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Short Review Paper

Nickel contamination of the environment

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Abstract

Nickel (Ni) and its compounds are being released in the environment regularly. Nickel and its compounds can be found in earth crust, windblown dust, volcanic eruptions as natural sources and many in anthropogenic sources. There are many sources responsible for the nickel emission to atmosphere. Nickel and its compounds are used in various industrial and consumer products therefore the presence of Ni can be found in almost all the environmental matrices. Nickel fumes and some volatile compounds of nickel make it an important occupational pollutant. Nickel and its compounds are known human carcinogens. This paper has made an effort to summarize the various aspects of nickel contamination of environment.

Keywords: Nickel, Particulate Matter, Environment, Toxicology, Pollution.

Introduction

Nickel is a metal frequently alloyed with other metals for creating common objects like jewelry, electronics and many types of industrial equipments. Nickel plating is one the familiar mechanism for the stunning mirror finish. Although in industrial and occupational site can give rise to various health issues. The nickel emission in the air differs because of multiple sources. There are many species of nickel that are linked with refining, smelting of metals, burning are basically Ni chloride, Ni sub sulfide and silicate. In the recent years Ni has gained focus among the researchers because of the rise in industrial and other commercial usage[1]. Increasingly the humans are getting exposed to Ni through air, food and water[2]. Inhalation is an important route of occupational exposure to nickel causing high health risks. The gastrointestinal route is not very important so much because of limited intestinal absorption[3].

The pollution from the urban traffic gives a major impact to the health of workers that expose for a long time due to outdoor work or their duties in high raffic area, being a reason for some fatal illness[4,5]. A lot of work has been reported to observed an relation between the critical or persistent exposure to the pollutants existing in urban traffic such as particulate matter (PM). The particulate matter(PM) from the urban pollutants is highly accountable (with adsorbed matter) for cardiovascular disorders. Inhalations of PM lessen the heart rate instability[6,7], leads to endothelial, autonomic dysfunction[8] and accelerates the succession of atherosclerosis[9,10]. The mechanisms of cardiotoxicity originated by air pollution comprise the rise in oxygen reactive species proceeded by initiation of pro-inflammatory and pro-thrombotic pathways[11,12].

The Nickel present in urban air released from (also adsorbed on PM[13,14]) from anthropogenic and natural sources viz procedure of extraction ,combustion of coal, nickel refining, automobile traffic, household heating, burning of waste products[15]; nickel is existed in solvents[16], paints, pesticides[17], electronic products and as a supplement in unleaded gasoline[18,19], also used in catalytic converter in form of catalyst[20,21].

Since the workers like taxi drivers, salesperson, firefighters, traffic Police etc; spend their time in urban areas for employment reasons that's why get exposed to particulate matter[18,17] (PM). For this it is better to implement biomarkers which are specific to measure the pollutants[22].

Due to the high intake of Nickel, many harmful reactions and effects like spew, dry cough, uneven respiration and tiredness[23]. Among the effluents of electroplating industries (tune of 20-200ppm)[24], Nickel is existed in high ratio and known as a heavy metal pollutant.

Occurrence in nature

Due to the properties of ductility, hardness, melting point, malleability nickel easily combine with other element and form many alloys[25,26]. Apart of this, Ni has good strength, corrosion and heat resistance; Nickel is ample in meteorites and in the terrestrial globe but comparatively less in terrestrial crust. Sulphidic and Oxidic are the two ores of Nickel. Sulphidic ores is analogous to chalcopyrite ($CuFeS_2$), pentlandite ($(Ni.Fe)_9S_8$) and nickeliferous pyrrhotite (Fe_7S_8). Except these minerals some are also exists like violarite (Ni_2FeS_4), ilmenite ($FeTiO_3$), pyrite (FeS_2), cubanite ($CuFe_2S_3$), and magnetite (Fe_30_4)[27].

"Pentlandite" is among the standard sulphidic minerals which approximately accounts for the production of 60% nickel. In case of nickel ore "Nickeliferous pyrrhotite" is considered as the most ample phase, because nickel is general contained in solid form (0.2-0.5%Ni). There are some regions where the sulphidic orebodies occurs viz. Finland, Zimbabwe, Australia, Canada, the republic of south Africa and the former soviet union[27].

In aqueous solution nickel is generally found in +2 oxidation state (Divalent state). It has some other higher oxidation states (+3,+4) but these occurs solely as dioxide(NiO_2) and impure sesquioxide(Ni_2O_3), which is considered as a unbalanced, variable stoichiometry. Nickel as a transition metal create complexes along with coordination number of 4(rarely, tetrahedral or square, planar)[28].

Sources in Nature

Number of studies have proved that the concentration of nickel inside the large particle of natural sources are comparatively not much than the in smaller particle (<1 µm) that are derived from the anthropogenic sources. Sources (Anthropogenic) that are responsible of releasing Ni are: i. Burning of oil, coal, residential, municipal, medical and industrial sewage. ii. Thermal metallurgical operations (manufacturing of nickel, coalition of metal and nickel recovery). iii. Production operations. iv. Catalytic and chemical sources of nickel is manufacturing of nickel- cadmium battery (NI-Cd battery), production of nickel chemical, electroplating etc. v. In harbors areas marine vessels are important sources of nickel, vi. Suspended particulate matter in atmosphere contain nickel bearing particle, fine air born particle in range of 0.6 to 10 µm are generally associated with nickel.

Air: Airborne nickel that is present in urban area is in between 0.003 to 0.03µg/m^3 whereas this level lies between 0.00001 to 0.003µg/m^3 in remote area[29]. In urban traffic particulate, heavy metal ion, nitrogen oxide, ozone, sulpher dioxide and carbon monoxide are present which causes different type of diseases such as blood pressure, heart failure etc.

Coke oven and cement manufacturing are also involved in emission of nickel in air but they are not the major sources. Cement manufacturing is a high temperature process where lime stone, clay, shales are used as raw material. Nickel present in these raw material, released in the form of nickel oxide during the process. Metallic nickel and sulphides of nickel are generally emitted from the coke oven because of highly reducing environment of ovens[28]. Some other and important sources are given in Table-1a and b.

Soil: Occurrence of nickel in granite, lime stone and sand stone is in between 5 to 20 mg/kg, mafic and ultramafic rock contains the higher concentration of nickel[33]. Weathering of rock material (mechanical and chemical) is the natural source of nickel in soil.

Table-1a: Sources of nickel in Atmospheric Air.

Natural		
Sources	Parentage Concentration	References
Windblown dust	56	30
Volcanoes	29	30
Vegetation	9	30
Forest fire	2	30
Meteoric dust	2	30

Table-1b: Sources of nickel in Atmospheric Air.

Anthropogenic		
Sources	Parentage Concentration	References
Burning residual and fuel oil	62	31
Metal and refining	17	31, 32
Municipal incineration	12	31, 32
Steel production	3	31, 32
Nickel containing alloy production	2	31, 32
Coal combustion	2	31, 32

The composition of soil is adversely effected by the discharge of large quantity of traces metal from industries to soil that become a threatening practice in most part of the world. In the soil (farm) 3 to 1000 mg/kg nickel is present but presence of refineries nearby area nickel concentration has reached up to 24000 mg/kg and 53000mg/kg in dried sludge. Solubility of nickel compound in soil is pH dependent. At pH more than 6.7 nickel occur in the form of insoluble hydroxide and at pH less than 6.5 nickel present in soil are soluble in nature[34].

The nickel distribution is site specific in soil. Texture of soil, presence of organic matter, density mineral present in clay, presence of hydroxide, flow of ground water and pH play an important role in the distribution of nickel in soil surface. The engrossment of Nickel in different horizon of the soil may be homogeneous but it is possible that its concentration in horizon B is tremendously high than horizon A because of wash out effect of rain. The assembling of nickel with other heavy metal causes a decrease in pH of soil and geochemical quality. For control and suppressing these kind of pollution, it is essential to keep a procedural record and develop the standard operating procedure (SOP) for monitoring of heavy metal[35].

Water: In India the water pollution level is reached at distressing situation and so the world. In India permissible limit for drinking water is 0.02mg/l, whereas in other countries the reported data of nickel concentration in natural, ground water and drinking water is given in Table-2.

Table-2: Average Nickel concentration in water.

Country	Concentration	References
Netherlands (average concentration in ground water)	7.9µg/liter (urban area)	36
Netherlands (average concentration in ground water)	16.69µg/liter (rural area)	36
Canada (median level in drinking water)	2-60µg/liter	37
USA (median level in drinking water)	<20 µg/liter	38
Europe (median level in drinking water)	<10 µg/liter	38
Denmark (median level in drinking water)	1 µg/liter	39, 40
Finland (median level in drinking water)	1 µg/liter	39, 40

In case of drinking water the concentration of nickel is depends upon the quality of pipe. Nickel concentration in hot water is lower than the cold water in case of metal pipe but if pipe is made from PVC the concentration of nickel is more in hot water than that of cold water. The nickel concentration reaches up to 6µg/liter by the leaching from new stainless steel pipes. In normal condition the concentration of nickel intake by an adult from water is 0.0075 to 0.015mg[1].

Home appliances that contain nickel as corroded plating or alloy are responsible for increasing the amount of nickel in drinking water. Significant amount of Nickel leached into boiling water from nickel plated utensil in that way the nickel concentration increase at a large extant in boiled water[41].

Food: The method and equipment (contain nickel alloy) used during processing of food like milling, catalytic hydrogenation of fat raises the nickel level by lixiviation[42,43]. Normally it remains within the range of 0.1mg/kg to 0.5mg/kg[44].

Dark chocolate, nuts, oatmeal, food material made by soya been and dried beans are the copious sources of nickel. 900µg per person per day nickel intake increases by using this foodstuff in daily intake[45] (Table-3).

Sediments: Man made sources such as fly ash and ash generated from the combustion of coal, metallurgical process such as mining, smelting, waste that is produced from commercial sector, atmospheric deposition, refuse from urban area and some of the natural sources increases the level of nickel in sediment and soil[26,48].

Table-3: Nickel concentration in food material.

Type of Food	Nickel Concentration	References
Beans, seeds, nuts and wheat bran	1 – 6 mg/kg	46,47
Cacao	8 – 12 mg/kg	46
Whole meal product	0.1 – 0.4 mg/kg	46

Various phases of nickel that is found in suspended solid and sediments are organic material, particle in crystalline form, co-precipitated and precipitated particle that are used for coating. The distribution of that particle is highly influenced by various chemical and physical parameters like ionic strength, concentration and type of inorganic and organic compounds act as adsorbent for nickel[49].

Exposure of the general population and effect

Food, drinking water, is the prime sources of Ni exposure whereas respiration is one of the minute sources of exposure of nickel for the population. The regular consumption of nickel by food varies by gender, by foodstuff, by age, by country. Estimated data from United State of America for daily intake is in range of 107–109 µg/day for females, 136–140 µg/day for males and 101–162 µg/day for adults[40]. Nickel and its alloy are commercially used over hundreds of years. Dust, fumes mist that contain nickel produced from nickel processing industry such as milling, mining smelting, refining and the industries that use nickel for different operation (e.g. manufacturing of stainless steel, welding, electroplating, cutting, grinding etc.) In nickel producing industry insoluble nickel is found in waste material and soluble nickel found in nickel using industries, workers of these industries are generally exposed to the nickel fumes or mist formed during manufacturing and processing.

Although the different type of health problem occur due to exposure of Nickel in high concentration such as lung nose, larynx and protest cancer. Nickel in gaseous form causes breath shortness, rapid respiration, Asthma, lung embolism, bronchitis even the fetal deformities. Skin allergic reactions are reported due to use of nickel plated jewelry. Cardiac disorder, headache, nausea, tightness of chest, dry cough, chest pain and extreme weakness are the most frequent health related problem observed.

Conclusion

In modern technology the use of Nickel is continuously increasing which leads to rise in its existence in atmosphere. The prime reason is the rapid increase in number of vehicles, technological development and release of various pollutants. The present paper suggests that it is essential to monitor the atmospheric air, soil, sediment and water parameter as well as the health effects at regular intervals.

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