An assessment of heavy metal exposure risk associated with consumption of cabbage and carrot grown in a tropical Savannah region

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Introduction
Santa located in the North West region is one of the highest producers of vegetables (such as tomatoes, cabbage, carrots, celery, leeks, onions, Irish potatoes and many others) in Cameroon (Pouokam et al., 2017). Food produced in Santa Sub-Division is not only consumed in the North West Region but is also supplied to neighbouring regions such as the West and South West, Centre and neighbouring countries in the CEMAC zone such as Gabon, Equatorial Guinea, Republic of Congo, Chad, Central African Republic, and Nigeria (Amawa et al., 2015; Bidogeza et al., 2016). The quality of the vegetables produced in this area therefore has health implications for most of Central Africa.

Most studies carried out in Santa have dwelt on characterizing the soil properties of some agricultural systems in Awing (Santa) and the determination of surface water quality of some of the streams running through these large agricultural farms (Mofor et al., 2017; Okha, 2016). These results indicate that the excessive use of agrochemicals have altered not only the soil structure but also the water quality of some of the streams running through these farms. But there is still a dearth of information on the quality of the vegetables produced in the region in terms of heavy metal concentrations and the health risk associated with the consumption of these vegetables. This work is therefore geared at determining the heavy metal concentration in cabbage and carrot grown in Santa, North West Region, in a tropical Savannah region in Cameroon and assessing the potential health risk associated with the consumption of these two vegetables.

Vegetables make up a major portion of the diet of humans in many parts of the world and play a significant role in human nutrition in providing good health, especially as sources of essential vitamins (C, A, B1, B6, B9, E), minerals (Ca, Fe, K, Zn, and Cu) (Butnariu, 2014), dietary fiber and phytochemicals like phenolic compounds, flavonoids, bioactive peptides (Dias and Ryder 2011). Interest in maintaining a healthy lifestyle around the globe has contributed to the increased consumption of fruits and vegetables both in raw and/or undercooked forms (Feroz et al., 2013). As a result, many health care organisations and associations, including the United State Food Pyramid, encourage 3–5 servings of vegetables daily (World Health Organization, 2016). The challenges associated with acquiring large expanse of agricultural lands for the...
cultivation of these vegetables have led to the same piece of land being cultivated repeatedly for very long periods. As a result of the ever-increasing demand for cabbages and carrots, farmers of this produce see it as an opportunity to produce throughout the year. Over cultivation causes the depletion of intrinsic soil nutrients thereby forcing farmers to rely on soil amendments to sustain production and increase the yield of these vegetables (Ai et al., 2020). Rapid development and industrialisation has brought in hazardous heavy metals through air, soil, water and eventually, through plants (Kumar et al., 2019). Agrochemicals such as fertilizers, pesticides and herbicides, which are sources of heavy metals, are most often inappropriately used especially in our developing countries. In some instances, water of doubtful quality is used for irrigation, exposing these crops to heavy metal contamination (Waseem et al., 2014). Heavy metals in the soil can also occur naturally from the processes of weathering of parent materials.

Even though some heavy metals such as manganese (Mn), zinc (Zn), chromium (Cr), copper (Cu), iron (Fe) and nickel (Ni), are required as micronutrients for living organisms (Alengebawy et al., 2021), they may induce noxious effects when their concentrations are above their permissible limits as per WHO standards (Shahid et al., 2015). Other non-essential metals induce severe toxicity to living organisms even at low concentrations, such as mercury (Hg), cadmium (Cd), arsenic (As) and lead (Pb) (Harguinteguy et al., 2016; Shahid et al., 2015). With increasing awareness on the importance of vegetables to human diet and increase in their intake, monitoring of different contaminants like heavy metals need to be done in order to reduce health risk. Heavy metals are of primary concern because of their toxicity, stability, persistence and bioaccumulation in plants, animals and humans (Verger & Boobis, 2013). As consumers’ demand for more vegetables is drastically increasing, studies have shown that heavy metals rank high among the chief contaminants of these vegetables (Waseem et al., 2014). However, vegetables thus differ widely in their ability to absorb and accumulate heavy metals. This depends widely on the type of vegetable and the soil’s physico-chemical properties (Säumel et al., 2012). Root vegetables such as carrot, when cultivated on contaminated land have the ability to absorb more heavy metals such as Pb which is dangerous for the human system (Attanayake et al., 2014). Also, species in the Brassicaceae such as cabbage are known to accumulate most heavy metals, thereby exposing animals and other consumers to heavy metal toxicity and related diseases. The monitoring of the concentrations of heavy metals in agricultural systems is therefore vital.

Various indices have been used by authors including Geo-accumulation Index (Igeo), Transfer Factor (TF) of the heavy metals and Health Risk Index have been used to assess the toxicity of these heavy metals to both the environment and human health. Igeo was used to evaluate heavy metal contamination in terrestrial environment by comparing current concentrations with background levels as determined by Muller (1981). The Igeo grades range from very strongly polluted to unpolluted, with the sediment Igeo contamination ranging from >5 to >0, respectively. It gives an indication of the risk of exposure by through the food chain, as described by Cui et al. (2004). TF values (≥1) indicate a high metal absorption by the plant from the soil. While TF values (≤1) indicate a low metal absorption by the plant from the soil, implying the plant in question is safe for human consumption. Health risk associated with consumption of these vegetables was determined using the HRI. If the value of HRI is <1 then the exposed population is said to be safe from the uptake of heavy metals due to the consumption of this vegetable (Integrated Risk Information System, 2003).

Materials and methods

Description of the study area

Santa is found in the North West Region (NWR), Cameroon (Figure 1). It is located between latitudes 5°42’ and 5°53’ North and longitudes 9°58’ and 10°18’ East (Santa Rural council, 2003) with a surface area of about 532.67 km2. Santa is located in the Western Highland Plateau (Agro-ecological Zone 3). The rainy season runs from mid-March to mid-November. The rest of the year is a dry season. Average annual rainfall is 2288 mm. The average annual temperature is 19.7°C and temperature ranges between 15°C and 32°C (Manu et al., 2015). Santa is characterized by ferrallitic soils. Farmers in Santa rely greatly on rains for irrigation and during the dry season, they turn to waste water as their source of irrigation in order to meet up with the high demand of water by the vegetables during production.

Sample collection

Samples were collected from four villages in Santa; Mbei, Akum, Moforbe and Matazem. Each village was considered as a study site. At each site, one cabbage and one carrot farm was selected based on the maturity of the vegetables in the field at the time of sampling, the availability of nearby water for irrigation and the distance of the farms from the main road. The Global
Positioning System (GPS) coordinates of all the farms were recorded using eTrex Garmin (Table 1).

A total of twenty-four (24) soil samples were collected (12 for cabbage and 12 for carrot) at a depth of 0–15 cm using a soil auger, since nutrient mobility in the soil is highly concentrated in the top 0–6 cm (Anderson et al. 2011). Distances between collecting sites of 0–10 m (depending on the different plot sizes) were also respected, so as to have a representative composite sample of the soil per plot and to reduce partial redundancy. The soils were packaged in polythene bags and transported to the Life Sciences Laboratory of the University of Buea, where they were air-dried to constant weight for four days, ground to fine particles in a porcelain mortar using a pestle and sieved through a 2 mm sieve (Benton, 2003).

Farms with a mono-cropping system were chosen for this work. At each cabbage farm (for all the four sites) samples of mature cabbage heads (leaves) were cut, and at each carrot farm (for all the four sites) carrot roots were uprooted. Collections were made in triplicates. The samples were packaged into clean bags, labelled and transported to the Life Sciences Laboratory of the University of Buea, where the leaves of cabbage and roots of carrot were first washed under running tap water to remove adhering dirt. They were further rinsed in distilled water, then weighed, sliced using a kitchen knife into smaller pieces to ease drying. The chopped vegetable samples were oven-dried to constant weight using Gallenkamp Hotbox Oven at 40°C for 5 and 7 days for carrot and cabbage, respectively. The dried vegetable and soil samples were labelled and transported by air to the Laboratory of Environmental Sciences of the University of South Africa for heavy metal and nutrient analyses.

**Sample analyses**

Soil physicochemical analysis involved the determination of soil texture, pH, organic carbon, organic matter, total nitrogen, C/N ratio, Ca, Mg, K, Na, Cation Exchange Capacity (CEC) and available P. Soil texture was determined using the soil texture triangle after determining the weight percent clay, sand and silt in each sample. The potential hydrogen (pH) of soils was measured using the electrometric method, pH meter (Foth & Ellis, 1997). The wet oxidation method (Black, 1965) was used to determine the organic matter present in the soil. This method measured the active or decomposable organic matter in the soil. The carbon in plant residues and humus was oxidized. Total nitrogen was determined using the Kjeldahl method (Nzengong, 2012). Cation Exchange Capacity was gotten by the saturation of an exchangeable complex with a given cation and then later on determined the total amount of the absorbed cations (Foth & Ellis, 1997). The modified Walkley Black method was used to determine organic carbon in the soil (Cottenie et al., 1982; Fonge, 2004). For the determination of heavy metals in the soil samples, aqua regia (a mixture of 32% HCl and 55% \( \text{HNO}_3 \) in a ratio of 3:1) was used to extract heavy metals.
Table 1. Study sites with their coordinates (UTM) and descriptions

| Areas  | Vegetables | Latitude | Longitude | Elevation (m asl) | Site description |
|--------|------------|----------|-----------|------------------|------------------|
| Akum   | Carrot     | 5°51'07.1" | 10°09'55.4" | 1884             | Both farms located on a slope of 0–5% with a stream below the farms. 3 km from the main road. |
|        | Cabbage    | 5°51'01.0" | 10°09'52.4" | 1883             |                  |
| Mbei   | Carrot     | 5°49'14.5" | 10°09'05.7" | 1853             | Farms located on a slope of 0–2%, surrounded by a range. 1 m from the road. Having a nearby river. |
|        | Cabbage    | 5°48'57.5" | 10°09'13.2" | 1814             |                  |
| Matazem| Carrot     | 5°46'28.2" | 10°08'34.8" | 1711             | Farms surrounded by celeries and potatoes farms, with a dam as a source of irrigation. 5 km from the main road. |
|        | Cabbage    | 5°46'22.6" | 10°09'12.2" | 1641             |                  |
| Moforbe| Carrot     | 5°46'49.0" | 10°09'26.9" | 1644             | Farms surrounded by cabbage and lettuce farms. 2 km from the main road with a nearby river. |
|        | Cabbage    | 5°46'50.3" | 10°09'22.7" | 1642             |                  |

**Note:** m asl—metres above sea level
metals in the samples as described by Lomonte et al. (2008) and Goddard and Brown (2014). To 1 g of each sample weighed into a beaker, 10 ml of aqua regia was added and the mixture evaporated to near dryness in a water bath at 110°C. Another 15 ml of aqua regia was added to the mixture after which it was also evaporated to near dryness. 1 M HNO₃ was added to the mixture and the extract filtered through acid washed Whatmann no. 42 filter paper. The filtrate was collected and used for determination of heavy metals in each sample. A ContrAA 300 atomic absorption spectrometer was used in the determination of heavy metal concentrations (As, Cr, Zn, Cu, Ni, Pb, Cd, Fe, Mn and Co) in the sample extracts. Heavy metal concentrations in the plant samples were determined using a Perkin Elmer 3000 ICP-MS after digestion with a HNO₃ in a Microwave. The microwave was heated up to a temperature of 200 and pressure of 20 bars for 20 minutes after which the sample was cooled, filtered, and used for the determination of heavy metals in the plant samples. Data for some heavy metal analyses for irrigation water were obtained from secondary data from (Tarla et al., 2013) in the study area.

For quality assurance and quality control purposes, two reagent blanks were included in each batch of samples analyzed. All samples were analyzed in duplicate. The reagent blanks were used as blanks in the determination of metal concentrations with the ContrAA 300 atomic absorption spectrometer. Values presented for heavy metals are therefore means of all samples analyzed per site.

**Data analysis**

Various indices including Transfer Factor of the heavy metals, Health Risk Index, Geo-accumulation index, and Pollution Load Index were used to analyze the data generated. Principal component analysis (PCA) was conducted to the physicochemical properties of the soil and the different heavy metals in the soil and across sites to find the possible sources of their origins. To determine the level of As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn contamination in soils in the area, heavy metal Geo-accumulation index (Igeo) and heavy metal contamination factor (CF) were used. Igeo is used to evaluate heavy metal contamination in terrestrial environment by comparing current concentrations with background levels (Muller, 1981). Geo-accumulation index was determined using the mathematical formula:

\[ I_{geo} = \log_2 \left( \frac{Cn}{1.5 \times Bn} \right) \]  \hspace{1cm} (1)

Where, Cn = average concentration of heavy metal measured in the soil; Bn= average geochemical background concentration of the same heavy metal (Mofor et al., 2017), 1.5 = background matrix correction factor due to lithogenic and anthropogenic influences.

According to Singh et al. (1999) values of Igeo are grouped in 7 classes describing various pollution levels, namely; unpolluted (Igeo< 0), unpolluted to moderately polluted (0< Igeo<1), moderately polluted (1< Igeo<2), moderately to strongly polluted (2< Igeo <3), strongly polluted (3< Igeo <4), strongly to very strongly polluted (4< Igeo <5), and very strongly polluted (Igeo >5).

The CF for each metal was calculated as indicated by Hakanson (1980) according to Equation 2. Values for CF<1 indicate low contamination, 1< CF<3 = moderate contamination, 3< CF<6 = considerable contamination; CF>6 = very high contamination.

\[ CF = \log_2 \left( \frac{Cm}{Bm} \right) \]  \hspace{1cm} (2)

where Cm = measured concentration of heavy metal in the soil and Bm = local background concentration value of the heavy metal (Mofor et al., 2017).

The extent of heavy metal accumulation from soil by the vegetables was determined using the heavy metal transfer factor (TF) as described by Cui et al. (2004). Heavy metal TF was determined as indicated in equation 3.

\[ Transfer \ factor \ (TF) = \frac{[Metal]_{vegetable}}{[metal]_{soil}} \]  \hspace{1cm} (3)

Where: TF stands for transfer factor for vegetable/soil system; [Metal]_{vegetable} is the total metal concentration in the edible portion of vegetable (mg/kg in dry matter); and [Metal]_{soil} is the total metal concentration in the soil where this vegetable was grown (mg/kg in dry matter).

Transfer quotient of 0.1 indicates that plant is excluding the element from its tissues, whereas TF values above 0.50 indicate high metal uptake by vegetable (Thornton & Farago, 1997). The greater the greater the chances of vegetables for metal contamination by anthropogenic activities will be and so the need for environmental monitoring of the area will be required (Sponza & Karaoglu, 2002).

Health risk associated with consumption of the vegetables was determined using the HRI (Equation 2). If the value of HRI is less than 1 then the exposed population is said to be safe (Integrated Risk Information System, 2003).
\[ \text{HRI} = \left( \frac{\text{DIM}}{\text{RfD}} \right) \] (4)

where HRI = Health risk index; DIM = Daily intake of metals; RfD = Oral reference dose for the metal.

The daily intake of heavy metals was estimated according to the average daily vegetable consumption by calculating the average Daily Intake of Metals (DIM) for adults using the equation 5 (Cui et al., 2004).

\[ \text{DIM} = \left( \frac{C_{\text{metal}} \times C_{\text{factor}} \times D_{\text{food intake}}}{\text{BW}} \right) \] (5)

Where: C metal = concentration of heavy metal in vegetable; C factor = conversion factor (0.085) as proposed by Rattan et al. (2005); D food intake = daily intake of vegetables (0.345 kg/person/day); BW average weight = average body weight of individuals (60 kg).

The RfD values for heavy metals analysed in this study were from the Codex Alimentarius commission (2013) and United States Environmental Protection Agency and Integrated Risk Information System (2006) (Table 2).

**Results**

**Soil amendments used by farmers in Santa**

The various agrochemicals used in the cultivation of these vegetables are potential sources of heavy metal contamination in vegetables. Different types of fertilizers and pesticides were used by the farmers who cultivate these vegetables (Table 6). These agrochemicals were analyzed to know their active ingredients and level of toxicity. The percentage of the respondents using these chemical and their toxicity levels were also recorded (Table 7). From our results, 98% of our respondents used both organic and inorganic fertilizer.

**Physicochemical properties of the soil**

Results of the physicochemical properties of soils from Santa (Table 3) and from the different study sites are presented in Table 8. Based on the soil triangle, the soil textural class of Akum, Mbei, Moforbe and Matazem were sandy loam, sandy loam, sandy loam and sandy clay loam respectively (Table 9). The pH of the study areas ranged between 4.2 and 6.1 across the study sites. The carbon/nitrogen ratio (11.41–13.49) was found to be medium according to the standard proposed by Beernaert and Bitondo (Table 4). According to the standard proposed by Beernaert and Bitondo (Table 5), the Ca values were very low (1.5–2 Cmol/kg), Mg values ranged from low to medium (0.90–2.60 Cmol/kg), K values were medium (0.40–0.60 Cmol/kg), Na values were very low (0.01–0.02 Cmol/kg).

**Heavy metal concentration in the soil and its relationship with the soil physicochemical parameters**

Based on the results on the heavy metal concentration in the soil (Table 10), As, Cd and Fe were found to be higher in the soils than their permissible limits by Food and Agricultural Organization/World Health Organization (2007). Cadmium, even though with very low values, had its concentration above its permissible limits.

Among the heavy metals that had a level of concentration above their permissible limit, As had a strong positive relationship with organic matter in the soil were the carrots were cultivated. Cadmium had a strong positive correlation with pH, organic C, K and CEC and a strong negative correlation with available P. Fe shows to have a strong positive correlation with Cd, Cu, Cr, Mn, Pb, Ca and Na (Figure 2).

The principal component analysis of heavy metal load and physicochemical parameters in the soil where carrots were cultivated, showed that, pH, OC, CEC, Cd, K and Mn were all closely associated with each other and with Matazem. High concentrations of Zn and Cr were more associated with Moforbe while high concentrations of Cu were more associated with Mbei (Figure 3).

As concerns the cabbage, all heavy metals that had a strong positive correlation with CEC also had a strong negative correlation with available P in the soil (Figure 4). Because of the strong negative correlation between CEC and available P, all heavy metals that were strongly positively correlated with CEC were by implication strongly negatively correlated with available P. Also, all heavy metals that were strongly positively correlated with Ca were equally strongly positively correlated with Na. Lastly, all heavy metals that had strong positive correlation with CEC, also had a strong positive correlation with OC. A close association existed between OC, CEC, Co, pH, K and Zn as per the principal component analysis and soil physicochemical properties in cabbage (Figure 5). These variables were more associated with Matazem.

**Uptake of heavy metals by plants**

In order to know the human exposure to heavy metals through the consumption of these vegetables, the
| Heavy metal | As     | Cd    | Co   | Cr | Cu | Fe | Mn | Ni  | Pb  | Zn   |
|------------|--------|-------|------|----|----|----|----|-----|-----|------|
| Reference Dose (RD) | 0.0004 | 0.001 | 0.0003 | 1.5 | 0.04 | 0.7 | 0.014 | 0.02 | 0.004 | 0.3  |

Source:
- United States Environmental Protection Agency and Integrated Risk Information System (2006)
- Codex Alimentarius commission (2013)
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Table 3. Soil physicochemical properties of the study areas in Santa, Cameroon

| Properties       | Mean values | Sources |
|------------------|-------------|---------|
| Soil texture     | 40% loamy: 10% clay loam: 10% sandy clay | Okha (2016) |
| Total N          | 2.43%       | This work |
| Soil pH          | 5.6         | Okha (2016) |
| C/N ratio        | 13.96       | This work |
| Organic matter   | 4.68%       | Okha (2016) |
| Ca Cmol/kg       | 1.66        | Okha (2016) |
| Mg Cmol/kg       | 1.31        | Okha (2016) |
| K Cmol/kg        | 0.67        | Okha (2016) |
| Na Cmol/kg       | 0.02        | Okha (2016) |
| CEC Cmol/kg      | 11.37       | Okha (2016) |

Table 4. Critical values of nutrient and soil properties

| Properties       | Critical values               |
|------------------|-------------------------------|
| OM               | <1 1–2 2–4.2 4.2–6 >6        |
| Total N          | <0.5 0.5–1 2–2.5 >2          |
| C/N              | <0.5 = good, 10–14 = medium and >14 = poor |
| Ca Cmol/kg       | <2 2–5 5–10 10–20 >20        |
| Mg Cmol/kg       | <0.5 0.5–1 1.5–3 >3          |
| K Cmol/kg        | <0.1 0.1–0.3 0.3–0.6 0.6–1.2 >1.2 |
| Na Cmol/kg       | <0.1 0.1–0.3 0.3–0.7 0.7–2.0 >2 |
| pH               | 2.3–6.0 = moderately acidic, 6.0–7.0 = slightly acidic, 7.0–8.5 = moderately alkaline |
| CEC Cmol/kg      | 0–20 21–40 41–60 61–80 81–100 |

Source: Beernaert and Bitondo (1992)

Table 5. Fertility index and rating of soils

| Rating          | Fertility Index (FI) |
|-----------------|----------------------|
| Very low        | 0–50                 |
| Low             | 50–75                |
| Medium          | 75–100               |
| Very high       | 150–300              |

Source: Beernaert and Bitondo (1992)

Transfer factor was considered an important indicator. Mostly, the concentrations of heavy metals were higher in soils than vegetables grown on the same soils. The mean TF of heavy metals in cabbage and carrot across the site shows that Co had the highest mean TF (0.70 and 0.64 for cabbage and carrot, respectively). Meanwhile, the mean concentration of Co in the soil was 2.04 and 2.19 for cabbage and carrot, respectively.

Fe had the lowest mean TF (0.10 and 0.02 for cabbage and carrot, respectively), surprisingly, Fe had the highest heavy metal concentration in the soil. The trend of the mean TF for both vegetables in all the study sites followed the order: Co > Cu > Pb > As > Ni > Zn > Mn > Cr > Cd > Fe while the trend of the mean heavy metal concentration in the soil followed the trend Fe>Mn>Zn>Cr>Cu>Pb>Ni>Co>As>Cd for cabbage and for carrot, the trend is as follows: Fe>Mn>Cr>Zn>Cu>Pb>Ni>Co>As>Cd. Comparing the metal uptake by both plants, cabbage head had a TF range between 0.008 and 0.832 and carrot root TF ranged from 0.00 to 0.674 for As and Co, respectively. It was also observed from the results (Table 11) that Mbei had the highest transfer factor (0.36) and Moferbe had the least (0.33).

Environmental risks associated with the cultivation of cabbage and carrot in Santa

Geo-accumulation indices (Igeo) of the heavy metals in the soils

The calculated Igeo index for heavy metal concentrations in the soils ranged from 0.18 to 159.20 in cabbage (Table 12) and from 0.19 to 169.27 in carrot (Table 13). Based on the Müller scale (1981), As, Cd, Cr, Cu, Pb, Ni

Table 6. Different fertilizers used in the cultivation of cabbage and carrot in Santa, Cameroon

| Properties       | Types of fertilizers | Percentage (%) |
|------------------|----------------------|----------------|
| Kind of fertilizer | Only Inorganic       | 2              |
|                  | Only Organic         | 0              |
| Type of inorganic fertilizer | NPK               | 48             |
|                  | Urea                 | 18             |
|                  | NPK + Urea           | 28             |
|                  | Phosphate fertilizer | 6              |

Table 7. Chemicals mostly used by farmers for the cultivation of cabbage and carrot in Santa, NWR, Cameroon, their heavy metal content and their level of toxicity

| Chemical         | Active ingredient | Percentages (%) of respondents using these chemicals | Heavy metals | Toxic class |
|------------------|-------------------|----------------------------------------------------|--------------|-------------|
| Pesticides       |                   |                                                    |              |             |
| Action (H)       | Diuron            | 30.1                                               | -            | III         |
| Round up (H)     | Glyphosate        | 12.3                                               | As (Lajmanovich et al., 2019) | III |
| Mancoze super (F)| Metalaxyl         | 5.5                                                | -            | III         |
| Ridomil Plus (F) | Mefenoxam         | 32.9                                               | -            | III         |
| Gramaxone (P)    | Paraquat          | 16.4                                               | -            | II          |
| Inorganic fertilizers | Urea          | 46                                                 | Ni, Pb, Cd (Benson et al. 2014) | II |
| NPK (20:10:10)   | N, P and K fertilizer | 76                                               | Pb, Cd, Cu and Mn (Milinovic, et al. 2008) | III |
| Phosphate fertilizer | Phosphate     | 6                                                  | Cu and Zn (Benson et al. 2014) | III |

Class II = Toxic, Class III = Harmful
Table 8. Physicochemical properties of soils from the different study sites in Santa, NWR, Cameroon

| Parameter          | Mbei | Moforbe | Akum   | Matazem |   |
|--------------------|------|---------|--------|---------|---|
| Soil pH            | 4.66 | 4.20    | 6.10   | 5.95    |   |
| Organic Carbon %   | 4.50 | 4.20    | 6.40   | 7.50    |   |
| Organic Matter%    | 8.10 | 8.12    | 7.29   | 9.10    |   |
| N %                | 0.70 | 0.58    | 0.52   | 0.58    |   |
| C/N                | 13.48| 11.41   | 12.41  | 11.65   |   |
| Ca (Cmol/kg)       | 2.0  | 1.5     | 1.5    | 2       |   |
| Mg (Cmol/kg)       | 1.20 | 2       | 0.90   | 2.60    |   |
| K (Cmol/kg)        | 0.60 | 0.40    | 0.70   | 0.80    |   |
| Na (Cmol/kg)       | 0.02 | 0.01    | 0.01   | 0.02    |   |
| CEC                | 9.5  | 9.2     | 12.4   | 16      |   |
| Available P(mg/kg) | 45.5 | 46.2    | 38     | 31.1    |   |

Table 9. Soil texture across the different study sites in Santa, NWR, Cameroon

| Soil texture Sites | Coarse sand | Fine sand | Silt | Clay |
|--------------------|-------------|-----------|------|------|
| Akum               | 23.12       | 39.99     | 27.89| 9.00 |
| Mbei               | 18.02       | 49.57     | 16.00| 14.00|
| Moforbe            | 11.02       | 51.08     | 16.00| 14.00|
| Matazem            | 12.00       | 58.67     | 23.00| 11.8 |

Table 10. Mean concentration of soil heavy metals where cabbage and carrot were cultivated in Santa, NWR, Cameroon

| Heavy metals | Cabbage soil (mg/kg) | Carrot soil (mg/kg) | Food and Agricultural Organization/World Health Organization (2007) (mg/kg) |
|--------------|----------------------|---------------------|-----------------------------------------------------------------------|
| As           | 1.16                 | 1.55                | 0.5                                                                   |
| Cd           | 0.87                 | 0.91                | 0.07                                                                 |
| Co           | 2.04                 | 2.19                | 10                                                                   |
| Cu           | 4.61                 | 4.65                | 6                                                                    |
| Cr           | 9.70                 | 10.07               | 65                                                                   |
| Fe           | 841.40               | 843.93              | 150                                                                  |
| Mn           | 27.10                | 45.68               | 45                                                                  |
| Ni           | 2.29                 | 2.27                | 75                                                                   |
| Pb           | 3.03                 | 3.08                | 10                                                                   |
| Zn           | 11.47                | 9.16                | 50                                                                   |

and Co in both Cabbage and Carrot soil were between unpolluted to moderately polluted. But in regard to Fe and Zn, they were in the moderately polluted rate across all the site and Mn was very strongly polluted across all the sites. Igeo due to the cultivation of cabbage and carrot showed the trend Mn > Fe > Zn > As > Pb > Cr > Ni > Co > Cu > Cd across all the sites.

Contamination factor (CF) and Pollution Load Index (PLI) of heavy metals in the soils in Santa

PLI across the study sites was in the order; Akum > Moforbe > Mataze > Mbei. Pollution Load Index (PLI) for soils in this study took into account the combined contamination factor of As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb and Zn (Tables 12 and 13). Results of the present study show that the CF values of some heavy metals such as Cd, Cr, Cu, and Ni in the study areas were moderately contaminated (1 < CF < 3) while contamination factor for metals such as As, Fe, Mn, Pb and Zn showed higher (3 < CF < 6) values.

Heavy metal contamination in cabbage and carrot

Across all the sites and in both vegetables, Fe had the highest concentration value ranging from 3.77 mg/kg to 302.31 mg/kg. Cadmium, on the other hand, had the lowest concentration value across all the sites and in both vegetables with a range of 0.12 mg/kg to 0.19 mg/kg and was equally within permissible limits. Values for heavy metal concentrations in carrot followed the order Fe > Mn > Zn > Cu > Co > Pb > Cr > Cd > Ni > As, while values for heavy metal concentrations in Cabbage followed the order Fe > Mn > Zn > Cu > Co > Pb > Cr > Ni > As > Cd.

Figure 2. Correlogram of heavy metals concentration in carrot and soil physicochemical parameters.
The concentrations of As, Co and Pb in both vegetables were higher than the permissible limit for human consumption while Cd, Cr, Ni, Cu, Fe, Mn and Zn were all below their permissible limits (Table 14). Comparing the concentration in carrot and cabbage, the mean heavy metal concentrations were higher in cabbage than in carrot. Nevertheless, some heavy metals such as As in Akum and Moferbe; Cd in Akum, Matazem and Moferbe; Cu in Mbei; Cr in Mbei; Mn in Moferbe; Pb in Mbei and Zn in Matazem were higher in carrot than cabbage.

**Health risk associated with the consumption of carrot and cabbage cultivated in Santa**

In carrot and cabbage, HRI >1 was observed only in Co (2.26 in carrot and 2.31 in cabbage). All the other heavy metals had their HRI<1. HRI in carrot followed the
order Co>As>Mn>Pb>Cd>Fe>Ni>Cu>Zn>Cr while the HRI in cabbage followed the order Co>As>Mn>Pb>Fe>Ni>Cu>Zn>Cd and Cr. Mean values for both vegetables indicated that HRI due to the consumption of cabbage was slightly above that of carrot (Table 15).
Table 13. Geo-accumulation index, contamination factor and pollution load index for studied heavy metals in soils used for the cultivation of carrot in Santa, NWR, Cameroon

|       | Igeo As | Igeo Cd | Igeo Co | Igeo Cu | Igeo Cr | Igeo Fe | Igeo Mn | Igeo Ni | Igeo Pb | Igeo Zn |
|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Akum  | 0.91    | 0.21    | 0.39    | 0.30    | 0.43    | 1.34    | 169.27  | 0.37    | 0.62    | 0.33    |
| Mbei  | 1.09    | 0.22    | 0.46    | 0.29    | 0.49    | 1.34    | 149.87  | 0.42    | 0.60    | 1.19    |
| Matazem | 0.86   | 0.20    | 0.38    | 0.29    | 0.50    | 1.46    | 138.23  | 0.46    | 0.61    | 1.21    |
| Moforbe | 1.29   | 0.19    | 0.37    | 0.29    | 0.50    | 1.54    | 151.80  | 0.42    | 0.64    | 1.13    |

Contamination Factor

|       | CF-As  | CF-Cd  | CF-Co  | CF-Cu  | CF-Cr  | CF-Fe  | CF-Mn  | CF-Ni  | CF-Pb  | CF-Zn  | PLI    |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Akum  | 4.57   | 1.06   | 1.92   | 1.46   | 2.14   | 6.71   | 846.33 | 1.83   | 3.09   | 1.65   | 5.93   |
| Mbei  | 5.43   | 1.08   | 2.31   | 1.44   | 2.43   | 6.70   | 749.33 | 2.1    | 2.98   | 5.96   | 7.38   |
| Matazem | 4.30   | 0.96   | 1.92   | 1.44   | 2.52   | 7.26   | 691.17 | 2.25   | 3.05   | 6.04   | 7.02   |
| Moforbe | 6.43   | 0.96   | 1.85   | 1.47   | 2.50   | 7.70   | 759.00 | 2.09   | 3.20   | 5.64   | 7.42   |

Table 14. Mean heavy metal concentrations in carrot and cabbage cultivated in Santa, NWR, Cameroon, compared with Food and Agricultural Organization/World Health Organization (2007) standards

| Heavy metals | Cabbage (mg/kg) | Carrot (mg/kg) | Food and Agricultural Organization/World Health Organization (2007) (mg/kg) |
|--------------|----------------|----------------|----------------------------------------------------------|
| As           | 0.51           | 0.38           | 0.20                                                     |
| Cd           | 0.15           | 0.16           | 0.30                                                     |
| Co           | 1.41           | 1.39           | 0.05                                                     |
| Cu           | 2.61           | 2.51           | 40                                                       |
| Cr           | 1.30           | 1.26           | 1.30                                                     |
| Fe           | 62.56          | 14.35          | 425                                                      |
| Mn           | 7.31           | 5.97           | 500                                                      |
| Ni           | 1.23           | 1.16           | 1.50                                                     |
| Pb           | 1.36           | 1.31           | 0.30                                                     |
| Zn           | 3.69           | 3.51           | 60                                                       |

Table 15. Mean values for the daily intake of metals and the health risk index of carrot and cabbage cultivated in Santa, NWR, Cameroon

| HRI | Carrot | Cabbage |
|-----|--------|---------|
| As  | 0.46   | 0.62    |
| Cd  | 0.08   | 0.00    |
| Co  | 2.26   | 2.31    |
| Cr  | 0.00   | 0.00    |
| Cu  | 0.02   | 0.02    |
| Fe  | 0.04   | 0.04    |
| Mn  | 0.21   | 0.26    |
| Ni  | 0.03   | 0.03    |
| Pb  | 0.16   | 0.17    |
| Zn  | 0.01   | 0.01    |

Discussion

Based on the soil triangle, the soil textural class of Akum, Mbei, Moforbe and Matazem are sandy loam, sandy loam, sandy loam and sandy clay loam, respectively. There was therefore more of sand than silt and clay. Soils of this nature are reported by Dube et al. (2001) to cause more dispersion of contaminants because of their high porosity and permeability. The pH of the study areas ranged between 4.2 and 6.1 across the study sites, indicating acidic soil. A similar result was reported by Okha (2016) who carried out a research on a comparative study of changes in soil quality under two cropping systems in Santa and found out that the soils were moderately acidic. Such weak acidic pH in the study area can be attributed to agricultural inputs such as pesticides, fungicides and fertilizers (Fonge et al., 2017). Acidification has the ability to increase the mobility and uptake of heavy metals in the soil (Yang et al., 2010). This can therefore be hazardous since vegetables are known to take up and accumulate heavy metals from contaminated soils in their edible portions (Wei et al., 2005).

The carbon/nitrogen ratio (11.41–13.49) was found to be medium according to the standard proposed by Beernaert and Bitondo. This is an indication that microbial activity in the soils was slow, leading to low organic matter production. This could have been the cause of more fertilizer application by farmers to improve fertility and to meet up with demand. Therefore, continuous indiscriminate use of these fertilisers has altered the nature of the soil and led to an increase in the concentration of some heavy metals in the soil and vegetable. According to the standard proposed by Beernaert and Bitondo, the Ca values were very low (1.5–2 Cmol/kg), Mg values ranged from low to medium (0.90–2.60 Cmol/kg), K values were medium (0.40–0.60 Cmol/kg), Na values were very low (0.01–0.02 Cmol/kg). This generally low presence of exchangeable cations can be
caused by nutrient wash down (leaching) which is prompted by low organic matter. Leaching washes down nutrients and reduces soil fertility, this causes farmers to apply more organic fertilizers to the soils (Okha, 2016).

Heavy metal contamination in the soil

As, Cd and Fe were found to be higher in the soils than their permissible limits by Food and Agricultural Organization/World Health Organization (2007). Very high concentrations of total and available Fe could be from the soil parent materials which are natural sources of Fe in the soils in Santa (Mofor et al., 2017). According to Ruqia et al. (2015), excess amount of Fe more than 10 mg/kg in human blood causes rapid increase in pulse rate, coagulation of blood in blood vessels, hypertension and drowsiness. Cadmium, even though with very low values, had its concentration above its permissible limits. Cadmium has been found to be a common additive to phosphate fertilizers (Asongwe et al., 2014). From our study, 6% of respondents used phosphate fertilizers for the cultivation of these vegetables.

Among the heavy metals that had a level of concentration above their permissible limit, As had a strong positive relationship with organic matter. Studies have proven that, the addition of fermented livestock droppings on the soil has been known to have greater potential to increase the risk of arsenic solubilization than plant-based composts (Suda & Makino, 2016). And from our results, 98% of our respondents used both organic and inorganic as fertilizer. Therefore, increase in organic matter here could be the reason for increase in As uptake by plants. Arsenic also had a positive correlation with Ca, Mg and Na, the main ions associated with CEC. Cadmium had a strong positive correlation with pH, organic C, K and CEC and a strong negative correlation with available P. Soil pH has the ability of controlling Cd availability and plant uptake (Barančíková et al., 2004). Low pH favors increased solubility and accumulation of Cd in the soil (Kirkham, 2006). Fe shows to have a strong positive correlation with Cd, Cu, Cr, Mn, Pb, Ca and Na. Given that Santa is characterized by ferralitic soils, the presence of Fe in the soil has the ability to attract other heavy metals.

The principal component analysis in carrot soils showed that, pH, OC, CEC, Cd, K and Mn were all closely associated with each other and with Matazem. High concentrations of Zn and Cr were more associated with Moferbe while high concentrations of Cu were more associated with Mbei.

With respect to cabbage, all heavy metals that had a strong positive correlation with CEC, had a strong negative correlation with available P. Because of the strong negative correlation between CEC and available P, all heavy metals that are strongly positively correlated with CEC are by implication strongly negatively correlated with available P. The strong negative correlation between CEC and AP is owing to the fact that as CEC increases, the increasing number of cations bind to the available P since Phosphorus is an anion. Hence, as the CEC increases, the concentration of available P decreases. Also, all heavy metals that are strongly positively correlated with Ca are equally strongly positively correlated with Na. This may be due to the strong positive correlation that exists between Ca and Na which implies that they are either influencing each other or are both under the influence of one or more variables. In view of this observation, further research is required to investigate the possibility of using the concentrations of Ca and Na in the soil as an indicator of the need to investigate heavy metal load in cabbage. All heavy metals that have strong positive correlation with CEC also have a strong positive correlation with OC. This may be due to the strong positive correlation between CEC and OC. In view of both cabbage and carrot, the heavy metal load was somewhat dissimilar. This implies that soil physicochemical parameters influence the uptake of heavy metals in cabbage and carrot differently.

A close association exists between OC, CEC, Co, pH, K and Zn as per the principal component analysis and soil physicochemical properties in cabbage. These variables were more associated with Matazem. The association of OC with Matazem may be due to the use of organic manure as soil supplements. The increasing use of OC may be responsible for the association of high levels of CEC with Matazem if the sources of organic carbon are rich in cations. Moreover, increasing OC may also alter soil pH if is the source of organic carbon is rich in acidic and basic ions. Ca, Na, Cd, Cu and Pb were closely associated while Cr, Mn, C/N and N were equally closely associated. Available P was opposite to most of the other variables, explaining the inverse relationship between available P and most of these variables. This may be due to the fact that Phosphorus is a more negative ion.

Uptake of heavy metals by plants

Mostly, the concentrations of heavy metals are higher in soils than vegetables grown on the same soils. This indicates that only a small portion of soil heavy metals
is transferred to the vegetables and the root acts as a barrier to the translocation of heavy metals within plant (Davies & White, 1981). TF greater than 1 indicates higher transfer factor and represents relatively poor retention in soils or greater efficiency of plants to absorb metals. Low coefficient demonstrates the strong sorption of metals to the soil colloids. Also, according to Sponza and Karaoglu (2002), TF >0.50, indicates the greater chances of metal contamination on vegetables by anthropogenic activities. The mean TF of heavy metals in cabbage and carrot across the site shows that, Co had the highest mean TF (0.70 and 0.64 for cabbage and carrot respectively). Meanwhile, the mean concentration of Co in the soil was 2.04 and 2.19 for cabbage and carrot respectively.

While Fe had the lowest mean TF (0.10 and 0.02 for cabbage and carrot respectively), surprisingly, Fe had the highest heavy metal concentration in the soil. The trend of the mean TF for both vegetables in all the study sites followed the order: Co > Cu > Pb > As > Ni > Zn > Mn > Cr > Cd > Fe while the trend of the mean heavy metal concentration in the soil followed the trend Fe>Mn>Zn>Cr>Cu>Pb>Ni>Co>As>Cd for cabbage and for carrot, the trend is as follows: Fe>Mn>Cr>Zn>Cu>Pb>Ni>Co>As>Cd.

Comparing the metal uptake by both plants, cabbage head had a TF range between 0.008 and 0.832 and carrot root TF ranged was from 0.00 to 0.674 for As and Co, respectively. This implies that cabbage has a higher TF (potential to take up heavy metals) than carrot, and both vegetables have higher transfer factor than their soils (Figure 6). This is in accordance with Ilya et al. (2001) who found higher heavy metal levels in members of Brassicaceae especially in both shoots and roots. Wang et al. (2008) and Wei and Liu (2005), showed that cabbage absorbs more metals than other leafy vegetables and may be a candidate plant to remediation of soil contaminated with heavy metal. This therefore shows that, the uptake and bioaccumulation of heavy metals in vegetables is influenced by many factors such as the type of vegetable, the degree of maturity of the plants, the part of the vegetable were the heavy metal is to be determined, the concentrations of heavy metals in the soil, the nature of soil, climate, atmospheric and deposition (Scott et al., 1996; Voutsa et al., 1996). The highest transfer factor recorded by Co shows that the soil did not retain much of the Co and it moved substantial to the vegetable. The lowest transfer factor recorded for Fe and Cd also showed that it might have remained bound in the soil.

Generally, the heavy metal concentration in the soil was inversely related to transfer factor. When the heavy metal concentration in the soil was high, its TF was low and vice versa. This trend was observed in all heavy metals except for Zn. It was therefore observed that even though Fe had the highest concentration in the soil, it had the lowest TF—confirming the inverse relationship that exists between TF and concentration of heavy metals in the soil. This also suggests that the soil may not be the only source of Fe enrichment in these crops—other sources such as aerosols may also be implicated. De Temmerman and Hoenig (2004) stated that heavy metals through aerosols get absorbed on aerial surfaces of the plants. Sharma et al. (2004) reported that, relatively high Fe concentration (3.30 mg/kg—15.80 mg/kg) in vegetables can reduce...
the uptake of Cd from the soil. This goes to confirm the result observed in this study in which Fe recorded the highest concentration in the vegetables while Cd recorded the least TF (except for Fe).

Mbei had the highest transfer factor (0.36) and Moferbe had the least (0.33). The sites at Mbei were closest (1 m) to the road. There could have therefore been particulate matter released from vehicular emissions and taken up by the vegetables in this area. Heavy metals from particulate matter and from the soil therefore increased the transfer factor of heavy metals in the vegetables from Mbei.

**Environmental risks associated with the cultivation of carrot and cabbage in Santa**

**Geo-accumulation indices (Igeo) of the heavy metals in the soils**

Based on the Müller scale (1960), As, Cd, Cr, Cu, Pb, Ni and Co in both Cabbage and Carrot soil were between unpolluted to moderately polluted. This suggests that the present concentration of some of these metals in the soils of Santa reflect the background values of these heavy metals in this region. But with regard to Fe and Zn were in the moderately polluted rate across all the site and Mn was very strongly polluted across all the sites. This shows that Fe, Mn and Zn exceeded greatly their background values. Igeo due to the cultivation of Cabbage and Carrot showed the trend Mn > Fe > Zn > As > Pb > Cr > Ni > Co > Cu > Cd across all the sites.

**Contamination factor (CF) and Pollution Load Index (PLI) of heavy metals in the soils in Santa**

PLI across the study sites was in the order; Akum > Moferbe > Mataze > Mbei. Pollution Load Index (PLI) for soils in this study took into account the combined contamination factor of As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb and Zn. Pollution severity and its variation along the sites and vegetables were determined with the use of pollution load index. This index is a quick tool in order to compare the pollution status of different places. Results of the present study show that the CF values of some heavy metals such as Cd, Cr, Cu, Co and Ni in the study areas were moderately contaminated (1 < CF < 3) while contamination factor for metals such as As, Fe, Mn, Pb and Zn showed higher (3 < CF < 6) values. This high values of CF may be as a result of unsustainable agricultural activities and other direct anthropogenic drivers such as fertilizers, pesticides, herbicides and fungicides (Fonge et al., 2017), dumping of large quantities of solid waste, deforestation and soil erosion (Mofor et al., 2017). This implies that all the sample sites in this study were polluted according to Harikumar et al. (2009) who stated that, PLI value > 1 indicates pollution, whereas PLI < 1 indicates no pollution. Pollution in soil has adverse effect on plant growth (Seyed & Ebrahim, 2005). Pesticides not only bring toxic effect on human and animals but also decrease the fertility of the soil which is the reason for fertilizer application. Tóth et al. (2016), reported that, the effects of soil pollution are: reduced soil fertility, reduced nitrogen fixation, larger loss of soil and nutrients, reduced crop yield, create toxic dusts, poison children playing in the area and imbalance in soil fauna and flora.

**Heavy metal contamination in cabbage and carrot**

Heavy metal accumulation from soil to plant depends on the nature of soil, plant species and type of metal and soils (Albanese et al., 2008). Across all the sites and in both vegetables, Fe had the highest concentration value ranging from 3.77 mg/kg to 302.31 mg/kg. It was, however, within the permissible limits for human consumption. Cadmium, on the other hand, had the lowest concentration value across all the sites and in both vegetables with a range from 0.12 mg/kg to 0.19 mg/kg and was equally within permissible limits. Values for heavy metal concentrations in carrot followed the order 

\[
Fe > Mn > Zn > Cu > Co > Pb > Cr > Cd > Ni > As
\]

As, Co and Pb in both vegetables were higher than the permissible limit for human consumption while Cd, Cr, Ni, Cu, Fe, Mn and Zn were all below their permissible limits. This could be explained by the relatively high transfer factor observed in As, Co and Pb. The heavy metals which were above their permissible limit (As, Co and Pb) are all also in the second and third group of heavy metals as classified by Fernández et al. (1992). The second group consists of metals with no known biological function and toxic if present in concentrations above trace amounts. The third group of heavy metals and evidently the most dangerous group also serve no known biological function and are toxic at all concentrations; hence, their presence in food is not beneficial for human health. Comparing the concentration in carrot and cabbage, the mean heavy metal concentrations were higher in cabbage than in carrot. This is in agreement with Gyorgy and Krisztina (2009), who found out that carrot leaves accumulate heavy metals in higher concentration than its roots. This is as a result of diffusion that occurs at the level of the roots, where nutrient ions always move from an area of higher concentration to an area of lower concentration up the concentration gradient.
Nevertheless, some heavy metals such as As in Akum and Moferbe; Cd in Akum, Matazem and Moferbe; Cu in Mbei; Cr in Mbei; Mn in Moferbe; Pb in Mbei and Zn in Matazem were higher in carrot than cabbage. The closeness of site 1 and 4 to the highway may have served as an additional source of Pb enrichment. This could be an indication that though officially there is a change from the use of leaded fuel to unleaded, fuel from unofficial markets may still be leaded. Furthermore, owing to the fact that this change is quite recent, leaded fuel may still be a source of Pb enrichment since Pb from gasoline is normally found in aerosol particles for a long time after the introduction of unleaded fuel. Also, according to Ngole (2016), cultivation areas near highways are also exposed to atmospheric pollution in the form of metal containing aerosols.

**Health risk associated with the consumption of carrot and cabbage cultivated in Santa**

The Health Risk Index (HRI) shows the dangers of consuming vegetables having high quantities of heavy metals. In carrot and cabbage, HRI > 1 was observed only in Co (2.26 in carrot and 2.31 in cabbage). This could be attributed to the high Transfer Factor value and high mobility rate of Co. Also water soluble Co has a high uptake by crop plants (Kabata & Beeson, 1961). On the contrary, Cr has a low mobility ability and a low transfer factor. This is also because has no specific transporter and mostly accumulates in plant roots (Muhammad et al., 2017). All the other heavy metals had their HRI < 1. HRI in carrot followed the order Co>As>Mn>Pb>Cd>Fe>Ni>Cu>Zn>Cr while the HRI in cabbage followed the order Co>As>Mn>Pb>Fe>Ni>Cu>Zn>Cd and Cr. Mean values for both vegetables indicated that HRI due to the consumption of cabbage was slightly above that of carrot. According to Integrated Risk Information System (2003), if HRI > 1 for a heavy metal, the exposed population is said not to be safe from heavy metal contamination upon consuming that vegetable. The accumulation of these heavy metals in the human system has been known to cause serious health hazards to humans due to the consumption of such contaminated vegetables (Gupta et al., 2020).

**Conclusion**

The soils where carrot and cabbage were cultivated in Santa contained high levels of As, Cd and Fe above Food and Agricultural Organization/World Health Organization (2007) standards. This explains why these two vegetables had elevated levels of As, Co and Pb in their edible parts. Given that Co>1 was observed with the HRI, these crops are at risk of causing diseases to man. High level of these heavy metals are known to be detrimental to the human health. Heavy metals have been known to cause a range of diseases. If this indiscriminate use of agrochemicals is not checked in these study areas, heavy metal contamination may jeopardize the lives of consumers of these vegetables. It is suggested that the use of agrochemicals should be controlled and organic farming should be encouraged.

**PUBLIC INTEREST STATEMENT** Cabbage and carrots grown in Santa Cameroon, together with the soils on which they were grown were tested for the presence of heavy metals. Results showed that both the cabbage and carrots together with the soils on which they were grown were found to have heavy metal levels above threshold values set by International organizations regulating food safety. Some of these toxic heavy metals have been reported to cause cancer, neurological ailments amongst others. This is, therefore, a point of concern on the health of consumers of these vegetables. It is recommended that periodic monitoring of these sites be carried out and appropriate measures be taken by the Ministry of Agriculture to sensitize these vegetable growers on the health risks associated with indiscriminate use of agrochemicals and educating them on the health benefits of organic farming, which improves the soil structure and enhances both the growth, yield and the nutritional quality of the crops.

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