

# Physicochemical Parameters in Soil and Vegetable Samples from Gongulon Agricultural Site, Maiduguri, Borno State, Nigeria

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**ABSTRACT:** Anthropogenic activities are a leading cause of metal emission, often associated with high elevated soil and plant metal concentrations. The accumulation of heavy metals and anions in soil and vegetables in the vicinity of Gungulung agricultural site were investigated. Soil samples were collected at depths of 0-5 cm, 5-10 and 10-20 cm. Soil properties including pH, electrical conductivity (EC), organic matter, organic carbon, cation exchange capacity (CEC) and heavy metals content were determined using standard procedures. Vegetable samples (spinach, *Amaranthus caudatus*; carrot, *Daucus carota*; lettuce, *Lactuca sativa*; cabbage, *Brassica oleracea*; tomato, *Lycopersicon sculentum*; waterleaf, *Talinum Triangulare* and onion *Allium cepa* were used for this research. The plant samples were prepared for heavy metals and anions determination using standard procedures. Results show that the soil metal content, conductivity and organic carbon decreased with depth, suggesting anthropogenic sources of contamination while pH, organic matter and CEC decreased with depth. The results obtained from this analysis revealed that Zn and Mn show the highest concentrations, Ni shows the lowest levels. Similarly, the results also revealed that Fe, Zn and Cu show the highest concentrations, while Pb shows the lowest levels in the whole vegetables parts studied. The leaves contained much higher concentrations of heavy metals and anions than roots and stems. The concentrations of the above parameters in the vegetable samples were higher than the FAO, WHO/EU and FAO/WHO allowed limit. The high values might be attributed to the use of wastewater from river Ngada and application of sewage sludge by farmers for the irrigation of these vegetables. The results of this study suggest that the vegetables grown in the vicinity of Gugulung agricultural site are subjected to anthropogenic activities. Thus, the high values of these metals in the vegetable samples could put the consumers of these vegetables at health risk with time due to bioaccumulation. [Journal of American Science. 2010;6(12):78-87]. (ISSN: 1545-1003).

**Key words:** Physicochemical, Parameters, Soil, Vegetables, Bioavailability, Uptake.

## 1. INTRODUCTION

Several studies have indicated that vegetables, particularly leafy crops, grown in heavy metal contaminated soils have higher concentrations of heavy metals than those grown in uncontaminated soil (Guttormsen et al. 1995; Dowdy and Larson 1995). A major pathway of soil containing through atmospheric deposition of heavy metals from point sources such as: metaliferous metal smelting and industrial activities. Other non point sources of contamination affecting agricultural soils include inputs such as, fertilisers, pesticides, sewage sludge and organic (Singh 2001). Additionally, foliar uptake of atmospheric heavy metals emissions has been identified as an important pathway of heavy metal contamination in vegetable crops ( Salim et al. 1992). Vegetable growing areas are often situated in, or near sources of deposits, and thus have an elevated risk of potential contamination. There have been a number of studies which have investigated atmospheric deposition in soil and/or vegetables growing in the vicinity of industrial areas (Gzyl 1995). These studies

indicate high concentrations of heavy metals in vegetables grown in the vicinity of industries and polluted areas and identify leafy vegetables at greatest risk of accumulating elevated concentration. Each plant species has its nutritive requirements differing from others. Thus different plants supported by identical solutions will contain varying concentrations of minor and macro elements. Application of industrial effluent decreases the budding and growth rate of vegetables (Ihekeronye and Ngoddy 1985). Leafy vegetables occupy a very important place in the human diet, but unfortunately constitute a group of foods which contributes maximally to nitrate and other anions as well as heavy metals consumption. The excessive application of nitrogen and other inorganic fertilizers and organic manures to these vegetables can accumulate high levels of nitrate and other anions as well as heavy metals. Consequently their consumption by humans and animals can pose serious health hazards. Although some heavy metals such as Cu, Zn, Mn and Fe are essential in plant nutrition, many of them do not play any significant

role in the plant physiology. The uptake of these heavy metals by plants especially leafy vegetables is an avenue of their entry into the human food chain with harmful effects on health (Ihekeronye and Ngoddy 1985).

Although the nutrient content of wastes makes them attractive as fertilizers, when untreated wastes are used in crop production, consumers risk to contact diseases like cholera and hepatitis, or to undergo heavy metal contamination (Drechsel et al., 1999). In fact, large amounts of the waste comprise organic material, but there are considerable proportions of plastic, paper, metal rubbish and batteries which are known to be real sources of heavy metals (Lisk, 1988; Zhang et al., 2002; Pasquini and Alexander, 2004). Heavy metals and non-biodegradable materials can accumulate in soils to toxic concentrations that affect plant and animal life. Contamination of soils by heavy metals can be caused by many factors such as metal-enriched parent materials, mining or industrial activities, non point sources of metals, especially automotive emission, and use of metal-enriched materials, including chemical fertilizers, farm manures, sewage sludge, and wastewater irrigation (Freedman and Hutchinson, 1981). However, soil contamination by heavy metals and toxic elements due to parent materials or point sources often occurs on a limited area and is easy to identify (He et al., 2005). In agricultural production systems, soil contamination of heavy metals is mainly related to input and accumulation of these elements through repeated use of metal enriched chemicals such as fungicides, farm manures, chemical fertilizers and biosolids (Webber, 1981). Biosolids and/or municipal composts made of biosolids and yard wastes often contain higher concentrations of Cu, Zn, Cd, Cr and Ni than those found in soils (He et al., 2001). Several works have been done in developed countries and showed excessive concentrations of heavy metals in agricultural soils and plants (Alloway, 1995).

The effect of pH on heavy metal availability to plants has been reported by many researchers and it is accepted that as pH decreases, the solubility of cationic forms of metals in the soil solution increases and, therefore, they become more readily available to plants (Gray et al., 1998; Salam and Helmke, 1998; Oliver et al., 1998, Singh et al., 1995; Evans et al., 1995; Filius et al., 1998; Mann and Ritchie, 1995; Chlopecka et al., 1996; Vigerust and Selmer-Olsen, 1985). Evans (1989) explained that pH has a major effect on metal dynamics because it controls adsorption and precipitation, which are the main mechanisms of metal retention to soils. Metal solubility in the solution depends on the solubility product of the solid phase (precipitate) containing the metal.

He and Singh (1993) found that application of sludge increased the cation exchange capacity (CEC) value of the soil (that is the ability of the soil to retain metals). The movement of heavy metals down the soil profile is often evident in high applications of heavy metals, usually in sewage sludge, in soils with low organic matter and clay contents, acidic conditions, and when high rainfall or irrigation water rates have been applied. The movement occurs through soil macropores or cracks which is also referred to as preferential flow (Dowdy and Volk, 1983).

Since organic matter plays an important role in metal binding, some researchers have tested whether organic carbon (OC) compounds influence metal leaching. Fotovat et al. (1996) reported that metals such as Cd, Ni and Zn may be influenced in their solubility characteristics from the presence of OC. LaBauve et al. (1988) applied synthetic waste water to soils and measured the soluble metals. It was found that the synthetic material increased the solubility of metals, especially Cd and Ni, and this was particularly attributed to the soluble organic matter of the waste.

Gongulon is an agricultural site located in Maiduguri Metropolis, Borno State, Nigeria along the coast of River Ngada. Vegetables are grown in this area of Gongulon for commercial purposes. The river receives copious amounts of wastes from residence houses and abattoirs sited along its course. Urban waste management and garbage disposal practices in the city are very poor. Process water from the Municipal waste and Abattoir located near the river contains large amounts of heavy metals. The contaminated water from river Ngada is used extensively for the irrigation of these vegetables particularly at the agriculture site in Gongulon. Hence, this poses significant effect on the soil and vegetable crops thereby exposing consumers of these vegetable crops to bioaccumulation of trace metals and anions with time. This study is aimed at determining the levels of some physicochemical parameters in vegetable and soil samples.

## 2. MATERIALS AND METHODS

### 2.1 Sample Areas

Soil and vegetable samples were collected from the agricultural sites of Gongulon located within Maiduguri Metropolis, Borno State, Nigeria. In these areas of study, sewage sludge and waste water from river Ngada are used by farmers to improve soil fertility for the growth of vegetables.

### 2.2 Sample Collections and Preparations

In the field, soil samples were collected from twelve plots. In each plot, soil samples were collected

at three depths (0-5 cm, 5-10 cm and 10-15 cm), by using spiral auger of 2.5cm diameter. Soil samples from the Agricultural site were randomly sampled and bulked together to form a composite sample. In all cases, soil samples were put in clean plastic bags and transported to the laboratory. Soil samples were then air-dried, crushed and passed through 2mm mesh sieve. The samples were then put in clean plastic bags and sealed. Soil samples were analysed for the following parameters: pH, electrical conductivity, organic matter, organic carbon, cation exchange capacity and heavy metals.

Vegetables (spinach, *Amaranthus caudatus*; carrot, *Daucus carota*; lettuce *Lactuca sativa*; cabbage, *Brassica oleracea*; tomato, *Lycopersicon sculentum*; waterleaf, *Talinum Triangulare* and onion (*Allium cepa*) from the Gongulon agricultural site were freshly harvested from twelve farms and packaged into labelled paper bags, and transported to the laboratory awaiting analysis. The vegetable samples were collected and divided into root, stem and leaf. Soil and vegetable samples were collected four times a month from the period of January to July, 2008.

### 2.3 Soil sample analysis

The pH was measured using a 1:2 soil: water ratio (Mclean, 1982); electrical conductivity was determined using the aqueous extraction (1/5) method (Mathieu and Pieltain, 2003). Organic matter and organic carbon (OC) were determined using Anne method (modified Walkey-Black method) (Mathieu and Pieltain, 2003). Cation exchange capacity (CEC) was determined using standard method taken from Rowell (1994). The cation used in this method to saturate the soil solution is Na. Five gramme (5g) of soil were weighed into a 50 ml plastic centrifuge tube and 30 ml of 1 M NaOAc pH 8.2 were added. The sample was shaken at an end-to-end shaker at 21°C for 5 minutes and was then centrifuged for 10 minutes at 4000 rpm. The supernatant was discarded and 30 mL of 1 M NaOAc pH 8.2 was added the sample was resuspended and the procedure was repeated for 2 more times. After the supernatant was discarded for the third time 30 ml of 95 % ethanol solution were added, the sample was resuspended and another 3 cycles were conducted. At the end of the third cycle, 30 ml of NH<sub>4</sub>OAc pH 7 were added, the sample was resuspended and a new phase of 3 cycles was commenced. This time the supernatants were filtered through a filter paper, Whatman No 42, and collected into a 100 mL volumetric flask. At the end of this, the flask was made to the volume with NH<sub>4</sub>OAc pH 7 solution. The samples were kept at 4 °C until Na was measured on the FAAS according to standard procedure. CEC value was then determined by the

formular

$$\text{CEC, cmol}_c \text{ kg}^{-1} \text{ soil} = \frac{10 * \text{Na concentration in mg L}^{-1}}{\text{Mass of sample (g)}}$$

### 2.4 Determination of Heavy Metals in Soil Sample

Two grammes of the soil samples were weighed into acid-washed glass beaker. Soil samples were digested by the addition of 20cm<sup>3</sup> of aqua regia (mixture of HCl and HNO<sub>3</sub>, ratio 3:1) and 10cm<sup>3</sup> of 30% H<sub>2</sub>O<sub>2</sub>. The H<sub>2</sub>O<sub>2</sub> was added in small portions to avoid any possible overflow leading to loss of material from the beaker. The beakers was covered with a watch glass, and heated over a hot plate at 90°C for two hours. The beaker wall and watch glass were washed with distilled water and the samples were filtered out to separate the insoluble solid from the supernatant liquid. The volumes were adjusted to 100cm<sup>3</sup> with distilled water. Blank solutions were handled as detailed for the samples. All samples and blanks were stored in plastic containers. The results were expressed in mg/kg dry weight. All statistical analyses were carried out with the program SPSS 12.3 for windows.

### 2.5 Sample Preparation and Digestion of Vegetables for Heavy Metals Determination

The vegetables samples were weighed to determine the fresh weight and dried in an oven at 80°C for 72 hours to determine their dry weight. The dry samples were crushed in a mortar and the resulting powder digested by weighing 0.5g of oven-dried ground and sieved (<1mm) into an acid-washed porcelain crucible and placed in a muffle furnance for four hours at 500°C. The crucibles were removed from the furnance and cooled. 10ml of 6M HCl were added covered and heated on a steam bath for 15minute. Another 1ml of HNO<sub>3</sub> was added and evaporated to dryness by continuous heating for one hour to dehydrate silica and completely digest organic compounds. Finally, 5ml of 6 M HCl and 10ml of water were added and the mixture was heated on a steam bath to complete dissolution. The mixture was cooled and filtered through a Whatman no. 541 filter paper into a 50ml volumetric flask and made up to the mark with distilled water.

### 2.6 Elemental Analysis of Samples

Determination of Cu, Zn, Co, Mn, Mg, Fe, Cr, Cd As, Ni and Pb in soil and vegetable samples were made directly on each of the final solution using Perkin-Elmer AAnalyst 300 Atomic Absorption Spectroscopy (AAS).

### 2.7 Determination Of Nitrate, Nitrite, Sulphate And Phosphate In The Vegetable Samples

#### 2.7.1 Determination of nitrate and nitrite

The concentration of nitrate and nitrite analyzed in each of the vegetable samples were carried out using smart spectro Spectrophotometer (LaMotte 2000). Vegetable samples solutions were prepared by chopping each sample into smaller sizes. A known amount (1g) of the chopped sample was transferred into 100ml flask and soaked with 50ml of distilled water. The flask was capped and shaken for 30 minutes, then filtered into another 100ml volumetric flask and the volume made to the mark with distilled water (Radojevic and Bashkin 1999). Nitrate was determined spectrophotometrically using standard cadmium reduction method 3649 – SC (Lamotte, 2000), while Nitrite was determined using standard diazotization method 3650 – SC (Lamotte, 2000).

### 2.7.2 Determination of Phosphate

Each of the vegetables samples was chopped into small pieces. The chopped samples were then air-dried. The air-dried samples were ground and sieved with a siever of mesh 1mm. A known amount (1g) of each of the ground and sieved samples was weighed into acid-washed porcelain crucibles. The crucibles were labelled and 5ml of 20% (w/v) magnesium acetate were added and evaporated to dryness. The crucibles were then transferred into the furnace and the temperature was raised to 500°C. The samples were ashed at this temperature for four (4) hours, removed and cooled in desiccators.

Ten (10) ml of 6 M HCl were then added to each of the crucible and covered, then heated on a steam bath for fifteen minutes. The contents of each crucible were completely transferred into different evaporating basins and 1ml of concentrated HNO<sub>3</sub> was added. The heating was made to continue for 1 hour to dehydrate silica. 1ml of 6M HCl was then added, swirled and then followed by the addition of 10ml distilled water and again heated on the steam bath to complete dissolution. The contents of the evaporating

basins were cooled and then filtered through a Whatman no.1 filter paper into 50ml volumetric flasks and the volumes made up to the marks with distilled water (Radojevic and Bashkin 1999). Phosphate was determined using Hach Direct Reading 2000 Spectrophotometer.

### 2.7.3 Determination of Sulphate

For sulphate determination, 5ml of magnesium nitrate solutions were added to each of the ground and sieved samples in the crucibles. These were then heated to 180°C on a hot plate. The heating process was allowed to continue until the colour of the samples changed from brown to yellow (Kenneth, 1990). The samples were then transferred to the furnace at a temperature of 500°C for four hours. Magnesium nitrate was added to prevent loss of sulphur. The contents of each crucible were carefully transferred to different evaporating basins. 10ml of concentrated HCl were added to each of them and covered with watch glasses. They were boiled on a steam bath for 3 minutes. On cooling, 10ml of distilled water were added to each of the basins and the contents of each were filtered into 50ml volumetric flasks and the volumes made up to the marks with distilled water (Radojevic and Bashkin 1999). Sulphate was determined using Smart spectro Spectrophotometer (2000).

## 3. RESULTS

### 3.1 Soil Properties

The soil properties had a wide range of values for measured soil properties (Figures 1). The soil pH values range from acidic (5.98) to moderately alkaline (7.26) and varied with depth. Conductivity values ranged from 2.03  $\mu\text{S cm}^{-1}$  to 2.54  $\mu\text{S cm}^{-1}$ . Organic carbon ranged from 1.03% to 2.11% and decreased with depth. Cation exchange capacity values were 20.45 to 23.54 C.mol/kg, while organic matter ranged from 8.56 to 10.55 %.

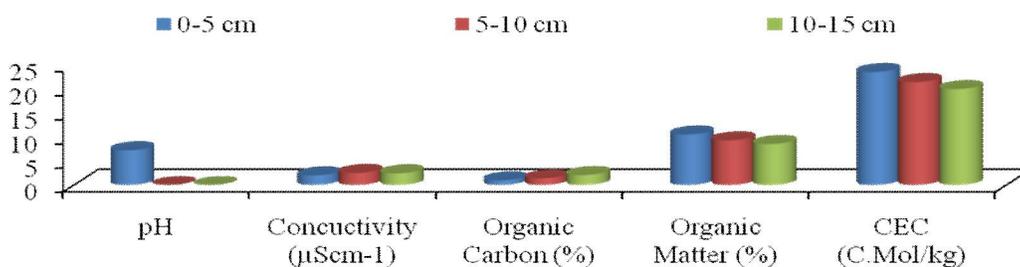


Figure 1: Mean concentration of chemical and physical properties of soil sample from Gongulon agricultural site

### 3.2 Distribution of Heavy Metals in Soil Profiles

At the Gongulon farming area, heavy metals concentrations increased significantly ( $p < 0.05$ ) with depth

(Figure 2) suggesting anthropogenic sources of contamination. The concentrations of Cr in the soil sample from different depths were 2.21 to 5.32 mg/kg; Co ranged from 0.12 mg/kg (0-5cm) to 3.43 mg/kg (10-15cm). Fe concentrations in the soil ranged from 2.54 mg/kg to 4.21 mg/kg with depth; 0.98 to 1.22 mg/kg Ni; 6.75 to 14.54 mg/kg Pb; 23.75 to 33.92 mg/kg Zn; 8.94 to 15.97 mg/kg Cd; 6.88 to 7.65 mg/kg Cu; 1.03 to 1.76 mg/kg As and 13.76 to 19.96 mg/g Mn.

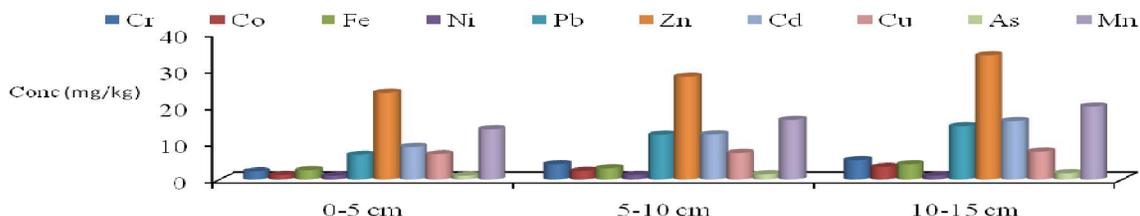


Figure 2: Mean concentration of heavy metals in soil samples from Gongulon agricultural site with depth

### 3.3 Heavy Metals in Vegetables

The concentrations of heavy metals in all the vegetable samples are presented in Figure 3a and b. The concentration of Cr ranged from 0.12 to 1.02 mg/kg; 0.11 to 0.72 mg/kg Mn; 0.33 to 3.21 mg/kg Fe; 0.11 to 1.21 mg/kg Cu; 0.11 to 0.53 mg/kg As; 0.11 to 2.04 mg/kg Ni; 0.11 to 0.39 mg/kg Pb; 0.11 to 1.44 mg/kg Zn and 0.11 to 0.66 mg/kg Cd.

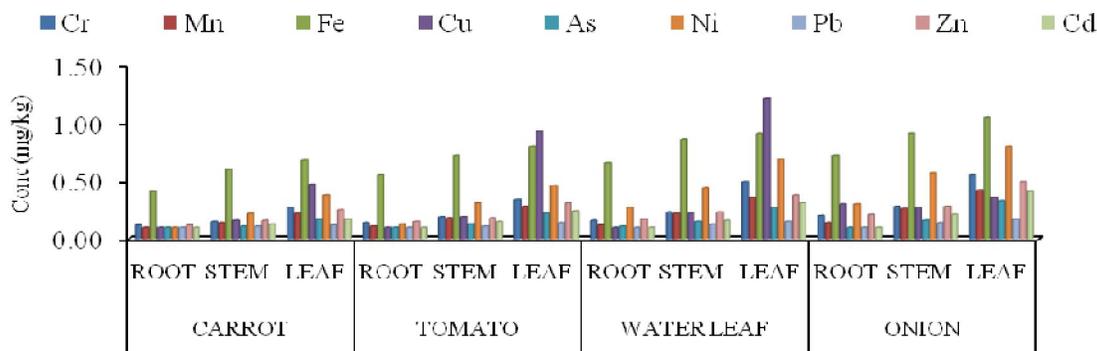


Figure 3b: Mean concentration of heavy metals in different parts of vegetable samples from Gongulon agricultural site

### 3.4 Anions in Vegetable Samples

The mean concentrations of anions for all the organs of different vegetable samples are as presented in Figure 4, 5, 6 and 7. The concentrations of sulphate (Figure 4) ranged from 267.67 to 388.76 mg/kg carrot; 678.33 to 989 mg/kg spinach; 456.44 to 807.09 mg/kg lettuce; 378.66 to 487.66 mg/kg water leaf; 312.23 to 411.12 mg/kg cabbage; 217.81 to 294.55 mg/kg tomato and 422.45 to 566.70 mg/kg onion. For phosphate concentrations Figure 5, carrot ranged between 43.45 and 65.34 mg/kg; 134.77 and 187.99 mg/kg spinach; 118.45 and 154.33 mg/kg lettuce; 78.94 and 92.45 mg/kg water leaf; 56.23 and 74.00 mg/kg cabbage; 33.27 and 58.44 mg/kg tomato and 98.05 and 123.68 mg/kg onion. The levels of nitrate ranged from 210.03 to 359.67 mg/kg carrot; 421.22 to 674.22 mg/kg spinach; 322.56 to 587.33 mg/kg lettuce; 234.56 to 388.90 mg/kg cabbage; 289.00 to 412.33 mg/kg water leaf; 177.89 to 288.43 mg/kg tomato and 310.33 to 466.78 mg/kg onion Figure 6. Nitrite concentration ranged between 196.33 and 311.02 mg/kg carrot; 311.21 and 543.54 mg/kg spinach; 277.33 and 453.44 mg/kg lettuce; 211.02 and 398.77 mg/kg cabbage; 263.19 and 387.34 mg/kg water leaf; 167.88 and 281.07 mg/kg tomato and 233.23 and 428.11 mg/kg onion Figure 7. From figure 4, the maximum concentration of sulphate was found in spinach (678.33 to 989.01 mg/kg) and the minimum in tomato (217.81 to 294.55 mg/kg). Phosphate had the maximum concentration in spinach (134.77 to 187.99 mg/kg) and minimum in tomato (33.27 to 58.44 mg/kg) Figure 5. Nitrate content was higher in spinach (421.22 to 674.22 mg/kg) while tomato shows the least values (177.89 to 288.43 mg/kg) Figure 6. Nitrite showed the maximum concentrations in spinach (311.21 to 543.54 mg/kg) and the minimum concentrations in tomato (167.88 to 281.07 mg/kg) Figure 7.

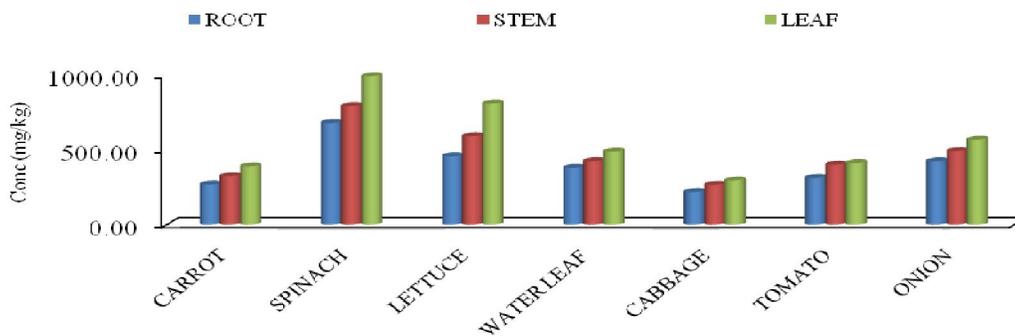


Figure 4: Mean concentration of Sulphate in different organs of vegetable samples from Gongulon agricultural site

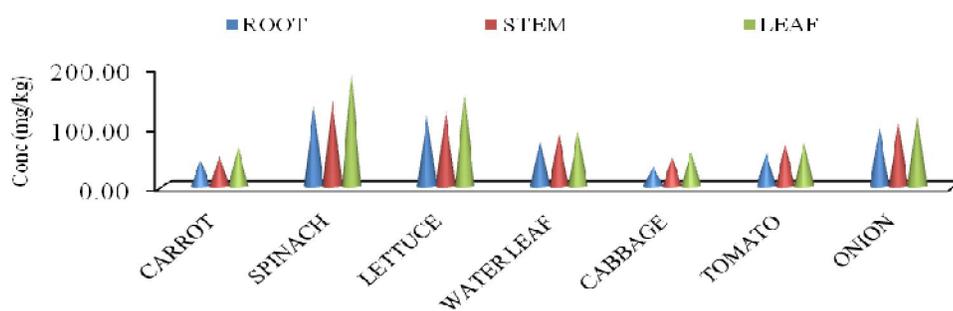


Figure 5: Mean concentration of phosphate in different organs of vegetable samples from Gongulon agricultural site

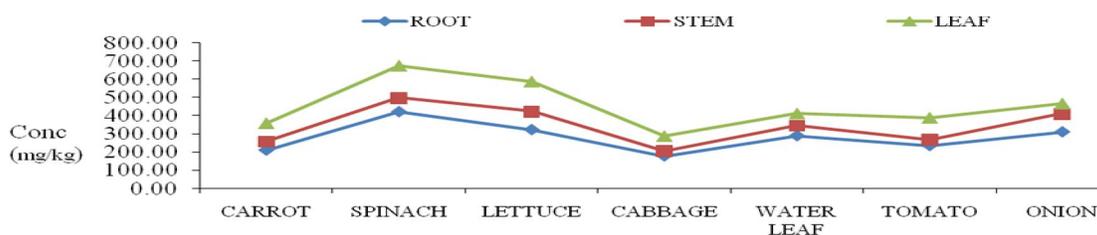


Figure 6: Mean concentration of Nitrate in different organs of vegetable samples from Gongulon agricultural site

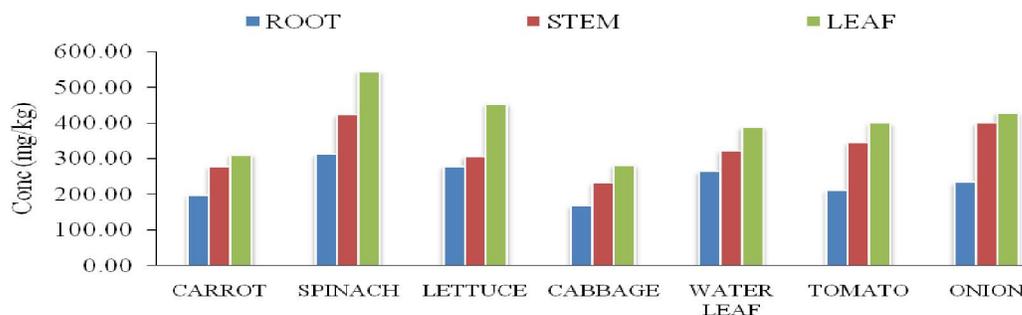


Figure 7: Mean concentration of Nitrite in different parts of vegetable sample from Gongulon Agricultural site

#### 4. DISCUSSION

The sequence of heavy metals in the cultivated soil samples from the Gongulon agricultural site was in the order of Zn > Mn > Cd > Pb > Cu > Cr > Fe > Co > As > Ni Figure 1. The concentrations of heavy metals showed spatial and temporal variations, which may be ascribed to the variation in heavy metal sources and the quantity of heavy metals in irrigation water and sewage sludge. This trend suggests that continuous application of sewage sludge and municipal wastewater influenced the soil physicochemical properties (Willett *et al.*, 1984). The levels of organic carbon in the soil sample increased significantly with depth, while organic matter decreased. OC also increased with the increase in the water rate Davis *et al.*, 1988). This may be of significant environmental consequences, because it was shown that higher rates of applied water (irrigation) during the study periods increased the amounts of OC Figure 2, and this also influence the solubility and availability of heavy metals.

Evidence that heavy metals may move in the soil profile was provided by Lund *et al.*, (1976), in their field experiment the researchers used sludge with a high content of heavy metals and found that Zn had moved down to 50 cm, Cd to 17 cm while Ni to 75 cm. Davis *et al.*, (1988) measured the metal distribution in the soil profile in a field experiment where sludge had been applied at a rate of 40 t ha<sup>-1</sup> and rainfall rate was around 560 mm per annum over a period of 4 years. They found a significant movement of Cd, Ni, Pb and Zn to a depth of 10 cm. Also Schirado *et al.*, (1986) reported that heavy metals had a uniform distribution in the soil profile to a depth of 1 m, due to their movement. Results such as these tend to have been obtained from the present study, where movement of heavy metals down the soil profile (leaching) to a depth of 15 cm due to application of sewage sludge and waste water from river Ngada were observed Figure 1. The concentrations of heavy metals in the soil samples obtained during the present study were higher than the FAO standard.

Soil pH was significantly greater and degreased with depth. pH is one of the factors which influence the bioavailability and the transport of heavy metals in the soil and according to Smith and Giller (1992) heavy metal mobility decreases with increasing soil pH due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes. In the present study, it was observed that heavy metals increase significantly with decrease in pH ( $p < 0.05$ ) Figures 1 and 2. The soil electrical conductivity (EC) also varied significantly with depth ( $p < 0.05$ ). By comparism, Boulding (1994) classified EC of soils as: non saline <2; moderately saline 2-8; very saline 8-16; extremely saline >16. From the result of the study, the

EC is classified as moderately saline. The amount of heavy metals mobilized in soil environment is a function of pH, properties of metals, redox conditions, soil chemistry, organic matter content, clay content, cation exchange capacity and other soil properties (Arun and Mukherjee, 1998; Kimberly and William, 1999; Sauve *et al.*, 2000). Heavy metals are generally more mobile at pH < 7 than at pH > 7. The pH of the soils from the Gongulon agricultural sites ranged from 5.98 to 7.26. This is therefore hazardous for agricultural purposes since crops are known to take up and accumulate heavy metals from contaminated soils in their edible portions (Wei *et al.*, 2005).

Leaves contained higher concentrations of heavy metals than roots and stems. Similar study carried out by (Santamaria *et al.*, 1999) shows that the heavy metal content of various parts of plant differs. They reported that in vegetable organs the concentrations of heavy metals are in the order of leaf > stem > root > tuber > bulb > fruit > seed. Amusan *et al.*, 1999, studied plant uptake of heavy metals on a similar site at University of Ife dump site and reported that Pb uptake by water leaf (*Talinum triangulare*), okra (*Albennucus esculentus*) increased in leaves and roots of water leaf and in the fruit of okra relative to those grown in the non-dump sites. Similar work by Ademoroti (1996) reported that vegetables accumulate considerable amount of heavy metals especially Pb, Cr, Cu and Zn in roots and leaves. The concentrations of heavy metals in all the vegetable samples analysed were higher than the FAO/WHO guideline values of 0.1-0.2 mg/kg Cr, 0.3 mg/kg Fe; 0.1 mg/kg Pb; 0.1 mg/kg Cu; 0.1 mg/kg Zn; 0.1 mg/kg Ni; 0.02 mg/kg Cd and 0.3 mg/kg Mn. Results from present and earlier reports (Liu *et al.*, 2005; Muchuweti *et al.*, 2006 and Sharma *et al.*, 2007) demonstrated that plants grown on wastewater-irrigated soils are contaminated with heavy metals and pose health concern. Absorption and accumulation of heavy metals in plant tissues depend upon many factors. These include temperature, moisture, organic matter, pH and nutrient availability, while the presence of organic matter has been reported to increase the uptake of zinc, chromium, lead, iron and copper in the wheat plant. (Rupa *et al.*, 2003). In the present study many soil factors such as pH, organic matter and organic carbon have interacted to impact on uptake. The acidic range of soil is known to increase the mobilization of heavy metals, thus increasing their uptake. The field data support this argument in that the soil pH was acidic.

The values of sulphate, phosphate, nitrate and nitrite in the vegetable samples show that the leaves are rich in this anion content than other organs studied. Similar study was carried out by Santamaria *et al.*, (1999) stated that nitrate and nitrite contents of

various parts of a plant differ in the order of leaf> stem> root> tuber> bulb> fruit> seed. Zhou *et al.*, (2000) reported that vegetables that are consumed with their roots, stems and leaves have a high nitrate and nitrite accumulation, whereas melons and those vegetables with only fruits as consumable parts have a low nitrate accumulation. This observation was also noted by Hunt and Turner (1994) where leaf and stem accumulate the most nitrate, sulphate and nitrite followed by stem and roots. The concentrations of these anions were higher in the leafy vegetables (spinach and lettuce) than in tomato. Results of analysis of variance (ANOVA) showed that variation between vegetables and organs were statistically significant ( $p < 0.05$ ).

### 5. Conclusion

The levels of soil and plants contamination in the agricultural site of Gongulon appear to be as a result of anthropogenic activities within the area. The levels of heavy metals, pH and organic carbon increased significantly ( $p < 0.05$ ) to a depth of 15 cm, while conductivity, organic matter and CEC, decreased to a depth of 15 cm. The results indicate that all the vegetable samples analyzed in this study had high levels of heavy metals. Heavy metal levels were higher than those recommended by Food and Agricultural Organization (FAO) and the WHO/EU joint limits. The high levels of these heavy metals might place the consumers of these and other vegetable crops grown within the vicinity of the area at health risk with time.

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