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Oncological Effects of Accumulation of Heavy Metals in Jos East, Plateau State, Nigeria.

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Abstract: Carcinogenic substances are those that induce tumors (benign or malignant), increase their incidence or malignancy or shorten the time of tumor occurrence when they get into the body through inhalation, injection, dermal application or ingestion. This work unveils the accumulates of heavy metals in Jos East using XRF. The results of this study showed that the Geo-Accumulation Index (I_{geo}) of water for different heavy metals decreased in the order of Cd (0.15) > Cr and As (0.03) > Pb (-0.13) > Ni (-0.6). Soil for different heavy metals decreased in the order of As and Cd (0.4) > Ni, Cr and Pb (0.2). The edible plants for different heavy metals decreased in the order of Cd (0.512) > As (0.25) > Pb (0.23) > Ni (0.01) > Ni (-0.06). 21% of these points are uncontaminated, except few points which are found within the uncontaminated to moderately contaminated level. It can be concluded that the area falls within uncontaminated-moderately contamination which calls for regulation. Hence this study can be used as a reference data for regulatory bodies like NNRA and the rest.

Keywords: Heavy Metals; Soil; Plant; Water; Contamination Factor.

1 Introduction

Carcinogenic substances are those that induce tumors (benign or malignant), increase their incidence or malignancy or shorten the time of tumor occurrence when they get into the body through inhalation, injection, dermal application or ingestion [1,2]. Carcinogens are classified as either genotoxic or nongenotoxic depending on their modes of action [3]. Genotoxic carcinogens are those which initiate carcinogenesis by direct interaction with DNA, resulting in DNA damage or chromosomal aberrations that can be detected by genotoxicity tests [4,5]. On the other hand, nongenotoxic carcinogens are agents that indirectly interact with the DNA, causing indirect modification to DNA structure, amount, or function that may result in altered gene expression or signal transduction [6,7]. Substances that induce tumors in animals are also considered human carcinogens until proven otherwise [8]. All known human carcinogens that have been evaluated adequately in animal bioassays have been found to be also carcinogenic in animal bioassay studies. In fact, it has been reported that of the nearly 100 known genotoxic and non-genotoxic human carcinogens, one-third were shown first to be carcinogenic in animals [9]. Other studies have demonstrated a strong correlation between carcinogenic potencies estimated from epidemiological data and those from animal carcinogenesis bioassays [10,11]. These observations have been used as guidelines to avoid human exposure to such chemicals found to be carcinogenic in laboratory animals [12]. According to evaluations done by the International Agency for Research on Cancer (IARC), carcinogenicity data reviewed of various trace elements are classified as reported by [13] as: (i) sufficient, when a casual association is established between exposure to an agent and human cancer; (ii) limited, when an association has been observed but chance, bias, and confounding cannot be ruled out and (iii) inadequate, when the data are of insufficient quality, consistency or statistical power to allow a conclusion [14]. The degree of solubility of chemical exposure, which influences biological effects as well as the long- or short-term experimental studies must be considered while deciding carcinogenicity classifications [15]. Certain trace elements like zinc and selenium have been found to have anti-carcinogenic effect where as others tend to be carcinogenic in specific organs while showing no such effect in certain organs [16,17]. No formal evaluation of anti-carcinogenic effects of these trace elements has been

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made by IARC. The carcinogenic capability of trace elements depends mainly on factors such as oxidation states and chemical structures. The oxidative concept in element carcinogenesis signifies that complexes formed by these elements, in vivo, in the vicinity of DNA, catalyze redox reactions, which in turn oxidize DNA [18]. The most significant effect of Reactive Oxygen Species (ROS) in the carcinogenesis progression is DNA damage, which results in DNA lesions like strand breaks and the sister-chromatid exchange [19]. It has been estimated that approximately 29104 DNA damaging events occur in every cell per day [20]; a major portion of these occur via ROS. Similarly, ROS damage results in lipid peroxidation and depletion of protein sulfhydryls. Even though the increase in oxidative DNA lesions has been frequently attributed to metal exposures, it is important to note that the molecular mechanism leading to tumor formation after such exposures is still not well understood [21]. The trace elements carcinogenesis is mediated either by the increased generation of ROS on the basis of ESR spin trapping studies or by interference with the repair process of DNA [22]. Some oxygen species are worst carcinogenic molecules. There is a very fine balance between enzymatic [such as superoxide dismutase (SOD), glutathione peroxidase and catalase] and non-enzymatic (such as ascorbic acid, a-tocopherol, b-carotene and isoflavons) antioxidants and free radicals in each cell. When ROS production is higher than the cell reduction capabilities, they can induce lipid peroxidation, depletion of the sulfhydryl groups, change signal transduction pathways, calcium homeostasis and DNA damage [23]. This may result in occurrence of aging effect and cancer infection.

Geo-accumulation Index (I_{geo})

This method assesses the trace elements accumulation in terms of seven (0 to 6) enrichment classes, ranging from background concentration to very heavily polluted according to [24] as follows:

$$I_{geo} = \log_2\left[\frac{C_m \text{Sample}}{1.5x(C_m \text{ Background})}\right] = \frac{\log_{10}\left(\frac{CF}{1.5}\right)}{\log_{10} 2} = \frac{\log_{10}\left(\frac{CF}{1.5}\right)}{0.3} \quad 1$$

The factor 1.5 is introduced in the equation to minimize the effects of possible variations in the background values. The recommended World Average Values and Ranges of Geo-Accumulation Index are presented in Table 1.

Table 1. World Average Values and Ranges of Geo-Accumulation Index

I_{geo} Values	I_{geo} Class	Description of Soil Quality
>5	6	Extremely contaminated
4-5	5	Strongly to extremely contaminated
3-4	4	Strongly contaminated
2-3	3	Moderately to strongly contaminated
1-2	2	Moderately contaminated
0-1	1	Uncontaminated to moderately contaminated
0	0	Uncontaminated

The purpose of this work is to unveil the extent to which heavy metals (Ni, Cr, As, Cd and Pb) accumulates in soil, water and edible plants in Jos East and assess their carcinogenic role to biological tissue that might result in cancer. This work will compare its results with the world standard limits and unveil whether the inhabitants of the study are liable to be affected by cancer in the long round or not.

2 Materials and Method

2.1 Materials

The materials that were used in carrying out this research are;

i. Hand trowel
ii. Plastic containers
iii. Hand gloves
iv. polyethylene sampling bottles
v. Geo-positioning System meter (GPS meter)
vi. Masking tape
vii. Permanent marker and Joter
viii. X-Ray Fluorescence Spectrometry System (XRF)

2.2 Method

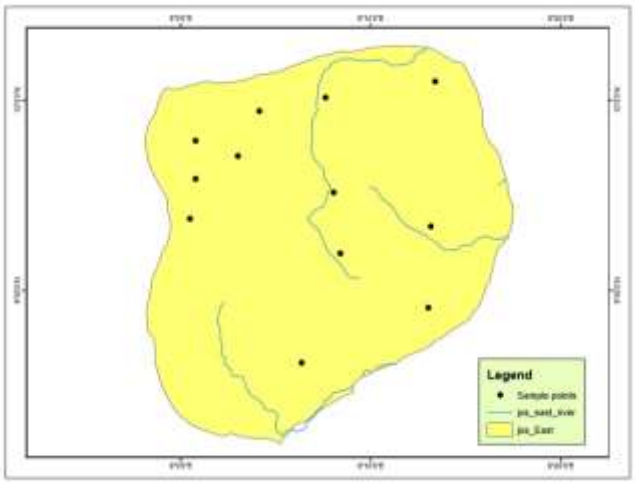
2.2.1 Study Area

Plateau is the twelfth-largest state in Nigeria. Approximately in the centre of the country, it is geographically unique in Nigeria due to its boundaries of elevated hills surrounding the Jos Plateau which is its capital, and the entire plateau itself [25].

Plateau State is celebrated as "The Home of Peace and Tourism". With natural formations of rocks, hills and waterfalls, it derives its name from the Jos Plateau and has a population of around 3.5 million people. Plateau State is located at North Central Zone out of the six geopolitical zones of Nigeria. With an area of 26,899 square kilometers, the State has an estimated population of about three million people. It is located between latitude 08°24'N and longitude 008°32' and 010°38' east. The state is named after the picturesque Jos Plateau, a mountainous area in the north of the state with captivating rock formations. Bare rocks are scattered across the grasslands, which cover the plateau. The altitude ranges from around 1,200 metres (3,900 ft) to a peak of 1,829 metres (6,001 ft) above sea level in the Shere Hills range near Jos. Years of tin and columbite mining have also left the area strewn with deep gorges and lakes [26,27,28,29,30].

The map of the study area showing sample points is

presented in Fig. 1.



2.2.2 Population Sample

The population of the study include all the notable towns where mining activities takes place within Jos East, Plateau State include 12 villages.

2.2.3 Sample Collection

Soil, water and vegetable samples were pair collected. A simple systematic random sampling technique was used to select twelve (12) soil sample, twelve (12) edible plant sample, and twelve (12) water samples from Jos East Local Government of Plateau State. Sixty (36) samples in all were analyzed in this study. Vegetables' rooted soil samples were taken at 0-20 cm depth. A composite sample composed of three (3) subsamples at each sampling site for water, vegetables and soils.

2.2.4 Soil Sample Collection and Preparation

Twelve sample of soil from the Jos East Local Government of Plateau State was collected. The sample was collected by coring tool to a depth of 5 cm or to the depth of the plough line. The collected samples each of approximately 4 kg in wet weight was immediately transferred into a high-density polyethylene zip lock plastic bag to prevent cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability and its position coordinates were recorded for reference purposes using GPS meter.

All soil samples were naturally air-dried until constant weight is reached. The dried soil samples were homogenized with pestle in a mortar, and then passed through standard sieves 0.9 mm, 0.3 mm, and 0.15 mm for analysis of pH, organic matter (OM) and heavy metal contents, respectively. Soil pH were measured using a pH electrode and the ratio of solid: water was 1:2.5. OM contents of soil samples were determined using the loss on ignition method. The soil sample was taken for XRF analysis.

2.2.5 Edible Plant Sample Collection and Preparation

Twelve edible plant samples were collected from the Jos East Local Government of Plateau State. The collected samples were immediately transferred into a high-density polyethylene zip lock plastic bag to prevent cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability.

Only the edible part of each plant sample was used for analysis. The plant samples were washed with ultrapure water three times. After the water had evaporated, the plant samples were weighed, oven-dried at 65 °C for 48 h, weighed again and then crushed into powder. The heavy metal concentrations in edible portions of plant was determined on a wet weight basis. The edible plant sample was taken for XRF analysis.

2.2.6 Water Sample Collection and Preparation

Twelve water samples were collected from streams from the Jos East Local Government of Plateau State. The collected samples were immediately transferred into plastic containers and was well covered to avoid cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability.

Water samples for heavy metals determination was acidified with two (2) drops of concentrated HNO_3; Samples for Dissolved oxygen determination was fixed with 2ml each of Manganese (II) sulphate solution (winkler A) and Alkali-iodide Azide reagent (Winkler B) per sample. These operations were carried out on the field. All samples were then placed in an ice-chest and taken to the laboratory on the same day. The digested water sample was taken XRF analysis.

2.2.7 Method of Results Analysis

Heavy Metals analysis was done using XRF analysis available at Centre for Solid Minerals Research and Development (CSMRD), Kaduna State Polytechnic, Kaduna State, Nigeria. The results obtained was used to assess the extent of the accumulation of these heavy metals in water, soil and plants through an index called the geo-accumulation index as reported by [24] in Equation (1).

3 Results and Discussion

3.1 Results

Table 2: Geo-Accumulation Index of Heavy Metals in Water from Jos East

S/P	Ni	Cr	As	Cd	Pb	Total
P01	-0.4	0.1	-0.65	0.17	0.046	**-0.66**
P02	-1.0	-0.4	-0.35	0.17	-0.176	**-1.66**
P03	-0.3	-0.1	0.35	0.47	-0.051	**0.415**
P04	-1.3	0.1	1.05	-0.13	-0.653	**-0.87**
P05	-0.7	-0.4	0.12	0.35	0.648	**0.114**
P06	-0.4	0.2	-0.18	0.17	-0.653	**-0.82**
P07	0.0	-0.1	-0.18	0.17	-0.051	**-0.11**
P08	-0.6	-0.4	0.35	-0.13	0.046	**-0.65**
P09	-1.3	0.5	0.05	0.35	-0.352	**-0.72**
P10	-0.5	0.1	0.35	0.17	-0.051	**0.114**
P11	-1.0	0.2	-0.18	-0.13	-0.352	**-1.36**
P12	-0.6	0.1	-0.35	0.17	0.046	**-0.57**
Mean	**-0.6**	**0.03**	**0.03**	**0.15**	**-0.130**	**-0.56**

P = Points; Ni = Nickel; Cr = Chromium; As = Arsenic; Cd = Cadmium; Pb = Lead.

It was observed from Table 2 that the accumulation of heavy metals in water for Ni, Cr, As, Cd and Pb has the total of -0.6, 0.03, 0.03, 0.15 and -0.13 respectively.
It was observed from Table 2 that the total Geo Accumulation Index from Water Samples of Jos East Local Government Area is in descending order trend with P03 (0.415) > P05 and P10 (0.114) > P07 (-0.11) > P12 (-0.57) > P08 (-0.65) > P01 (-0.66) > P09 (-0.72) > P06 (-0.82) > P04 (-0.87) > P11 (-1.36) > P02 (-1.66).

Table 3: Geo-Accumulation Index of Heavy Metals in Soil from Jos East

S/P	Ni	Cr	As	Cd	Pb	Total
P01	0.2	0.2	0.4	0.5	0.2	**1.6**
P02	0.3	0.2	0.4	0.4	0.2	**1.4**
P03	0.1	0.3	0.4	0.4	0.3	**1.4**
P04	0.4	0.1	0.4	0.6	0.2	**1.6**
P05	0.3	0.1	0.4	0.5	0.2	**1.6**
P06	0.4	0.3	0.4	0.4	0.2	**1.6**
P07	0.3	0.1	0.4	0.4	0.2	**1.4**
P08	0.2	0.1	0.3	0.4	0.2	**1.2**
P09	0.1	0.2	0.4	0.5	0.2	**1.4**
P10	0.3	0.2	0.5	0.5	0.1	**1.6**
P11	0.5	0.2	0.7	0.4	0.2	**2.0**
P12	-0.02	0.1	0.5	0.2	0.2	**1.0**
Mean	**0.2**	**0.2**	**0.4**	**0.4**	**0.2**	**1.5**

P = Points; Ni = Nickel; Cr = Chromium; As = Arsenic; Cd = Cadmium; Pb = Lead.

It was observed from Table 3 that the accumulation of heavy metals in water for Ni, Cr, As, Cd and Pb has the total of 0.2, 0.2, 0.4, 0.4 and 0.2 respectively.

It was observed from Table 3 that the total Geo Accumulation Index from Soil Samples of Jos East Local Government Area is in descending order trend with P12 (1.0) > P08 (1.2) > P02, P03, P07 and P09 (1.4) > P01, P04, P05, P06 and P10 (1.6) > P11 (2.0).

Table 2: Geo-Accumulation Index of Heavy Metals in Edible Plants from Jos East

S/T	Ni	Cr	As	Cd	Pb	Total
Zogale	0.21	-0.02	-0.26	0.56	0.20	**0.68**
Kuka	-0.03	-0.22	-0.10	0.48	0.18	**0.31**
Rama	0.03	-0.11	-0.33	0.54	0.21	**0.34**
Yateya	0.13	0.23	-0.61	0.79	0.39	**0.93**
Alayyahu	-0.03	0.12	-0.27	0.58	0.44	**0.84**
Shuwaka	-0.03	-0.23	-0.57	0.43	0.14	**-0.27**
Yakuwa	-0.08	0.06	-0.29	0.54	0.33	**0.56**
Karkashi	-0.02	0.18	-0.15	0.44	0.19	**0.65**
Ugu	-0.03	-0.22	-0.10	0.478	0.18	**0.31**
Rogo	0.21	-0.02	-0.26	0.551	0.20	**0.68**
Water Leaf	-0.08	-0.02	-0.15	0.407	0.06	**0.22**
Kabeji	-0.13	-0.56	0.063	0.368	0.23	**-0.03**
Mean	**0.01**	**-0.06**	**-0.25**	**0.512**	**0.23**	**0.44**

S/T = Sample Type

It was observed from Table 4 that the accumulation of heavy metals in water for Ni, Cr, As, Cd and Pb has the total of 0.01, -0.06, 0.25, 0.512 and 0.23 respectively.

It was observed from Table 4 that the total Geo Accumulation Index from Edible Plant Samples of Jos East Local Government Area is in descending order trend with Yateya (0.93) > Alayyahu (0.84) > Zogale and Rogo (0.68) > Karkashi (0.65) > Yakuwa (0.56) > Rama (0.34) > Kuka and Ugu (0.31) > Water Leaf (0.22) > Kabeji (-0.03) > Shuwaka (-0.27).

3.1.1 Comparison of Results with World Health Organization (WHO)

The results presented on Table 2, Table 3 and Table 4 were used to plot charts in order to compare the results of the present study with World Health Organization (WHO) as seen in Figure 1, Figure 2 and Figure 3.

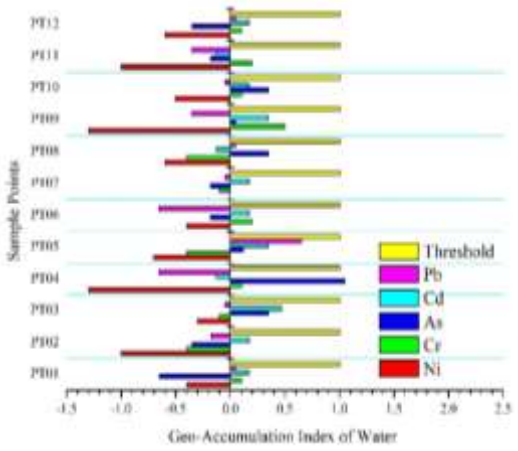


Fig. 1: Comparison of Geo-Accumulation Index of Water with World Health Organization

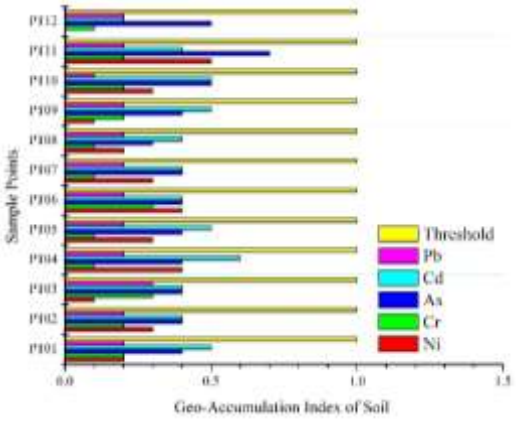


Fig. 2: Comparison of Geo-Accumulation Index of Soil with World Health Organization

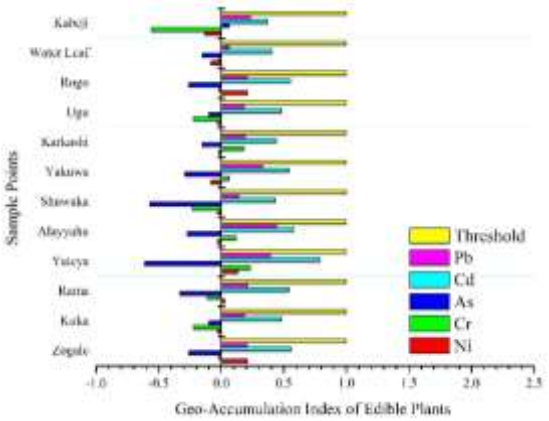


Fig.3: Comparison of Geo-Accumulation Index of Edible Plant with World Health Organization

3.2 Discussion

The results of this study showed that the Geo-Accumulation Index (I_{geo}) of water for different heavy metals (Ni, Cr, As, Cd and Pb) in all the sample points decreased in the order of P03 (0.415) > P05 and P10 (0.114) > P07 (-0.11) > P12 (-0.57) > P08 (-0.65) > P01 (-0.66) > P09 (-0.72) > P06 (-0.82) > P04 (-0.87) > P11 (-1.36) > P02 (-1.66) with heavy metals decreasing in the order of Cd (0.15) > Cr and As (0.03) > Pb (-0.13) > Ni (-0.6).

Based on the chart presented in Figure 1, water has not been contaminated by Nickel (Ni) in all the points except P07 which was found within uncontaminated to contaminated level. The water is also was not contaminated by Cadmium (Cd) in P04, P08 and P11, while other points are within uncontaminated to contaminated level. Figure 1 also showed that Chromium (Cr) in P02, P03, P05, P07 and P08 has their values at uncontaminated level, whereas in other points, Chromium (Cr) are within uncontaminated to contaminated level. The same figure also showed that Arsenic (As) in P01, P02, P06, P07, P11 and P12 has their values at uncontaminated level, whereas in other points, Arsenic (As) are within uncontaminated to contaminated level. Lastly, Figure 1 showed that Lead (Pb) in P02, P03, P04, P06, P07, P09, P10 and P11 has their values at uncontaminated level, whereas in other points, Lead (Pb) are within uncontaminated to contaminated level considering the World Health Organization recommended value of $I_{geo} \leq 0$ as uncontaminated, $0 < I_{geo} \leq 1$ as uncontaminated to moderately contaminated, $1 < I_{geo} \leq 2$ as moderately contaminated, $2 < I_{geo} \leq 3$ as moderately to strongly contaminated, $3 < I_{geo} \leq 4$ as strongly contaminated, $4 < I_{geo} \leq 5$ as strongly to extremely contaminated and $I_{geo} > 5$ as extremely contaminated.

On the Geo-Accumulation Index (I_{geo}) of soil for different heavy metals (Ni, Cr, As, Cd and Pb) in all the sample points decreased in the order of P12 (1.0) > P08 (1.2) > P02, P03, P07 and P09 (1.4) > P01, P04, P05, P06 and P10 (1.6) > P11 (2.0) with heavy metals decreasing in the order of As and Cd (0.4) > Ni, Cr and Pb (0.2).

The chart presented in Figure 2 showed that, soil has not been contaminated by all heavy metals in all the points except Nickel (Ni) in P12 considering the World Health Organization recommended value of $I_{geo} \leq 0$ as uncontaminated, $0 < I_{geo} \leq 1$ as uncontaminated to moderately contaminated, $1 < I_{geo} \leq 2$ as moderately contaminated, $2 < I_{geo} \leq 3$ as moderately to strongly contaminated, $3 < I_{geo} \leq 4$ as strongly contaminated, $4 < I_{geo} \leq 5$ as strongly to extremely contaminated and $I_{geo} > 5$ as extremely contaminated.

On the Geo-Accumulation Index (I_{geo}) of edible plants for different heavy metals (Ni, Cr, As, Cd and Pb) in all the sample points decreased in the order of Yateya (0.93) > Alayyahu (0.84) > Zogale and Rogo (0.68) > Karkashi (0.65) > Yakuwa (0.56) > Rama (0.34) > Kuka and Ugu (0.31) > Water Leaf (0.22) > Kabeji (-0.03) > Shuwaka (-0.27) with heavy metals decreasing in the order of Cd (0.512) > As (0.25) > Pb (0.23) > Ni (0.01) > Ni (-0.06).

Lastly, the chart presented in Figure 3, edible plants has not been contaminated by Nickel (Ni) in Kuka, Alayyahu, Suwaka, Yakuwa, Ugu, Water Leaf and Kabeji, while other edible plants are within uncontaminated to contaminated level. Figure 3 also showed that Chromium (Cr) in Kuka, Rama, Shuwaka, Ugu and Kabeji has its value at uncontaminated level, whereas in other edible plants, Chromium (Cr) are within uncontaminated to contaminated level. Lastly, Figure 3 showed that Arsenic (As) in all edible plants has their values at uncontaminated level, whereas in Kabeji, Arsenic (As) are within uncontaminated to contaminated level considering the World Health Organization recommended value of $I_{geo} \leq 0$ as uncontaminated, $0 < I_{geo} \leq 1$ as uncontaminated to moderately contaminated, $1 < I_{geo} \leq 2$ as moderately contaminated, $2 < I_{geo} \leq 3$ as moderately to strongly contaminated, $3 < I_{geo} \leq 4$ as strongly contaminated, $4 < I_{geo} \leq 5$ as strongly to extremely contaminated and $I_{geo} > 5$ as extremely contaminated.

4 Conclusions

Based on the results presented, 21 % of the area under investigation has their soil, water and edible plants at uncontaminated level considering the World Health Organization recommended value of $I_{geo} \leq 0$ as uncontaminated, $0 < I_{geo} \leq 1$ as uncontaminated to moderately contaminated, $1 < I_{geo} \leq 2$ as moderately contaminated, $2 < I_{geo} \leq 3$ as moderately to strongly contaminated, $3 < I_{geo} \leq 4$ as strongly contaminated, $4 < I_{geo} \leq 5$ as strongly to extremely contaminated and $I_{geo} > 5$ as extremely contaminated.

It can therefore be concluded that the soil, water and edible plants in the study area falls within the uncontaminated to moderately contaminated values which calls for serious concern and regulatory control especially for those points within moderate contamination level. Hence this study can be used as a reference data for regulatory bodies like NNRA and the rest.

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