which takes research towards phytoremediation. There is need of study to know about the details of biochemical and molecular levels both to know about the tolerance of nickel on nickel hyper accumulators.

Mainly effect of nickel has its outcomes on lands near industrial areas or may be affected by wastes like sewage and sludge (Bankov, 1983). Existence of nickel in soil is in different forms, like precipitate form, in the form of complexed or absorbed on cation exchange cites or absorbed on organic cation surfaces and also in the form of free ion or in soil solution, complex chelated metal (WHO 1991) [39]. Ni has many beneficial effects in plant e.g. in activity of urease and contributes in improvement of N use efficiency in studies of hydroponics. Ni deficiency in soil is reported rarely but deficiency of nickel has adverse effect on plant growth, metabolism of nitrogen and uptake of iron and has also effect on resistance of disease. For proper growth of plant and its development nickel is essential, Ni is required in sufficient level for plant to perform different physiological and morphological functions taking place from germination of seed to productivity. Without optimum supply of Ni life cycle of plant cannot be completed (Satish *et al*., 2015).

Nogueiraa *et al*. (2009) [46] Sewage sludge use in agriculture is major limitation and risk of contamination of soil with heavy metals, and might be transferred to human through food chain. Sewage sludge rates did not affect Ni content in the soil. Accumulation of nickel was noticed in stem and leaf but in grain it was not detected. Mineral fertilization and application of Sewage sludge for a longer period of time induces same impacts on production of dry matter and grain.

Singh *et al*. (2010) [36] heavy metals mean level in contaminated soil and in plant parts root and shoot was noticed that was in high amount then in uncontaminated soils. Soil contaminated with these heavy metals and their enrichment factor (EF) told that nickel was third most abundant after iron and cadmium. Metals enrichment factor in root and shoots was in the sequence of Cd>Fe>Zn and nickel was at 4th number respectively. Soils contaminated with heavy metals showed translocation factor in result from roots to shoot showed nickel at number four after Mn, Fe and zinc. This study helped for selection of those plant species which are naturally resistant against metals those are toxic to plant and are efficient in metals accumulation.

Masona *et al*. (2011) [17] concluded that waste-water irrigation for long term resulted in accumulation of heavy metals in soil and plants bioaccumulation was high MPL (maximum permissible limit) for consumption of human and animals both. Transfer factor of is Lead highest and iron with least transfer factor. The pH of soil was noticed in waste water exposed soils was less acidic (pH = 5.6) against those soils which were not irrigated with wastewater (pH = 5). It was recommended that heavy metals phytoextraction is needed by plants of maize intercropping with shrubs of local agro forestry to minimize heavy metals amount in the soil.

Improving the capacity of soil productivity, chemical and physical characteristics in agriculture by using organic wastes. Sewage sludge compost and application of inorganic fertilizer of nickel, soil having contents of copper and zinc and grains of corn (*Zea mays* L); productivity of maize, and nutritional quality of grain. The application of Sewage sludge and compost of sewage sludge were at 18 Mg ha^{-1} and mineral fertilizers (N-P-K) were at rate of 150-75-30 were applied. There were particular differences noticed in organic matter, P and Zn content with compost-soil and sewage sludge-soil, inorganic fertilizer-soil. Concentration of Copper was particularly higher in compost-soil. Inorganic fertilizer-soil have lower Productivity then compost-soil and with mixture of sewage sludge-soil. Grain quality was checked by relative percentage of total nitrogen, starch, neutral detergent fiber, acid detergent fiber and protein were proper for consumption of human. Sewage sludge Application or compost have no effect on increase of concentration of heavy metal in grain in comparison with inorganic fertilizer-soil (VACA1 *et al*. 2011) [38].

Kumar and Maiti (2014) [14] concluded that heavy metals concentration significantly of Cr and Ni in worlds different geological regions in ultramafic soil/rock produced by anthropogenic means or with natural weathering. Nutrient content in poor, having Ca: Mg ratio low, heavy metals concentration is when high then results in those soils in the form of sparse vegetation. Metal tolerant vegetation covers is present on that area are and few plants became hyper accumulator and are economically important and particular for metals extraction from it. This study was also serpentine/ultramafic soil and plants across the World.

Radziemska *et al*. (2013) [29] studied the heavy metals contaminated Soil, natural environment contamination highly with nickel the highest increase was shown by soil Contamination with amount of 240 mg Ni kg^{-1}. Doses of 160 mg Ni and 240 mg Ni kg^{-1} soil addition of Modified halloysite to soil resulted almost in double increase of content of phosphorus in comparison with plants that were not applied with neutralizing substances of maize. There was an impressive impact of Modified halloysite on potassium accumulation in maize above-ground parts, particularly in those plants which were exposed to minimum dose of nickel analyzed (80 mg kg^{-1} soil). Nickel contamination used to neutralize applied substances. Substances used to neutralize, applied modified halloysite showed to be most significant and highest average of content of calcium at 29%. Presence of highest Mg content in plant above ground parts was at concentrations of 160 mg kg^{-1} and 240 mg kg^{-1} soil in plants group. Sorption substances were applied and responded positively on average magnesium content of maize parts above the ground. Modified halloysite was when added it brought the increase in the average magnesium level at highest in plants that were tested in comparison with group of control plants. There was positive impact shown by natural halloysite and Zeolite to some extent.

Toxic metal is normally added as salts having relatively high solubility in as organic salt or inorganic, in eco-toxicological studies of soil. For this prospect sulfate, acetate, chloride, or Nitrate or are often considered as acceptable. Advanced studies showed that at same cationic concentration of same metal having various salts have different effect on soil organisms and plants due to their difference in toxicity level. This relevant information should be wondered when choosing data to use for soil environment building toxicological criteria. Ni addition to the soil caused variance in toxicity with other anionic partner that was selected showing toxicity of $NiSO_4$ was greater than $Ni(CH3COO)_2$ then Ni (II)-citrate moving toward $NiCl_2$ in last Ni (II)-EDTA. With example of plant height showed that 50% concentration resulting inhibition (50 EC) with highest for $NiSO_4$, then $NiCl_2$, and 3rd was Ni (II)-EDTA. Ni (II)-EDTA was up taken by plant more significantly by roots of maize and caused disastrous toxic effects on plants. Soluble sugar of leaf was reduced basically by nickel which showed its impact on carbohydrate metabolism of plant. Results of conducted study showed that different salts cause ecotoxicities of very different types. Research concluded that anionic opposite to metal cation potentially toxic must be considered as basic for ecotoxicological criteria development for soil environment evaluation, and must be favorable approach for reduction of anionic partner for leaching soil (Nie *et al*., 2015) [23].

4. Conclusion

Application of nickel (Ni) at lower concentration improves plant growth and also increased the final production in plants. However, at higher concentration Ni act as toxic element for plant and damage the plant physiology and also contaminate the soil that was not useful for the crop production by the accumulation of heavy metal nickel (Ni).

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