Available Online at http://www.recentscientific.com

CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 8, Issue, 12, pp. 22794-22798, December, 2017

ISSN: 0976-3031

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Review Article

SOURCES OF NICKEL POLLUTION AND ITS IMPACTS ON ENVIRONMENT: A REVIEW

Atia Arzoo and Kunja Bihari Satapathy*

Department of Botany, Utkal University, VaniVihar, Bhubaneswar, 751004, Odisha

DOI: http://dx.doi.org/10.24327/ijrsr.2017.0812.1337

ARTICLE INFO

Article History:

Received 15th September, 2017
Received in revised form 25th October, 2017
Accepted 28th November, 2017
Published online 28th December, 2017

Key Words:

Environment, nickel, occurrence, pollution.

ABSTRACT

Nickel is an essential trace element for plants and animal health. It has widespread distribution on the environment and released to the environment by industrial production, mining and smelting of metalliferous ores. It has many commercial and industrial uses. Nickel and nickel compounds belong to classic noxious agents and also affect plants, animals as well as microorganisms through air, water and soil. The objective of this paper is to summarize the current overview of the occurrence and sources of nickel in the environment and the effect of this metal and its compounds on the environment and also on living organisms.

INTRODUCTION

Nickel was first isolated in 1751, and a relatively pure metal was prepared in 1804. In nature, nickel is found primarily as oxide and sulphide ores (USPHS, 1977). Nickel is a silvery white metal that takes on a high polish. It is a transition metal, hard and ductile. Nickel is one of the five ferromagnetic elements. Nickel is also a naturally magnetostrictive material, meaning that in the presence of a magnetic field, the material undergoes a small change in length. The properties of nickel and its environmental distribution have been summarized by the US Agency for Toxic Substances and Disease Registry (ATSDR, 1988).

Nickel has been considered to be an essential trace element for human and animal health. The permissible limit of nickel in plants recommended by WHO is 10 mg/kg. The maximum permissible limit for Ni in water is 0.2 mg/l.

Occurrence of nickel

Nickel is primarily found combined with oxygen or sulphur as oxides or sulphides that occur naturally in the earth's crust. Nickel combined with other elements is present in all soils, in meteorites, and is emitted from volcanoes. As for most metals, the toxicity of nickel is dependent on the route of exposure and the solubility of the nickel compound (Coogan, 1989). Natural nickel is a mixture of five stable isotopes; nineteen other unstable isotopes are known. Although it can exist in several different oxidation states, the prevalent oxidation state under environmental conditions is Ni(II), nickel in the divalence state. Other valences (-1, +1, +3, and +4) are also encountered, though less frequently (Young,1995; Clayton *et. al.*,1994).

It occurs most usually in combination with sulphur and iron in pentlandite, with sulphur in millerite, with arsenic in the mineral nickeline, and with arsenic and sulphur in nickel glance (Nestle, 2002). More than 90% of the world's nickel is obtained from pentlandite [$(FeNi)_9Sg$], a nickel-sulfitic mineral mined underground in Canada and the former Soviet Union (Sevin, 1980; WHO, 1991). One of the largest sulfitic nickel deposits is in Sudbury, Ontario (USPHS, 1993). Nickeliferous sulfide deposits are also found in Manitoba, South Africa, the former Soviet Union, Finland, western Australia, and Minnesota (USPHS, 1993). Most of the nickel obtained is from nickel minerals such as laterite, a nickel oxide ore mined by open pit techniques in Australia, Cuba, Indonesia, New Caledonia, and the former Soviet Union (Sevin, 1980). Lateritic ores are less well defined than sulfitic ores, although the nickel content (1-3%) of both ores is similar (USPHS, 1993). Important deposits of laterite are located in New Caledonia, Indonesia, Guatemala, the Dominican Republic, the Philippines, Brazil, and especially Cuba, which holds 35% of the known reserves (USPHS, 1993). Nickel-rich nodules are found on the ocean floor, and nickel is also present in fossil fuels (Sevin, 1980). Stainless steel cooking utensils (e.g., oven pans, roasting pans) contributed markedly to the levels of nickel in cooked food, sometimes

Corresponding author:* **Kunja Bihari Satapathy
Department of Botany, Utkal University, VaniVihar, Bhubaneswar, 751004, Odisha

exceeding 1 mg/kg in meat (Dabeka and McKenzie, 1995)

Annual consumption of nickel in India is about 15000 tonnes and almost the entire quantity is met through imports. Hence, Sukinda ultramafic complex, the only indigenous resources of nickel ore of India, should be utilized. The Sukinda ultramafic body is stratiform in nature and comprises inter-layered nickel and chrome rich rocks (dunite-peridotite and orthopyroxenite). The serpentinised dunite peridotite members have been subjected to intense chemical weathering resulting in the formation of a nickel rich limonite cover. Thus the lateritic nickel ore is of secondary origin (Sahoo, 1998).

Uses of Nickel

Nickel and nickel compounds have many industrial and commercial uses. Most nickel is used for the production of stainless steel and other nickel alloys with high corrosion and temperature resistance. Nickel metal and its alloys are used widely in the chemical and food processing industries, especially as catalysts and pigments. The nickel salts of greatest commercial importance are nickel chloride, sulphate, nitrate, carbonate, hydroxide, acetate and oxide (Grandjean,1984). Nickel is used in a wide variety of metallurgical processes such as electroplating and alloy production as well as in nickel-cadmium batteries. There is evidence suggesting that nickel may be an essential trace element for mammals (Goyer, 1991). Nickel is reportedly an essential micronutrient for maintaining health in certain species of plants, invertebrates, birds, and mammals, including humans (NAS, 1975).

Impacts of nickel on environment

Impacts of nickel on atmosphere

Nickel in the atmosphere is mainly in the form of particulate aerosols (WHO, 1991) resulting from human activities (Sevin, 1980). Air concentrations of nickel are elevated near urbanized and industrialized sites and near industries that process or use nickel (USPHS 1993). The greatest contributor to atmospheric nickel loadings is combustion of fossil fuels in which nickel appears mainly as nickel sulfate, nickel oxide, and complex metal oxides containing nickel (USEPA, 1986). Nickel concentrations in the atmosphere of the United States are highest in winter and lowest in summer, demonstrating the significance of oil and coal combustion sources (USPHS, 1993; Pirrone *et. al*., 1996).

Nickel concentrations in remote areas are in the range of 1-3 ng/m^3, whereas concentrations in rural and urban air range from 5 to 35 ng/m^3. It has been estimated that non-occupational exposure via inhalation is 0.2-1.0 µg/day in urban areas and 0.1-0.4 µg/day in rural areas (Bennett, 1984). The mainstream smoke of one cigarette contains about 0.04-0.58 µg of nickel (IARC, 1990). Cigarette smoke contributes significantly to human intake of nickel by inhalation; heavy smokers can accumulate as much as 15 µg of nickel daily from this source.

Nickel in the atmosphere is removed through rainfall and dry deposition, locating into soils and sediments; atmospheric removal usually occurs in several days. When nickel is attached to small particles, however, removal can take more than a month (USPHS, 1993).

Impacts of nickel on hydrosphere

Nickel concentrations in ground water depend on the soil use, pH, and depth of sampling. The average concentration in ground water in the Netherlands ranges from 7.9 µg/litre (urban areas) to 16.6 µg/litre (rural areas). Acid rain increases the mobility of nickel in the soil and thus might increase nickel concentrations in ground water (IPCS, 1991). In ground water with a pH below 6.2, nickel concentrations up to 980 µg/litre have been measured. In Canada, the median nickel level in drinking-water supplies was below the detection limit of 2 µg/litre; the maximum level observed was 69 µg/litre. Increased nickel concentrations in ground water and municipal tap water (100-2500 µg/litre) in polluted areas and areas in which natural nickel was mobilized have been reported. Water left standing overnight in plumbing fittings plated with chromium on a base of nickel contained a nickel concentration of 490 µg/litre (Andersen *et. al*., 1983). Certain stainless steel well materials were identified as the source of increased nickel concentrations in ground water wells in Arizona, USA. Mean nickel levels were 8-395 µg/litre; in some cases, nickel levels were in the range 1-5 mg/litre. The average concentration in ground water in the Netherlands ranges from 7.9 µg/litre (urban areas) to 16.6 µg/litre (rural areas). Acid rain increases the mobility of nickel in the soil and thus might increase nickel concentrations in ground water (IPCS, 1991).

Leaching of nickel from chromium-nickel stainless steel pipe work into drinking water diminished after a few weeks; as chromium was rarely found at any time in the water, this indicates that the leakage of nickel is not of corrosive origin, but rather attributable to passive leaching of nickel ions from the surface of the pipes. Concentrations of nickel leaching from new stainless steel pipes used for drinking-water were up to 6 µg/litre. This maximum concentration can be increased when the pipes are assembled with tinned copper and gunmetal fittings. Fittings such as taps, which are chromium-plated, release much higher concentrations, but these decrease significantly with time (EU, 2004). Concentrations of nickel in water boiled in electric kettles may, depending on the material of the heating element, be markedly increased, especially in the case of new or newly decalcified kettles. The greatest concentrations are associated with nickel plated elements; however, leaching decreases over time. Nickel concentrations in the range 100–400 µg/litre, with extreme values over 1000 µg/litre, have been reported. Nickel concentrations in bottled mineral water will depend on the source and any treatment applied. Levels of nickel in a selection of bottled mineral waters were below the detection limit of 25 µg/litre (Allen *et. al*., 1989).

Impacts of nickel on lithosphere

Nickel is generally distributed uniformly through the soil profile but typically accumulates at the surface from deposition by industrial and agricultural activities. Nickel may present a major problem in land near towns, in industrial areas, or even in agricultural land receiving wastes such as sewage sludge. Its content in soil varies in a wide range from 3 to 1000 mg/kg (Bencko, 1983). Nickel can exist in soils in several forms: inorganic crystalline minerals or precipitates, complexed or adsorbed on organic cation surfaces or on inorganic cation exchange surfaces, water soluble, free-ion or chelated metal complexes in soil solution (Bennet, 1982). This metal apparently does not seem to be a major concern outside urban areas at this time but may eventually become a problem as a result of decreased soil pH caused by reduced use of soil liming in agriculture and mobilization as a consequence of increased acid rain (Bencko, 1983). The median nickel content was 3.9 µg/g for fresh alluvium samples and 9.8 µg/g for urban alluvial soils. Overall, significantly higher metal values occur in the inner city and lower values occur in outlying areas. In Poland, the level of nickel in 60 samples of the soil collected from the Stalowa Wola area, which is affected by industrial emissions, was higher (average 17.20 mg/kg) than that in the reference samples (average 9.72 mg/kg). All the values, however, were below the highest allowable concentration. Similarly, nickel content in soils in allotment gardens in post-flooded industrialized areas of the Dolnośląski Region during 2000-01 also did not exceed the highest allowable concentration (Bozek *et. al*, 2003). According to the current Polish regulation the allowable limit for nickel in the soil depends on many factors, and for not industrialized areas is set as 50 mg/kg d.w. (Baralk *et. al*., 1999).

Nickel pollution in biosphere

Nickel is ubiquitous in the biosphere. Nickel introduced into the environment from natural or human sources is circulated through the system by chemical and physical processes and through biological transport mechanisms of living organisms [National Academy of Sciences (NAS), 1975; Sevin, 1980; WHO 1991]. Nickel is reportedly an essential micronutrient for maintaining health in certain species of plants, invertebrates, birds, and mammals, including humans (NAS, 1975)

Impacts of nickel on plants

In several species of higher plants, including jack beans *(Canavalia* sp.), soybeans *(Glycine max),* rice *(Oryza sativa),* and tobacco *(Nicotiana tabacum),* nickel is required for effective urea metabolism and urease synthesis (Kasprzak, 1980). Some terrestrial plants, such as *Alyssum* spp., accumulate nickel and require it for growth. Nickel is essential for the active synthesis of urease in plant cells (Thauer *et. al*., 1980).

Impacts of nickel on animals

The adverse health effects of nickel depend on the route of exposure (inhalation, oral, or dermal) and can be classified according to systemic, immunologic, neurologic, reproductive, developmental, or carcinogenic effects following acute (01day), subchronic (10-100 days), and chronic (100 days or more) exposure periods. The most common harmful health effect of nickel in humans is an allergic skin reaction in those who are sensitive to nickel. Nickel is the most observed cause of immediate and delayed hypersensitivity noticed in occupationally exposed as well in the general population. The metal is not only an allergen but also a potential immunomodulatory and immunotoxic agent in humans. Based on studies of nickel workers and laboratory animals, all nickel compounds, except for metallic nickel, have been classified as human carcinogens by the International Agency for Research on Cancer (IARC, 1990 and the U.S. Department of Health and Human Services, 1994).

The accidental inhalation of nickel carbonyl generally causes acute toxic effects in two stages, immediate and delayed. The immediate symptoms include headache, vertigo, nausea, vomiting, insomnia, irritability, which usually last a few hours, followed by an asymptomatic interval of 12 h to 5 days. Then delayed symptoms appear-tightness of the chest, nonproductive cough, dyspnoea, cyanosis, tachycardia, palpitations, sweating, visual disturbances, vertigo, weakness, and lassitude (Sunderman *et. al*., 1975). A fatal case of nickel poisoning was reported for a 2 ½ yr old girl who had ingested 15 g of nickel sulphate (Daldrup *et. al*., 1983). The cause of death was cardiac arrest. Death due to nickel-induced adult respiratory distress syndrome (ARDS) was reported for a worker spraying nickel using a thermal arc process (Rendall *et. al*., 1994). Nausea, vomiting, abdominal pain, diarrhoea, headache, cough, shortness of breath, and giddiness were reported for workers of an electroplating plant who drank water contaminated with nickel chloride and nickel sulphate (1.63 g/l) (Sunderman *et. al*., 1988). Signs and symptoms of toxicity lasted for up to 2 days with uneventful recoveries for all 32 workers. In male rats, a single dose of nickel chloride injection caused a profound and consistent increase in circulating prolactin levels after one day and lasted for four days (Clemons *et. al*., 1981). Kidney injury and frank haematuria were also observed in acute nickel toxicity (Kasprzak *et. al*., 1980).

In an evaluation of workers welding high-nickel alloys, it was reported that 6 week exposure to nickel fumes (0.07 to 1.1 mg nickel/m^3) caused an increase in airway and eye irritations, headaches, and tiredness (Akesson *et. al*., 1985). There is significant reductions in body weight, and signs of hepato and renal toxicities in animals as a result of daily exposure to nickel via diet are also found (Weber and Reid, 1969). Oral administration of nickel as $NiCl_2$ in male rats over a period of 28 days at concentration of 2.5, 5.0 and 10.0 µg /ml in drinking water (0.38, 0.75, or 1.5 mg/kg/ day) resulted in significant dose-dependent hyperglycaemia, decrease in serum urea and significant increase in urine urea. At 0.75 mg/kg doses increased leukocyte count was also observed (Weischer *et. al*., 1980). Toxic symptoms like lethargy, ataxia, hypothermia, salivation, diarrhoea were observed in the nickel treated rats at 10 mg/kg/day doses. The mortality rate among rats are very high in dose-dependent nickel treatment.

Impacts of nickel on microorganisms

In bacteria, nickel is required for the growth of *Oscillatoria* sp. and *Alcaligenes* sp., for the synthesis of carbon monoxide dehydrogenase in *Clostridium posterianum,* and as a component of coenzyme F430 in *Methanobacterium* spp. (Babich and Stotzky, 1982). Nickel deficiency in bacteria may adversely affect reproductive processes, such as endospore formation, and cause a decrease in nickel containing intracellular pigments in strains of *Bacillus cereus* (Thauer *et. al*., 1980); however, both of these observations require verification. Nickel is essential for the active synthesis of urease in various hydrogenases in bacteria (Thauer *et. al*., 1980; USEPA, 1986; WHO, 1991; Hausinger, 1993).

CONCLUSSION

Nickel and nickel compounds is known to be a noxious agents and also affects the living organisms through air, water and soil which is continuously deposited to the environment due to various natural as well as anthropogenic activities. So, it is well needed to intensify the research programmes for better understanding about the sources of nickel toxicity and its impacts on plants, animals and also on environments and its proper remediation.

Acknowledgment

We are thankful to University Grants Commission, New Delhi for providing financial support and Head, Post Graduate Department of Botany, Utkal University for providing Laboratory facilities during the investigation.

Reference

Akesson, B. and Skervfing, S. (1985). Exposure in welding of high nickel alloy. *Int Arch Occup. Environ. Health*, 56: 111-7.

Allen, H.E., Halley-Henderson, M.A. and Hass, C.N. (1989). Chemical composition of bottled mineral water. *Archives of Environmental Health,* 44: 102-116.

Andersen, K.E. (1983). Nickel in tap water. *Contact Dermatitis*, 9: 140-143.

ATSDR (Agency for Toxic Substances and Disease Registry). (1988). Toxicological profile for nickel. Atlanta, GA, USA: ATSDR/ U.S. Public Health Service, ATSDR/TP-88/19.

Babich, H. and Stotzky, G. (1982). Nickel toxicity to microbes: effect of pH and implications for acid rain. *Environmental Research*, 29: 335-350.

Barałk iewicz d.and siepak j (1999). Chromium, nickel and cobalt in environmental samples and existing legal norms. *Polish J. Environ. Studies*, 8 (4), 201-208.

Bencko, V. (1983). Nickel: A review of its occupational and environmental toxicology. *J. Hyg. Epidem. Micro. Immun.,* 27: 237-248

Bennett, B.G. (1982). Exposure of man to environmental nickel an exposure commitment assessment. *Sci. Total. Environ*., 22 (3): 203-211

Bennett, B.G. (1984). Environmental nickel pathways to man. In: Sunderman FW Jr, ed. Nickel in the human environment. Lyon International Agency for Research on Cancer, pp. 487-495 (IARC Scientific Publications No. 53).

Bożek, U.,and Król, I.K.B. (2003). Heavy metals in soils of allotment gardens in post-flooded industrialized areas of the Dolnośląski Region. *Med. Środow*., 6 (1): 57-66.

Clayton G.D. and Clayton F.E. (1994). Patty's Industrial Hygiene Toxicology, 4th ed.; A Wiley-Interscience Publication: New York, pp 2157-2173.

Clemons, G. and Garcia, J.F. (1981). Neuroendocrine effects of acute nickel chloride administration in rats. *Toxicol. Appl Pharmacol.*, 61: 343-348.

Coogan T.P., Latta D.M., Snow E.T., Costa M. (1989). Toxicity and carcinogenicity of nickel compounds, In: McClellan RO, editor. Critical reviews in toxicology. vol. 19. Boca Raton, FL: CRC Press;. 341-84,

Dabeka, R.W. and McKenzie, A.D. (1995). Survey of lead, cadmium, fluoride, nickel, and cobalt in food composites and estimation of dietary intakes of these elements by Canadians in 1986–1988. *Journal of the Association of Official Analytical Chemists International*. 78: 897-909.

Daldrup, T. Haarhoff, K. and Szathmary, S.C. (1983). Toedliche nickelsulfaye-intoxikation. Berichte zur Serichtlichen Medizin; 4: 141-4.

EU. (2004) Nickel sulphate risk assessment. Draft, May 2004. Prepared by the Danish Environmental Protection Agency for the European Union.

Goyer, R. (1991). Toxic effects of metals. In: Amdur MO, Doull JD, Klaassen CD, editors. Casarett and Doull's toxicology. 4th ed. New York: Pergamon Press; 623-80.

Grandjean, P. (1984). Human exposure to nickel. IARC Sci. Publ. 53. 469.

Hausinger, R.P. (1993). Biochemistry of nickel. Plenum Press, New York. 280 pp.

IARC (International Agency for Research on Cancer). (1990). Nickel and nickel compounds. In: Chromium, nickel and welding. Lyon, International Agency for Research on Cancer. IARC Monograph on the evaluation of carcinogenic risks to humans. vol. 49. Lyans, France: IARC; 318-411.

IPCS (1991) *Nickel.* Geneva, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 108).

Kasprzak, K., Gabryel, P. and Jarezewska, K. (1980). Nickel toxicology. Proc. Int. Conference 1980., 2: 59-62.

National Academy of Sciences (NAS). (1975). Medical and biological effects of environmental pollutants. Nickel. National Research Council, National Academy of Sciences, Washington, D.C. 277 pp.

Nestle F.O., Speidel H. and Speidel M.O. (2002). Metallurgy: High nickel release from 1- and 2-euro coins. *Nature* 419 : 132.

Pirrone, N., Keeler, G.J., Nriagu, J.O. and Warner, P.O. (1996). Historical trends of airborne trace metals in Detroit from 1971 to 1992. Water, Air, and Soil Pollution, 88: 145-165.

Rendall, R.E.G., Phillips, J.I. and Renton, K.A. (1994). Death following exposure to fine particulate nickel from a metal arc process. *Ann. Occup. Hyg*., 38: 921-30.

Sahoo, R.K. (1998). Nickel Ore. In, B.K. Mohanty (Ed)- Geology and Mineral Resources of Orissa. Society of Geoscientists and Allied Technologist. 323-338.

Sevin, I. F. (1980). Nickel. *in* H. A. Waldron, editor. Metals in the environment. Academic Press, London. 263-291.

Sunderman FW (1988). Acute nickel toxicity in electroplating workers who accidentally ingested a solution of nickel sulfate and nickel chloride. *American Journal of Industrial Medicine,* 14:257-266.

Sunderman, F.W. Jr., Coulston, F. and Eichhorn, G.L. (1975). Nickel. Washington DC: National Academy of Science,pp 97- 143.

Thauer, R.K., Diekert, G. and Schönheit, P. (1980). Biological role of nickel. Trends in Biochemical Sciences, 5: 304-306.

U. S. Environmental Protection Agency (USEPA). (1986). Health assessment document for nickel and nickel compounds. EPA Report 600/8-83/012FF. 460 pp.

U. S. Public Health Service (USPHS). (1977). Criteria for a recommended standard . . . occupational exposure to inorganic nickel. U.S. Department of Health, Education, and Welfare, Public Health Service, Centre for Disease

Control, National Institute for Occupational Safety and Health. DHEW (NIOSH) Publication No. 77-164. 282.

U. S. Public Health Service (USPHS). (1993). Toxicological profile for nickel. U.S. Public Health Service, Agency for Toxic Substances and Disease Registry, Atlanta, Georgia. Report TP-92/14. 158 pp.

U.S. Department of Health and Human Services (DHHS). (1994). Seventh annual report on carcinogens: Summary *1994*. Research Triangle Park, NC, USA: DHHS, National Institute of Environmental Health Sciences; 262-9.

Weber, C.W. and Reid, B.L. (1969). Nickel toxicity in young growing mice. J. Anim. Sci., 28: 620-623.

Weischer, C.H., Kordel, W. and Hochrainer, D. (1980). Effects of $NiCl_2$ and NiO in Wistar rats after oral uptake and inhalation exposure, respectively. Zentral Bakteriol Mikrobiol Hyg., 171: 336-51.

World Health Organization (WHO). (1991). Nickel. Environmental Health Criteria 108. 383.

Young R.A., Toxicity Profiles. (1995). Toxicity summary for nickel and nickel compounds. Web site: http://risk.lsd.ornl.gov/tox/profiles/nickel (accessed 03.03.2005).

How to cite this article:

Atia Arzoo and Kunja Bihari Satapathy.2017, Sources of Nickel Pollution and Its Impacts on Environment: A Review. *Int J Recent Sci Res.* 8(12), pp. 22794-22798. DOI: http://dx.doi.org/10.24327/ijrsr.2017.0812.1337

****