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Accumulation of Nickel in the soil and analysis of physico-chemical parameters of soil collected from SIPCOT industrial complex, Cuddalore District, Tamil Nadu

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ABSTRACT

Heavy metals are bio-accumulated and bio-transferred both by natural and anthropogenic sources. The contamination by heavy metals in plants and water is one of the major issues to be faced throughout the world and requires attention because heavy metals above their normal ranges are extremely threatened to both flora and fauna. Therefore in this study, we have estimated the level of heavy metals in plants and soil. The toxic effects of these metals, even though they do not have any biological role, remain present in some or the other form harmful for the human body. They sometimes act as a pseudo element of the body while at certain times they may even interfere with metabolic processes. Few metals, such as aluminum, can be removed through elimination activities, while some metals get accumulated in the body and food chain, exhibiting a chronic nature. Various public health measures have been undertaken to control, prevent and treat metal toxicity at various levels, such as occupational exposure, environmental factors and accidents. Metal toxicity depends upon the absorbed dose, the route of exposure and duration of exposure, i.e. acute or chronic. This can lead to various disorders and can also result in excessive damage due to oxidative stress induced by free radical formation. This study gives details about some heavy metals and their toxicity mechanisms, along with their health effects. The present study was designed to determine the Nickel (Ni) level in the soil samples collected from the industrial area-SIPCOT Cuddalore. Soil samples were collected from the different region in the vicinity of the industrial area, processed and the Ni content was analyzed using atomic absorption spectroscopy.

Keywords: Nickel, heavy metal, toxicity, SIPCOT, Cuddalore.

1. INTRODUCTION

Heavy-metal pollution has been described in the Nile River and associated irrigation canal systems of the Nile Delta, particularly in suburban areas supporting light to moderate industry surrounding the city of Cairo. These aquatic environments support populations of a variety of molluscs, including the schistosome vectors, *Biomphalaria alex-andrina* Ehrenberg and *Bulinus truncates* (Audouin). Because schistosomiasis is present in many suburban and semi-rural locations, it is important to evaluate whether such pollution may be a significant factor directly affecting the life cycles of the vector populations, and directly and indirectly influencing disease transmission. Nickel (Ni), a naturally occurring metalloid, has ubiquitous distribution in the environment. Despite being the 20th most abundant element in the earth's crust, it ranks highest on the list of hazardous substances toxic to public health. Its existence as elemental, inorganic, and organic in large quantities all over the world makes it one of the most important metals, having adverse effects on the environment and human health. Existing in more than 200 different mineral forms, its availability as Ni accounts for approximately 60%, as sulphide or sulfosalt 20% and the remaining20% in the form of arsenites, arsenides, oxides, silicates, and elemental Nickel [1].

Volcanic activity, weathering of rocks, geothermal waters, and forest fires constitute some of the natural sources of Ni. In addition to pollution from natural sources, its applications in animal feed, glass and ceramics, herbicides, pesticides, wood preservatives, metallurgical operations and many others contribute to its anthropogenic pollution. Humans generally encounter Ni by natural as well as manmade sources through soil, water, air. It is readily found inappreciable concentrations in food items having origin from the sea. Its mere presence in rice, a staple food crop worldwide makes its entry into the human body easier than other sources [2]. Through rice, it poses a greater risk to infants who mainly depend on rice for their meals (baby foods). As per World Health Organization (WHO) guidelines, a safer limit of 200g/kg was established for white rice and a maximum of 400g/kg for brown rice. As a group I carcinogen, its contamination of drinking water is a serious environmental calamity worldwide [3]. Toxicity associated with water contaminated with Ni has been reported from different countries including Bangladesh, India, China, etc. It is estimated that around 200 million people are exposed predominantly through drinking water, having its concentration greater than the prescribed limit [4].

Ni is a relatively abundant metal discovered by German scientist, Friedrich Strohmeyer in 1817 as an impurity in zinc carbonate. Ni, is a lustrous, silver-white, malleable and ductile metal. The divalent Ni ion existing with other elements as oxide, carbonate, chloride, sulfide and sulfate (ATSDR, 1999). Specific ore and processing are not carried for Ni, since is associated in small amounts with the ores of nonferrous metals such as zinc, lead and copper and it is recovered as a byproduct in extraction, smelting and refining. Heavy metals are the class of elements that exhibit metallic properties with a density of at least five times higher than water. It mainly includes the transition metals, some metalloids, lanthanides and actinides. These elements constitute the major position in periodic table and varied in their physical and chemical properties and biological functions. The metals that form poisonous soluble compounds and have no biological role usually considered in this category but some are essential such as iron. Similarly, metals like beryllium possess toxicity with lesser density. Hence, the alternative term toxic metal can also be used for heavy metals. Heavy metals are placed under environmental pollutant category due to their toxic effects on plants, animals and humans by modulating the normal metabolic functions.

2. MATERIALS AND METHODS

2.1 Sample collection- SIPCOT – Cuddalore

The industrial estate SIPCOT (State Industrial promotion Corporation of Tami Nadu Limited) Cuddalore is situated in 8 km away from Cuddalore town, Tamil Nadu, India with the setup of a 200 hectare estate in the coastal region of Bay of Bengal (Fig.1). SIPCOT-Cuddalore discharges slow and continuous waste from the industries and heavily impact the environment and ecosystem. Rapid exposure like explosions may threaten and collapse the life style of the residential peoples. Soil, water and air are the basic component of the environment which directly impact on healthy life in humans. These three components are severely polluted by the SIPCOT-Cuddalore industries and the peoples living in this region facing numerous problems every day by industrial pollution. Unused raw materials, solid waste and the transport packing materials are dumped in the nearby land area. Raw and partially treated effluents directly drained in the water resources in the industrial estates, sea and Uppanar River. The pervasive bad odour in this living place evident the continuous release of gaseous materials in the environment. Soil samples were collected in different places in and around the SIPCOT area were processed and Ni was estimated using AAS.

2.2. Soil Sample Collection points:

1. Effluent discharge point, Chemplast-Sanmar in river Uppanar
2. Cultivable land - Sangolikuppam.
3. Public tank soil - Sangolikuppam.
4. Pioneer-Jellice Effluent pumping point-Sangolikuppam.
5. GSR-Asian paint backyard tank soil.
6. TANFAC road side canal soil.

Soil samples (6 samples from each point in different locations) were collected from the industrial area SIPCOT - Cuddalore in every month for the period of 6 months were processed and used for Ni analysis.

2.3 Soil sample processing and Nickel quantization

Ni present in soil samples collected from SIPCOT-Cuddalore was extracted by following the procedure recommended by the International Organization for Standardization (1995). 3g of soil sample was mixed with 28 mL of acid mixture (3:1 ratio of 37% HCl and 65% HNO_3) and kept in room temperature (RT) for 16 hours then digested at 130ºC for 2 hours. Refluxed samples were filtered through Whatmann 40 filter paper, made up to 100 mL using 0.5 M, HNO_3 and the processed samples were used for Ni analysis.

Ni present in the samples was analyzed by Flame Atomic Absorption Spectrophotometer. A Perkin-Elmer 5000 atomic absorption spectrometer furnished with a Ni hollow- cathode lamp (lamp current 4 mA) was used to determine the Ni concentration. The instrument was set at 228.8 nm with a slit width of 0.5 nm. The acetylene flow rate was 2.0 L/min and an airflow rate of 17.0 L/min was employed to ensure an oxidizing flame.

3. RESULTS

Nickel levels in soil samples collected from different areas in and around SIPCOT - Cuddalore were shown in table 1. This study shows the elevated levels of Ni in the industrial area and distribution of Ni in the soil samples were near and above the permissible threshold level of Ni in soil. Samples collected from Effluent discharge point Chemplast-Sanmar in river Uppanar and GSR-Asian paint backyard soil shows very of Ni in soil samples. Table 2, shows the Ni levels in water samples collected from SIPCOT area. Water collected from the effluent discharge point Chemplast-Sanmar in river Uppanar and GSR-Asian paint backyard pond shows very high values of Ni. Our study shows high contamination of Ni in water and levels are significantly closer to the permissible level of Ni in public tank water in Sangolikuppam and around three times higher than the permissible threshold water level in the remaining areas.

4. DISCUSSION

The anthropogenic introduction of metals into the environment is an ongoing concern for both conservation biology and human health. Our results clearly show complex detrimental effects of Ni upon nematodes at multiple stages of their life cycle, and at environmentally relevant concentrations in naturally occurring sediments and water. Additionally, our comparative approach using two ecologically and molecularly diverged nematode species, clearly demonstrates the advantage of applying a broader spectrum of nematode biodiversity to environmental toxicology assays [5]. Our study reveals several important considerations regarding aquatic Ni toxicity. First, even low concentrations of Ni in realistic environments can have some health and developmental impacts. Second, given the tractable nature nematodes as environmental and health model systems, it would seem wise to expand analyses to additional members of the phylum, adjusting test formats and parameters of the established sediment assays accordingly, to provide test results from a broader range of sediments and soils. Lastly, adjusting standard nematode tests to allow for multiple generations can provide a broader understanding of environmental toxicity effects.

SIPCOT - Cuddalore is creating the negative growth in humans in the living place near the industrial complex (approximately 45 surroundings) and to the aquatic organisms through its environmental impact. National Environmental Engineering Research Institute study report stated that ongoing industrial pollution has worsened the environmental, public health and economic crisis of local farmers, fishers and other residents in the industrial area SIPCOT - Cuddalore [6]. Atmosphere quality in this area is strenuously affected by the industrial smoke and fog. Around 25 toxic chemicals were found in the air including 8 carcinogens in SIPCOT air. Some of these chemicals were 20,000 times above the safe levels prescribed by the US Environment Protection Agency [7]. State Human Rights Commission headed by Retd. Justice Nainar Sundram investigated reported environment-related human rights violations in SIPCOT and the report stated that the SIPCOT Cuddalore is over-polluted and that people's living conditions at SIPCOT Cuddalore to be pitiable, health and the local environment cannot withstand the burden of any new chemical industries [8]. In this critical situation, least three new industrial units such as PVC plant Textile Park and Oil Refinery company threaten the SIPCOT area which were already refused by the fisher men and formers and stiff community opposition by other state. These units may further worsen the environment by releasing pollutants.

Environment and the well-being of communities in the chemical industrial estate was analyzed by a panel of neutral experts [9] and their assessment stated that these industries has damaged vast tracts of land, polluted the groundwater and the local river Uppanar, destroyed livelihoods, hurt many and killed others. During the assessment they have faced the severe itching in the throat, mild breathlessness with wheeze and watering of the eyes. In our study period, we have also faced similar problems. Peoples living in that area have complained the problem include cough, dryness and irritation of the nose and throat, headache, dizziness, weakness, fever, chills, and chest pain are persistently observed in common and these are similar to the symptoms of Ni toxicity. Our results correlates these symptoms with the elevated Ni in the collected samples, that the Ni may also take part in the ill health of the living population ni the industrial area. Disposal of solid and raw waste materials drastically affects the quality of soil. Apart from the pollution treatment, the living peoples of SIPCOT area were suffering from the water problem due to the salinity intrusion in this region groundwater in the area has been affected by contamination and salinity intrusion due to industrial activity, since the aquifer of the industries are close to the coast. Salinity intrusion turned the fertile agricultural lands to lying barren. Normal water sources are contaminated and these were not able to use by the peoples. Industrial development disproportionate impact on agricultural laborers and small and marginal farmers In this region, Nearby village said that, they used to get three crops a year until 1995, but have to struggle to raise one crop nowadays and paddy yields have dropped from 3000 kg per acre to 1500 kg bags and the quality of the product was below the normal.

In our study, we found that the Ni levels in these area soil samples were contaminated with Ni and the levels are nearer or above the permissible threshold limits. Nickel and its compounds are widely used as the fantastic colorant in paint companies, as a stabilizer in the PVC and plastic productions, major part in the battery production and handlings etc., in different industrial units of SIPCOT-Cuddalore [10] Nickel present in the industrial waste were distributed and reached to one state to another (soil, water and air) by the natural mode like rain, sedimentation, burnings etc. Previous studies conducted in SIPCOT area concludes that the heavy metals like Ni is polluted in ecosystem and affects the growth, development and reproduction in aquatic organisms [11].

Fisher folk in the SIPCOT area reported that during the past two decades, number of species had disappeared and many fish were caught with visible deformities such as tumors or skin diseases. Studies reported that heavy metals like Ni decreased the reduced the reproduction in aquatic life and disturb the delicate balance of the aquatic systems [12]. Nickel decreases the shoot and root growth and perturbs the stomata regulation, seedling, vegetative and water content, maturity status of leaves and nitrogen fixing stages in plants [13]. Toxic metal Ni polluted by the industries entered in to the environment are absorbed, accumulated and concentrated in plants and aquatic organisms and reaches to the food chain and critically affects humans.

5. CONCLUSION

The study concluded that most soils have an extremely high affinity for Ni and that once sorbed, Ni is difficult to desorb, which may indicate covalent bond formation. Observed Ni ferrite formation following adsorption found that when Ni levels were >10 ppm, adsorption decreased. High concentrations of chloride decreased adsorption, but not as much as calcium ions, which indicates that calcium competition for sorbing sites is more important than chloride complexation for reducing adsorption. The presence of complexing agents, such as EDTA, dramatically lowers Ni adsorption, which has important implications at waste disposal sites if liquid Ni waste containing chelating agents is released to soil.

Chelating agents that are added to soil containing adsorbed Ni appear to have a lesser effect. Elevated level of Ni was fond in the soil samples collected from the different region of SIPCOT Cuddalore. Environmental accumulation of the toxic heavy metal Ni in the SIPCOT - Cuddalore industrial complex has exacerbated the living situation for humans and the aquatic life in the ecosystem of the surrounding area. If the situation continues by the existing companies and the new plant entry, the released chemical toxicants and heavy metal Ni may worsen the living condition in the surroundings.

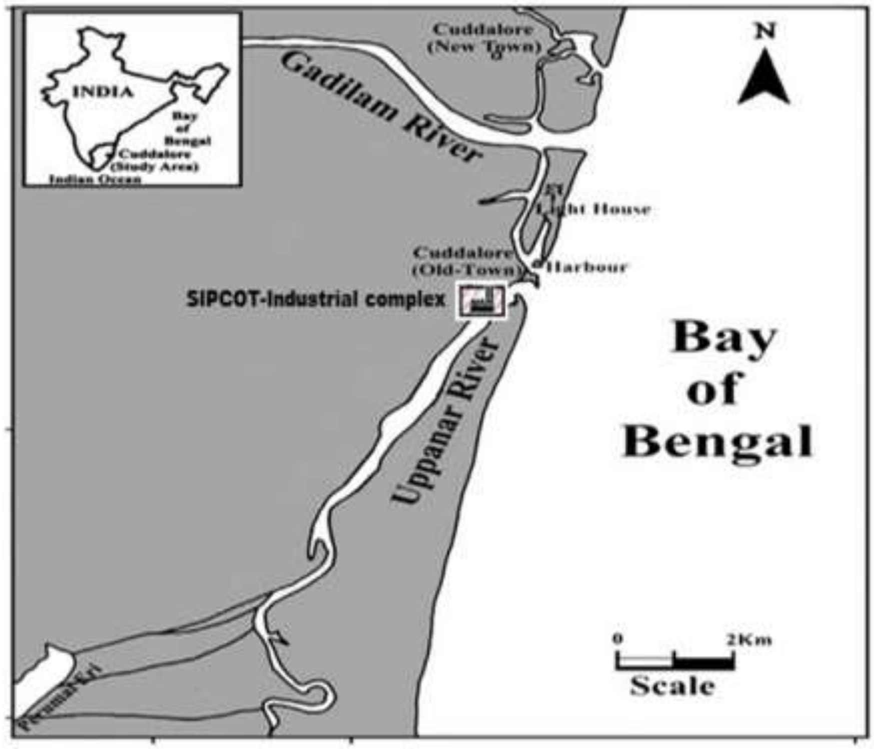

Figure 1. Location of SIPCOT-Industrial complex - Cuddalore, India

Table 1: Nickel levels in soil samples collected from different points in SIPCOT - Cuddalore

Area of Sample Collection	Nickel level (ppm)
Effluent discharge point, Chemplast-Sanmar in river Uppanar	3.29 ± 0.29
Cultivable land soil- Sangolikuppam	2.12 ± 0.12
Public tank Soil – Sangolikuppam	2.37 ± 0.13
Pioneer-Jellice Effluent pumping point-Sangolikuppam	2.36 ± 0.11
GSR-Asian paint backyard tank soil	2.30 ± 0.12
TANFAC road side canal soil	3.21 ± 0.14

Values are given as mean ± SD.
The permissible limit of Nickel in Soil is 1.4 ppm

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Conflicts of Interest

There are no conflicts of interest.

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