Health risk assessment of trace metals contamination in vegetables (*Telferia occidentalis*) irrigated with polluted effluent water from mechanic village, Uyo.

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ABSTRACT

This research investigates the health risk assessment of heavy metal contamination in vegetables (*Telferia occidentalis*) irrigated with polluted effluent water in the study area. The heavy metal analysis of Pb, Cd and Ni were carried out using the Atomic absorption spectrophotometer (AAS). The mean concentration of heavy metals in *Telferia occidentalis* from site A and B ranged from 0.6 -108.2 mg/kg with an increasing trend of Ni> Cd >Pb. These values are above the world Health Organization and National Environmental Standard and Regulations Enforcement Agency (WHO/NESREA). The population under study was found to be under low risk of Cd at stations B and control of B, Ni and Pb, because the health risk index is less than one (HRI <1), with exception of Cd at stations A and control of A. The Target Hazard Quotient (THQ) showed that all the heavy metals were lower than one (1), therefore poses no health risk concern.

Keyword: Heavy metal, vegetables, Health Risk Assessment, Target hazard quotient

1.0: Introduction

Vegetables are important ingredient of human diet that contain essential nutrients and trace elements (Abdulla and Chimielnicka, 1990). Waste water irrigation has resulted in the significant contamination of farmland with the heavy metal contents of the waste water. The heavy metals subsequently leached out of the soil and are taken up by the vegetation. The heavy metals are transferred to humans when contaminated plants are consumed by human. Furthermore, bioaccumulation, geoaccumulation and biomagnifications may result, because of entrance of these heavy metals into the ecosystem. Thus, long term waste water irrigation leads to the bioaccumulation of

ISSN 2229-5518

heavy metals in soil and food crops (Khan *et al.,* 2008). Rapid industrialization and urbanization with insufficient environmental monitoring planning often results in the discharge of the industrial and sewage waste into rivers and lakes. This leads to the gradual pollution of our water resources. In some cases, industrial wastewater is used for irrigating crops, including vegetables. The polluted effluent water is found to be rich, not only in organic compounds and nutrients, but also in heavy metals like cadmium, lead and nickel. These metals finally end up in the soil, leading to food chain contamination, since crops absorb them from the soil.

Vegetables are source of essential nutrients, antioxidants and metabolites in food item. However, their consumption by humans and animals can pose serious health hazards, because they are potential carcinogens or cause human organ dysfunction (Gebreyohannes and Gebrekidan, 2018). Although, some heavy metals such as Cu, Zn and Fe are essential in plant nutrition, many of them do not play significant role in the plant physiology. For instance, Pb and Cd are among the most abundant heavy metals and are particularly toxic. The uptake of these heavy metals by plants especially leafy vegetables is the path of their entry into human food chain which ends with harmful effects on health (Gebreyohannes and Gebrekidan, 2018). The daily accumulation of heavy metals in the environment has magnified in recent years because of population growth, industrialization and technological developments.

Environmental pollution by heavy metals is of major health concern globally due to their long-term cumulative health effects on flora and fauna. Heavy metals occur naturally in the ecosystem with large variations in concentrations in modern times; however, anthropogenic activities have also introduced some of these heavy metals into the ecosystem. The presence of heavy metals into the environment is of great ecological significance due to their toxicity at certain concentrations, translocation through food chains and non-bioaccumulation of the biosphere.

Heavy metals like cadmium (Cd), lead (Pb), and nickel (Ni), indirectly distributed in the environment as a result of human activities, could be very toxic even at low concentrations. Plants grown around automobile repair centers are contaminated with heavy metals, since the mobile metal ions present in the soil are absorbed through the plant roots or leaves. The absorbed metals are bio-accumulated in the roots, stems, fruits, grains, and leaves of plants.

A general concern about the safety of foods has been on the increase in recent years (Hansen *et al.,* 2002; Gyawali *et al.,* 2011). The concentrations of natural and synthetic chemical compounds in food contribute to its toxicity, it is therefore necessary to quantify the traditional nutrients, heavy metals, pesticides and various other constituents in food for the safety of consumers (Hansen *et al.,* 2002). Improving the nutritional quality of food is imperative for farmers and food industries. Vegetables are edible plants or parts of a plant; they are those herbaceous plants whose parts are eaten as supporting food or main dishes and they may be aromatic, bitter or tasteless (Mensah *et al.,* 2008). The utilization of leafy vegetable is part of Africa's cultural heritage and they play important roles in the customs, traditions and food culture of the African household (Mensah *et al.,* 2008). Nigeria is endowed with a variety of traditional vegetables and different types are consumed by the various ethnic groups for different reasons. The nutrient content of different types of vegetables varies considerably and they are not major sources of carbohydrates compared to the starchy foods which form the bulk of food eaten but contain vitamins, essential amino acids, as well as minerals and antioxidants (Fasuyi, 2006).

Effluent in automobile repair centers are discharged without due regulation in Nigeria. Vegetables take up heavy metals and accumulate them in their edible and non-edible part in quantities high enough to cause clinical problems in animal, plant and human beings.
Excessive contents of metals beyond WHO minimum permissible limit (MPL) leads to several health disorders which include: nervous, cardiovascular, renal, neurological impairment as well as bone disease and several other health disorders.

Vegetables are essential part of diet and are eaten in both cooked and raw form by humans. Metals like copper, zinc and manganese help in regulation of human metabolism but some elements like lead and cadmium are very toxic for human Adedokun et al., 2016. Vegetables contaminated with lead and cadmium significantly contribute to decrease human life expectancy within the affected areas. There is an increase in the number of vehicles used for both private and commercial purposes in the city. Since vehicles are prone to break down and require maintenance, there is a proliferation of automobile workshops in Uyo. This has resulted in an increase in soil contamination caused by discharges from these automobile repair centers. Health risk assessment of heavy metals in vegetable irrigated with polluted effluent water was necessary in order to ascertain the degree of contamination of lead, cadmium and nickel in vegetables consumed by humans around automobile repair Centers in Uyo, Akwa Ibom State Nigeria.

2.0 Materials and Methods

2.1 Location of Study Area

Uyo is the state capital of Akwa Ibom. The town became the capital of the state on September 23, 1987 following the creation of the state from Cross River State. The population of Uyo, according to 2006 census which comprises Uyo and part of Itu, is 427,873. While the urban area, including part of Uruan is 655,906. Uyo is situated between latitude $4^0 32^1$ N and $5^0 33^1$N and longitude $7^0 25^1$E and $8^0 25^1$. The state is located in the south-south geopolitical zone, and is bordered on the east by Cross River State, on the west by Rivers state and Abia State, and on the south by the Atlantic Ocean and the southernmost tip of Cross River State.

2.2 Description of Sampling Sites

Site A (Study Area) is located

SAMPLING STATIONS	LATITUDE	LONGITUDE	DESCRIPTION AND ACTIVITIES
station A	5°1′ 32.159″ N	7°53′ 56.602″ E	Servicing of vehicle engines, Painting of vehicle body rims
Control of station A	5°1′ 32.331″ N	7°53′ 53.304″ E	Neutral ground
Station B	5°1′ 33.916″ N	7°54′ 1.721″ E	Greasing and oiling of parts spray, Repairs of fuel tanks
Control of station B	5°1′ 40.191″ N	7°54′ 4.205″ E	Neutral ground

The sample area is the automobile repair center, known as "mechanic village", located along Abak road, Uyo, Akwa Ibom State. Activities conducted at the center include sales of spare parts, servicing of vehicle engines, repairs of fuel tanks, repairs or charging of battery, repairs of brake systems, greasing and oiling of parts, spraying or painting of vehicle parts and washing of vehicles.

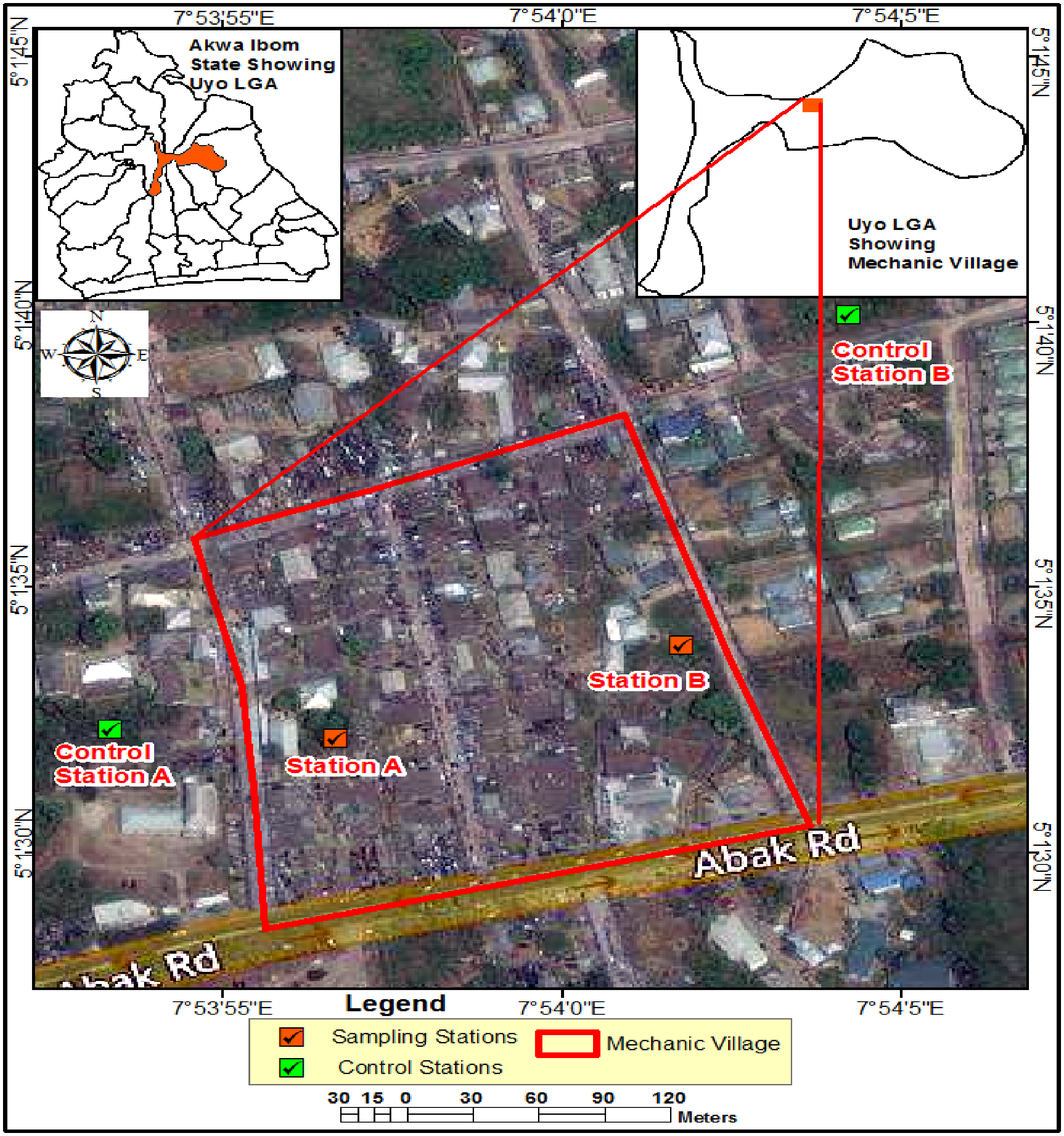
7°53'55"E
7°54'0"E
7°54'5"E
5°1'45"N
5°1'40"N
5°1'35"N
5°1'30"N
Akwa Ibom State Showing Uyo LGA
Uyo LGA Showing Mechanic Village
N
W
E
S
Control Station B
Station B
Station A
Control Station A
Abak Rd
Legend
Sampling Stations
Control Stations
Mechanic Village
30 15 0 30 60 90 120
Meters

Figure 3.1: Satellite Map of Mechanic Village in Uyo indicating Sampling Stations
Source: Compiled using Open Street Map Database and Fieldwork (2020)

2.3 Collection and Preservation

Samples of vegetables were randomly collected with hands from automobile repairs center in mechanic village Uyo, irrigated with untreated effluent water.
Leafy vegetables were preferred as they accumulate heavy metals in greater capacity than other vegetables. Four samples of vegetables were collected from both study and control sites.

Plate 1: Vegetable leaves (pumpkin)

2.4 Methods

All glass wares and containers for the analysis were first washed with distilled water. The vegetable samples were washed with distilled or deionized water to remove dust particles. Samples were then cut with hand into pieces of uniform size and then dried. The dried samples were kept in an oven for 2-3 days at 105^0c. The dried samples of vegetables were ground into fine powder using mortar and pestle, and then stored in polyethylene bags for acid digestion.

2.5 Preparation of Samples

One gram (1 g) of a well homogenized sample was weighed into digestion flask and clamp to a retort stand. Using aqua regia method (i.e. ratio3:1) of digestion, 15 ml of

HCl was mixed with five (5 ml) of HNO_3 and poured into the sample to form a mixture. The digestion flask was mounted on a heating equipment (heating mantle), and placed inside a fume cupboard. The digestion temperature was increased until a whitish appearance of sample and subsequently, clear solution was obtained. The flask was then removed and the digest was allowed to cool. Fifty ml (50 ml) of deionized water was added and filtered. It was made to mark of 100ml standard volumetric flask and labeled.

2.6 Metals Analysis: The digested samples were analyzed for heavy metals (Pb, Ni, Cd) using atomic absorption spectrophotometer (AAS VGP 210 System) in Ministry of Science and Technology, Uyo. The instrument setting and operational conditions were done in accordance with the manufacturers' specifications.

Statistical Analysis: T -test statistical analysis was used to assess the significant levels between the study area and the control. T-Test for two-sample assuming equal and unequal variances were analyzed.

2.7 Health Risk Assessment: The potential health risks of heavy metal consumption through vegetables were assessed based on the daily intake of metal (DIM) (Chary *et al.,* 2008), health risk index (HRI) (Jan *et al.,* 2010). The daily intake of metals (DIM) was calculated to averagely estimate the daily metal loading into the body system of a specified body weight of a consumer. This would inform the relative bioavailability of metal. This does not take into cognizance the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal. The estimated daily intake of metal (DIM) in this study was calculated based on the formula below:

$$\text{DIM} = \frac{Cmetal \times Cfactor \times Cfoodintake}{average\ body\ weight} \quad - \quad - \quad - \quad (1)$$

Where C metals is the heavy metal concentration in vegetable (mg/kg).c factor is the conversion factor of 0.085 is to convert fresh vegetable to dry weight (Gebreyohannes and Gebrekidan, 2018). Daily intake of vegetable was estimated at 65g/day (Oguntona, 1998) while the average body weight used for this study was 65kg (Oguntona, 1998).

The hazard index was calculated to determine the overall risk of exposure to all the heavy metals via the ingestion of irrigated vegetable (USEPA1996).

The health risk index (HRI) was calculated using formula below:

$$HRI = \frac{DIM}{RFD} \qquad (2)$$

The THQ was calculated below:

$$THQ = \frac{EFxEDxFIRxC}{RFDxWABxTA} \times 10^{-3} \qquad (3)$$

Where EF is the exposure frequency (350 days/year); ED is the exposure duration (54 years, equivalent to the average lifetime of the Nigerian population); FIR is the food ingestion rate (vegetable consumption values for adult in Nigeria is 65 g/person/day) (Oguntona, 1998); C is the metal concentration in the edible parts of vegetables (mg/kg); RFD is the oral reference dose (Pd, Cd, and Ni values were 0.0035, 0.001 and 0.020 mg/kg/day, respectively) (USEPA IRIS, 2006); WAB is the average body eight (65kg for adults vegetable consumer in Nigeria) (Oguntona, 1998); TA is the average exposure time for non-carcinogens (ED x 365 days/year). If the THQ value is greater than 1, the exposure is likely to cause obvious adverse effects but if less than 1, the food considered is safe for human consumption.

3.0 Results

The results of the concentrations of heavy metals in vegetable obtained from Automobile repair center, mechanic village Uyo, Akwa Ibom State are presented in Tables 4.1, 4.2, 4.3 and Figures 4.1, 4.2, 4.3 and Table 4.1 show the heavy metal concentration of vegetable (*Telferia occidentalis*) samples in mg/kg obtained in Mechanic Village, Uyo.

Table 3.1: Heavy metal concentration of vegetable (Telferia occidentalis) samples in mg/kg obtained from Mechanic Village, Uyo.

Stations	**Code**	Values	Lead (mg/Kg)	Nickel (mg/Kg)	Cadmium (mg/Kg)
1	**Station A**	Range	6.6-7.0	107.9-108.8	20.4-20.8
		Mean ± SD	6.8 ± 0.2	108.2 ± 0.5	20.6 ± 0.2
	Control of station A	Range	<0.001	42.4 - 42.8	16.2 – 16.6

ISSN 2229-5518

		Mean ± SD	0.00	42.6 ± 0.2	16.4 ± 6.9
2	**Station B**	Range	5.3-5.6	102.2-102.6	4.0 – 4.4
		Mean ± SD	5.5 ± 0.15	102.4 ± 0.2	4.2 ± 0.2
	Control of station B	Range	<0.001	92.2-92.6	0.4-0.8
		Mean ± SD	0.00	92.4 ± 0.2	0.6 ± 0.2

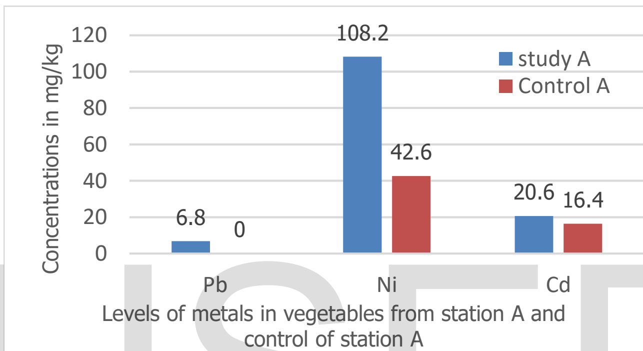

Figure 3.1: Heavy Metal Concentration in Vegetable from Station A and Control of A

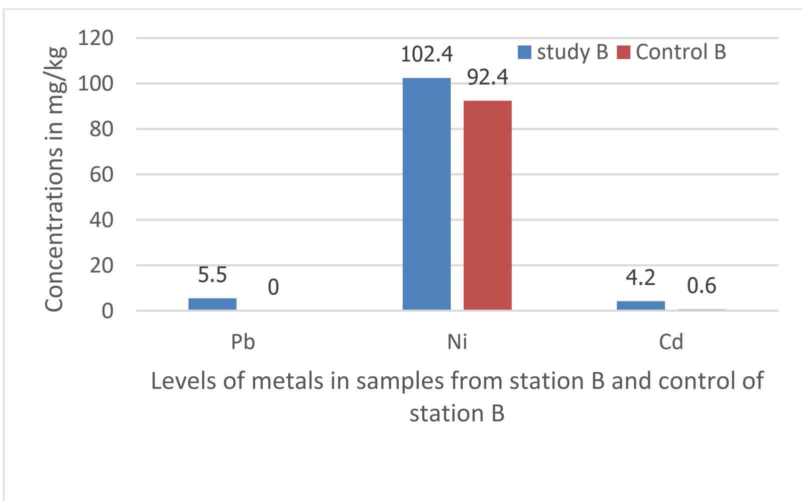

Figure 3.2: Showing the Heavy Metal Concentrations in Vegetable from Station B and Control of station B

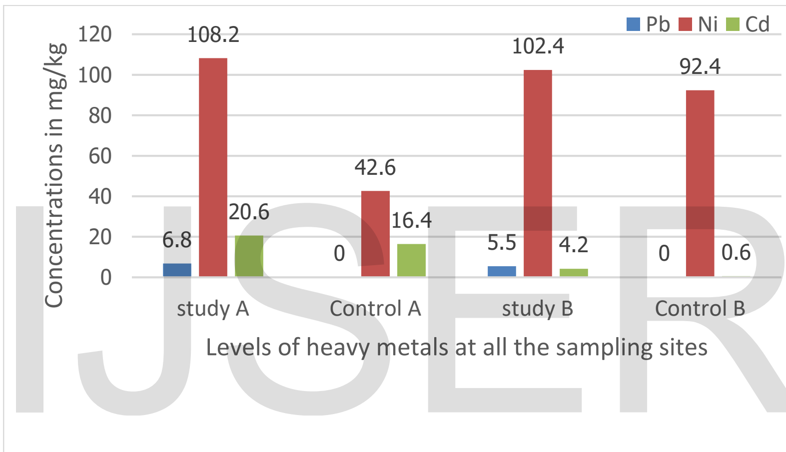

Figure 3.3: Showing the Heavy Metal Concentrations at all the sampling sites

Table 3:2: The Daily intake rate (mg person^{-1} day^{-1}) of heavy metals in vegetable from Mechanic village. Uyo.

STATIONS	**LEAD** (mg/kg)	**NICKEL** (mg/kg)	**CADMIUM** (mg/kg)
A	5.78 x 10^{-4}	9.197 x 10^{-3}	1.751 x 10^{-3}
Control of A	8.5 x10^{-8}	3.621 x 10^{-3}	1.394 x 10^{-3}
B	4.675 x10^{-4}	8.704 x 10^{-3}	3.57 x 10^{-4}
Control of B	8.5 x10^{-8}	7.854 x 10^{-3}	5.1 x 10^{-5}
***DI (mg day^{-1} person^{-1})**	0.00	0.50	0.0000
***UL (mg day^{-1} person^{-1})**	0.240	1.00	0.064

*Recommended Daily Intake (DI) and Upper Tolerable Daily Intake (UL) Levels of heavy Metals in foodstuffs (FDA, 2001 ; Garcia Rico 2007)

Table 3.3: Calculated values of health risk index (HRI) and target hazard quotient (THQ) for heavy metals in vegetables obtained from Mechanic Village, Uyo.

STATIONS	Pb		Ni		Cd	
	HRI	THQ	HRI	THQ	HRI	THQ
A	0.1651	1.8630 x 10^{-3}	0.4599	5.1877 x 10^{-3}	1.7510	1.9753 x 10^{-2}
Control of A	2.4286 x 10^{-5}	2.7396 x 10^{-7}	0.1811	2.0425 x 10^{-3}	1.3940	1.5726 x 10^{-2}
B	0.1336	1.5068 x 10^{-3}	0.4352	4.9096 x 10^{-3}	0.3570	4.0274 x 10^{-3}
Control of B	2.4286 x 10^{-5}	2.7396 x 10^{-7}	0.3927	4.4301 x 10^{-3}	0.0510	5.7534 x 10^{-4}

3.2 Discussion

Table 3.1 shows the levels of heavy metals at the sampling sites**.** Pb concentration of vegetable (*Telferia occidentalis*) samples at station A ranged from 6.6 - 7.0 mg/kg with a mean of 6.8± 0.2 mg/kg. Ni had values which varied between 107.9 – 108.8 mg/kg with a mean of 108.2 ± 0.5 mg/kg while Cd values were 20.4 -20.8 mg/kg and the mean was 20.6±0.2mg/kg. At the control site of station, A, the observed values for Pb was below the detection limit of the equipment used. Nickel had values which ranges from 42.4 – 42.8 mg/kg with the mean of 42.6 ± 0.2 mg/kg and Cd was 16.2- 16.6 mg/kg and mean of 16.4± 6.9 mg/kg (Fig. 3.1).

Figure 3.2 presents the levels of Pb at Station B, which varied between 5.3 – 5.6 mg/kg with a mean of 5.5 ± 0.15 mg/kg and Ni varied from 102.2 – 102.6 mg/kg with the mean of 102.4 ± 0.2 mg/kg. The values of Cd also varied from 4.0 – 4.4 mg/kg with the mean of 4.2 ± 0.2 mg/kg. The control site of station B had levels of Pb that were below the detection limit of the equipment used. Ni varied from 92.2 – 92 .6 mg/kg and the mean is 92.4±0.2 mg/kg while Cd values were between 0.4 – 0.8 mg/kg with the mean of 0.6 ±0.2 mg/kg. The recommended maximum limit of cadmium and lead by FAO/WHO, 2001 were 0.2 and 0.3 mg/kg respectively (Maleki and Zaravand, 2008). The Chinese Department of Protection Medicine 1994 has the safe limit for lead in vegetable as 0.2 mg/kg (Asdeo and Loonker, 2011).

Levels of Cd in this study at stations A and B including the control were higher than the permissible limit of 0.2 mg/kg by FAO/ WHO 2001. Observed values of Cd at station A were higher than those of the control, the main activity that were in operation at this station A were servicing of vehicle engines and painting of vehicle. Values of Cd observed at station B were comparatively lower than station A. Cadmium is a heavy metal with high toxicity and it is a non-essential element in foods and natural waters and it accumulates principally in the kidneys and liver (Divrikli *et al*., 2006; Adesuyi *et. al*, 2015). Higher values of Cd have been previously reported for leafy vegetables cultivated along road sides (0.27 mg/kg) by Oluwole *et al*., (2013).

Though minimal amount of Nickel is needed by human to produce red blood cell, excessive amount of nickel can become toxic. Short term overexposure is not known to cause any health problem but long-term exposure can decrease body weight, liver damage and skin irritation. Concentration of nickel in stations A and B were higher than the estimated maximum guideline set by United State Food and Drug Administration of 70 - 80 mg/g (Iwebue, 2010). Figure 4.3 shows that Ni has the most prominent peak at station A which implies that it is the most abundant metal in the study area. In control stations of A and B, nickel concentrations were less than the observed levels in the stations A and B.

Lead concentration in stations A and B were higher than recommended limits of 0.3mg/kg by WHO/FAO 2001 (Table 3.1 and Figures 3.1 and 3.2), which made the vegetable unsafe for human consumption. Lead contamination in vegetable can cause damage to the central nervous system; kidney and in extreme cases may cause death. However, in control stations of A and B, lead was below the detection limit of the equipment used, indicating that the vegetable in these sites were safe for human consumption. The order of concentration of metal in the vegetable obtained from Mechanic village were found to be Ni > Cd >Pb.

3.3 Health Risk Assessment

The health risk of the inhabitant of Uyo and the environs were assessed due to heavy metal intake of vegetable consumption from the mechanic village. The daily intake of metals (DIM), health risk index (HRI) and target hazard quotient (THQ) were calculated from equations 1, 2 and 3 respectively and the results are presented in Tables 3.2 and 3.3. The DIM results in Table 3.2 were compared with the recommended daily intake of metals and the upper tolerable daily intake level (FDA, 2001; Garcia Rico 2007) in Table

3.2. It was observed from the Table 3.2 that the daily intake of metals in vegetable for Pb (5.780×10^{-4}) at station A and station B (4.675×10^{-4}) was lower than the recommended daily intake of metals and the upper tolerable daily intake level of 0.00 and 0.240mgday^{-1}person^{-1} respectively. In control stations A and B, levels of Pb was 8.500×10^{-8} .

Nickel in stations A and B (9.197×10^{-3} mg day^{-1} person^{-1}, 8.704×10^{-3} mg day^{-1} person^{-1}) were also lower than the recommended daily intake of metal and the upper tolerable daily intake level of (0.5, 1.0 mg day^{-1} person^{-1}) which means that there is no health risk implication because they were less than 1, in control stations A and B, Ni (3.621×10^{-3} mg day^{-1} person^{-1}, 7.854×10^{-3} mg day^{-1} person^{-1}) fell below the recommended daily intake of metal and the upper tolerable daily intake level of (0.5, 1.0 mgday^{-1} person $^{-1}$) and were less than 1 which has no health risk implication. Cadmium in stations are A and B (1.751×10^{-3}. 3.57×10^{-4}) were lower than the recommended daily intake and upper tolerable daily intake (0.000, 0.064 mgday^{-1}person^{-1}) which has no health risk implication for consumers. In control station of A, Cd was also lower with a value of 1.394×10^{-3} mg day^{-1} person^{-1}, however control station of B recorded low value of 5.1×10^{-5} mg day^{-1} person^{-1} which was lower than the recommended daily intake level (0.064 mgday^{-1}person^{-1}) which has no health risk implication for consumers (Table 3.2). The HRI for Pb, Ni and Cd from stations B and control of B of this study were lower than 1 in all the study sites except Cd at control station of A and station A whose values were higher than 1. (Table 3.3). Generally, HRI >1 means that the exposed population is not safe of metal health risk while HRI<1 means the reverse (Khan *et al.*, 2008). The population under study at stations A and control of A were therefore under risk of Cd, while HRI for Pb, Ni and Cd from stations B and Control of B were safe of metal health risk.

The THQ values of Cd, Ni and Pb due to consumption of the vegetable for adults of the study area are presented on Table 3.3. THQ is the ratio between the measured concentration and the oral reference dose, weighted by the length and frequency of exposure; amount ingested and body weight (Tsafe *et al*, (2012). The THQ values range showed that Cd was 4.0274×10^{-3} – 1.9753×10^{-2} at stations A and B, Ni was 4.9096×10^{-3} – 5.1877×10^{-3} for stations A and B, while Pb was 1.5068×10^{-3} - 1.863×10^{-3} for stations A and B. This result reflects that, there was no risk associated with Cd, Ni and Pb exposure for the period of life expectancy considered. In this study, the THQ in all the metals were lower than 1, therefore it poses no health risk concern. Higher THQ for Cd, Pb and Ni were reported by Singh *et al.,* (2010) in vegetables from waste water irrigated area. THQ calculations showed that the THQ in all metals were far less than 1 in all the vegetable species studied by Adedokun *et al.*, 2016.

3.4 Statistical analysis using t-Test: Two-Sample Assuming Equal Variances between the sampling sites summarily showed that, there was no significant difference between sites at p>0.05, which implies there is no significant difference between the mean concentration at the study sites.

3.5 Conclusion

Several studies have linked excessive bio-accumulation of heavy metals to numerous health abnormalities. They pose both short and long-term environmental health risks. Leafy vegetables produced in farmlands contaminated with irrigated effluent water from Auto mobile repair centers were found to possess high concentration of heavy metals in this study; that had a trend of Nickel>Cadmium>Lead. The concentration of all the metals in study area A and B were higher than the permissible limit level of WHO/FAO, 2001, excepts Pb at control area A and B were low. The HRI for Pb, Ni, Cd from stations B and control of B from this study were lower than 1 in all the study sites except Cd at control station of A and station A whose values that were higher than 1. (Table 3.3). Generally, HRI >1 means that the expose population is not safe of metal health risk while HRI<1 means the reverse (Khan *et al.*, 2008). The population under study were therefore under low risk of Cd at stations B and control of B, Ni and Pb except the Cd at stations A and control of A sites are not. THQ calculations showed that, the THQ in all the metals were lower than 1, therefore it poses no health risk concern.

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