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Assessment of chromium and nickel in agricultural soil: implications for sustainable agriculture

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Assessment of chromium and nickel in agricultural soil: implications for sustainable agriculture

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Abstract: Fertilizers in soil management can alter soil physical, chemical and biological compositions, and introduce trace elements such as chromium (Cr) and nickel (Ni) into the agricultural soils. The carcinogenic tendencies of these trace elements at elevated concentrations in plants, animals and humans make it a serious concern. Soil samples from a farm in Ota, Southwest Nigeria wereanalysed using inductively coupled plasma mass spectrometry (ICP-MS). The results indicate that the farm's nickel (Ni) is within the permissible limits, while chromium (Cr) concentrationsexceeded the WHO/FAO allowable limits. Nickel has a mean value of 47.12 mg/kg in the soil, while chromium has a mean value of 152.20 mg/kg. These toxic elements' contamination assessment result has shown the descending order of Ni>Cd in the studied farm. The toxicity of nickel and chromiumin soils causes chlorosis, stunted rootsand inhibits plants growth.

Keywords: Chromium, Nickel, Soil, Sustainable Agriculture, Nigeria

1. Introduction

The global craving to increase crop production and achieve food security due to population growth has led to the massive use of pesticides and chemical fertilizers in agricultural soils (Sudhakaran et al., 2018; Kayode et al., 2021).Excessive usage of these chemical fertilizers contaminates soil health and groundwater resource. However, trace elements or heavy metals have been mainly attributed to be the most significant environmental contaminant (Benson et al., 2014; Emenike et al., 2020).In agroecosystem, certain trace elements such as manganese (Mn), iron (Fe), copper (Cu), and molybdenum (Mo) are needed for plant growth but at low concentrations (He, Tang and Stofella, 2005). Other trace elements that are considered as contaminants having toxic effects on living organisms include arsenic (As), nickel (Ni), cadmium (Cd), chromium (Cr), mercury (Hg) and lead (Pb)(He et al., 2005; Mansaurri and Madani, 2016). The selected trace elements followed the sequence of a level of toxicity Co<Al<Cr<Pb<Ni<Zn<Cu<Cd. Soil parent materials (geogenic) and input from human activities are the primary sources of these trace elements into the agricultural soils. These trace elements are released into the environment through natural sources and anthropogenic activities such as

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incineration of sludge and waste, industrial waste, combustion of coal, fuel oil and diesel oil, forest fire, application of fertilizers, and other miscellaneous sources (Yahaya, 2011, Kabata-Pedias, 1992, Cempel and Nikel, 2006).

Chromium (Cr) is a significant soil contaminant, toxic and non-essential to plants even at low concentrations (Asati et al., 2016, Minari et al., 2020). Cr is a highly toxic metal and is classified as one of the priority contaminants by the United States Environmental Protection Agency (USEPA). Exposure to elevated chromium concentrationscan cause hypertension, lung cancer, kidney disorder, and renal dysfunction (Jean et al., 2018, Minari et al., 2020). Chromium can enter the food chain, causing an excess production of red blood cells and arteries problems in humans (Khan et al., 2013).

Nickel (Ni) at low concentration is essential for plant development (Yusuf et al., 2011, Correia et al.,2018, Minari et al., 2020); however, at elevated concentrations, Ni causes chlorosis (reduced production of chlorophyll) and inhibits root growth in plants (Dohnalova et al., 2017, Minari et al., 2020). Ni can cause skin rash, dizziness, heart issues, respiratory disorders, headaches, and fatigue (Khan et al., 2013). Yahaya 2011 and Kabata-Pedias, 1992 have reported that nickel concentration is higher in basic igneous rocks than in sedimentary rocks such as limestones, clay, shales and sandstones. The geochemical association of nickel (Ni) with cobalt (Co) and iron (Fe) is responsible for the practical content of nickel found in soils with high content of these trace elements (Co and Fe) (Harasim and Filipek, 2014). Specific authors have indicated that Ni can serve as a micronutrient and is responsible for certain biological functions in the soil (Hänsch and Mendel, 2009). However, Ni may cause toxic effects at an elevated rate, including cancer and contact allergy promotion (Dohnalova et al., 2017).The contamination level of nickel in soils worldwide has been reported (Chen et al., 1999). The application of phosphatic fertilizers to soils is the primary source of chromium and nickel pollution (Kebata-Pendias and Mukherjee, 2007; Chauhan et al., 2008). This study aims to quantify the amount of these two trace elements in the agricultural soil in Ota, Ogun State,Southwest Nigeria and highlight the effects these contaminants (Chromium and Nickel) have on the crops grown in the farm area.The study area is a farm within Covenant University, Ota (Figure 1).

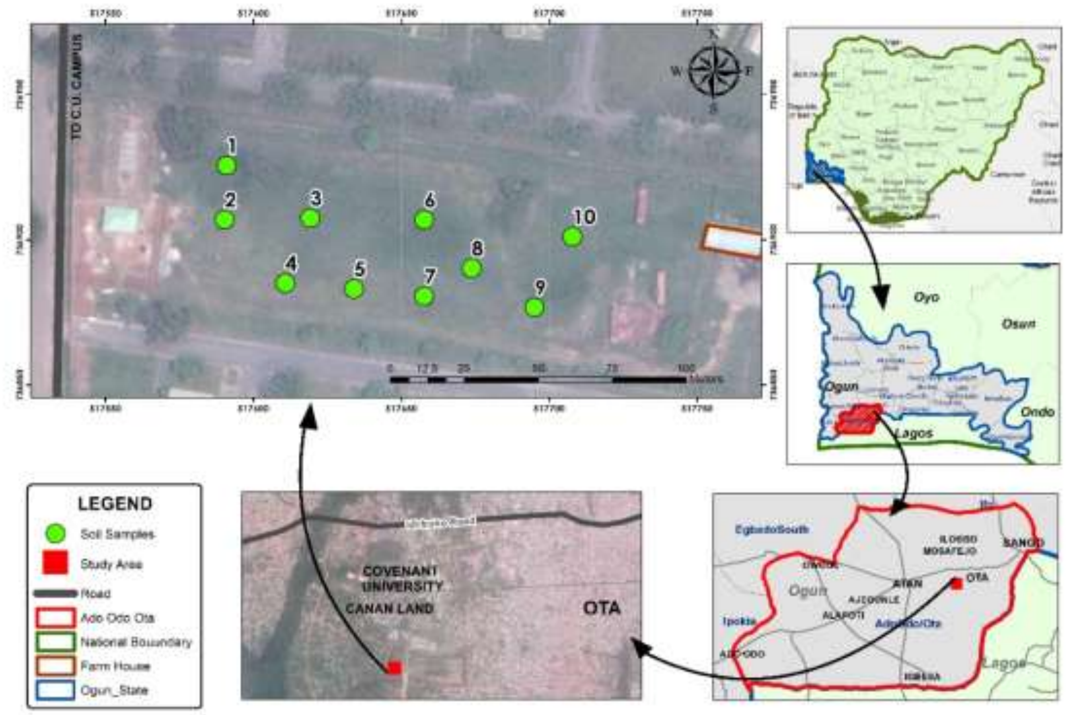

Figure 1: A topographic map of the study area showing sampling points

2. Material and Methods

Ten (10) soil samples were collected in a clean labelled nylons using a hand trowel at depth of 50 cm at the farm site. The soil samples were subjected to drying in the oven at 40˚C, hammered to reduce agglomeration and homogenized in porcelain mortal after which samples were sieved in a 2 mm sieve. The multi-acid chemical analysis of inductively coupled plasma mass spectrometry (ICPMS) at the Bureau Veritas Laboratory Vancouver, Canada, was used to digest the samples. A 0.25 g split of each soil sample was heated in triple acid digestion to fuming and then dried. HCL solution was then used to dissolve the residue after drying. Organic matter was removed using strong oxidizing agents. The measurement detection limits (MDL) for chromium (Cr) and nickel (Ni) are1 mg/kg and 0.1 mg/kg, respectively. The analysis followed standard procedures using STD OREAS25A and STD OREAS45E as standard reference materials (Cecconi et al., 2019; Wilschefski and Baxter, 2019).OF represents Ota farm.

3. Results and Discussion

Chromium concentrations in this farm ranged from 22.0 mg/kg to 444.0 mg/kg (Table 1) with mean value of 156.20 mg/kg. All samples except samples 7 and 8 exceeded the permissible limit of 20 mg/kg chromium in soil (FAO/WHO, 2001). Table 2, on the other hand, presents the nickel concentrations at the farm, which ranged from 18 mg/kg to 240 mg/kg, with a mean value of 47.12 mg/kg. Table 3 presents the descriptive statistics of chromium (Cr) and nickel (Ni)

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constituents in the soil samples from the study area. The mean value of chromium concentrations in the farm is higher than the maximum permissible limits in agricultural soils. The mean concentrations of nickel (Ni) in the farm are lower than the 68 mg/kg permissible limit in soil set by WHO/FAO (2001) and the threshold of 50 mg/kg in agricultural soils, according to Toth et al. (2016).

Figure 2 shows the line graph for chromium concentrations in the farm. The line graph reveals that there is an outlier in the chromium concentrations on the farm. Also, the line graph of nickel (Ni) concentrations in the farm showed outliers (Figure 3). The outliers in both Cr and Ni concentrations are far higher than the median values. The overall results indicate that chromium concentration is the primary contaminant in the agricultural soil of the farm under investigation.

The accumulation of chromium in the farm may be due to the application of phosphate fertilizers at the previous planting season to boost the crop yield potency of the soil, as previously reported in India (Srivastava et al., 2021). Phosphate fertilizers, which are constituents of rock phosphates from igneous and sedimentary rocks, contain high chromium levels (Samreen and Kausar, 2019). Mangi L. Jat. (2014); Nadarajan and Sukumann. (2021) have reported that chromium (Cr) is mainly enhanced in Diammonium Phosphate (DAP), the farmer's world's most commonly used phosphorus fertilizer. Therefore, the long-term exposure of these chemical fertilizers to the soil may result in more accumulation of chromium and nickel beyond the permissible limits, thereby leading to the total degradation of the agricultural soil.

Table 1: Chromium (Cr) concentrations in the farm site

Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	1	1	1	1	1	1	1	1	1	1
Sample No	1	2	3	4	5	6	7	8	9	10
OF	136.0	161.0	187.0	92.0	148.0	138.0	22.0	41.0	444.0	193.0

Table 2: Nickel (Ni) concentrations in the farm site

Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.1	0.1	0.1	0.1	0.1	0,1	0.1	0.1	0.1	0.1
Sample No	1	2	3	4	5	6	7	8	9	10
OF	18.8	18.0	21.7	22.8	20.4	26.3	10.9	18.3	240.0	74.0

Table 3: Descriptive statistics

Unit	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
OF Cr	10	422.0	22.0	444.0	152.20	116.124	13484.844
OF Ni	10	229.1	10.9	240.0	47.12	10.9	4900.308

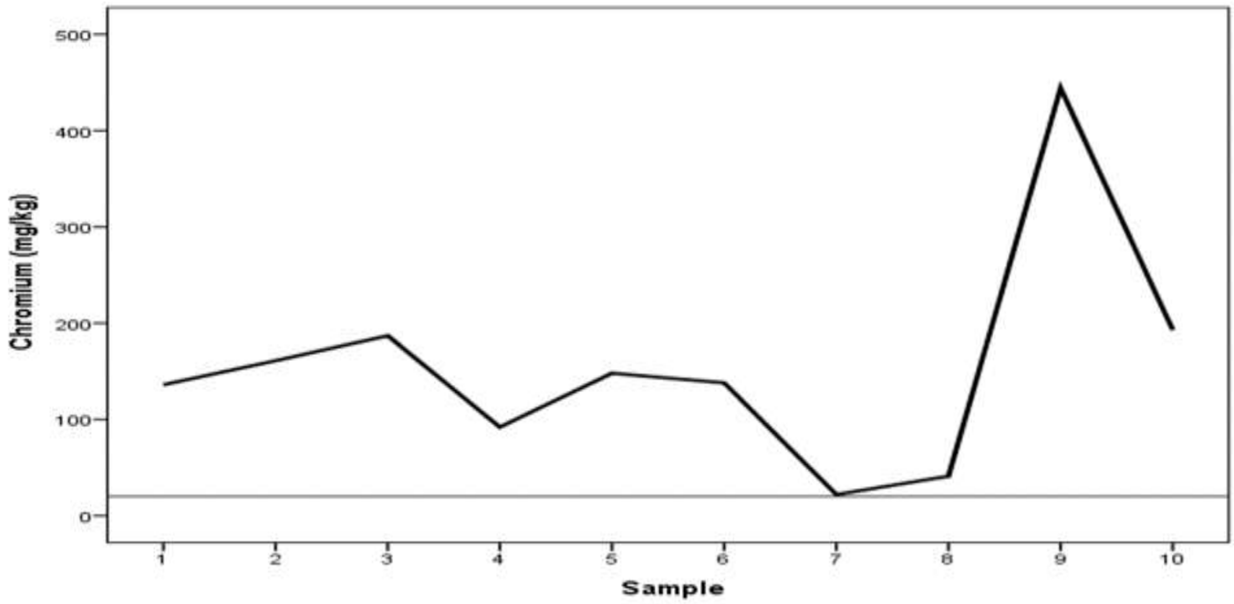

Figure 2: Line graph showing a baseline of 20 mg/kg for chromium concentrations

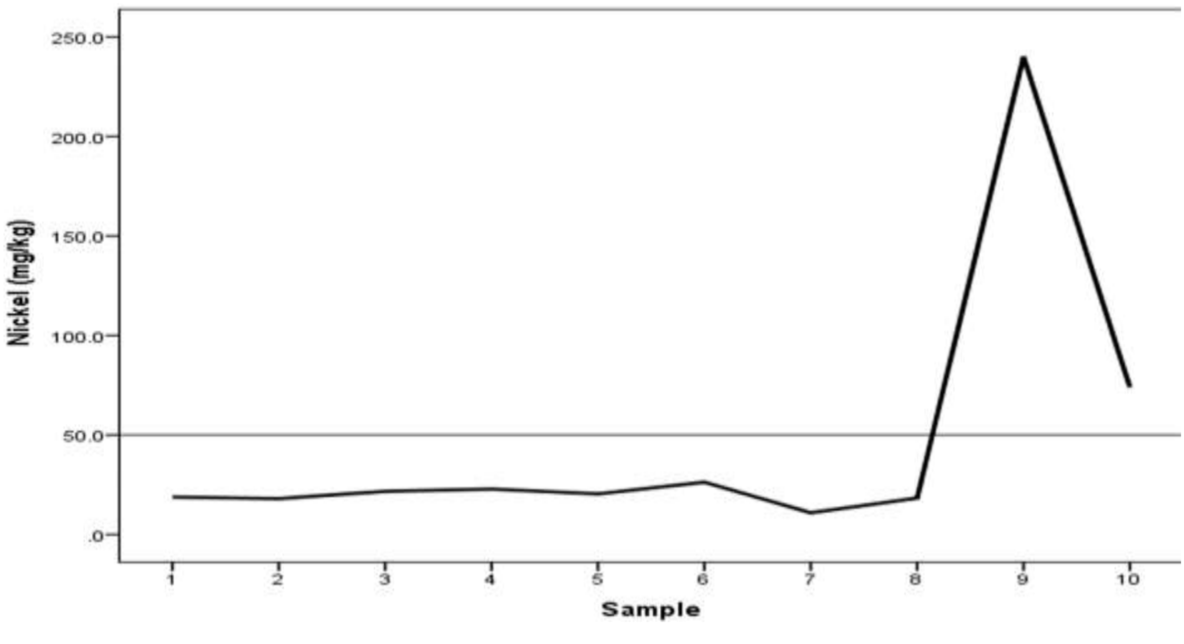

Figure 3: Line graph showing a baseline of 50 mg/kg for nickel concentrations

4. Conclusion and Recommendation

The soil samples of the farm in the study area have been evaluated for chromium (Cr) and nickel (Ni) concentrations. The nickel concentrations in the farm are within the FAO/WHO permissible limits, while chromium (Cr) concentrations in the farm are adjudged the primary contaminant. Chemical/phosphate fertilizers and soil amendments used in agriculturearethe primary source of chromium and nickel contamination in the farmland. Chemical fertilizers should be highly discouraged on the farm because of the carcinogenic tendencies of chromium and nickel concentrations. The adverse effects of chromium (Cr) toxicity in plants include a decrease of yield, impairment of photosynthesis, nutrient and oxidative imbalances, mutagenesis, and a reduction in seed germination. Nickel is also a pollutant with biological functions but toxic at high concentrations in soils. The toxic effects of Ni in plants include the inhibition of chlorophyll and root growth.

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