# Determination of Heavy Metals in Soil and Some Selected Vegetables Irrigated with Waste Water Along Asikolaye Stream Kaduna, Nigeria

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**Abstract: Contamination of soil and vegetables with heavy metals may be caused by irrigation with water contaminated by domestic waste, fertilizers and agrochemicals. Studies have shown that vegetables can absorb some heavy metals from waste water used for irrigation by farmers and these heavy metals can accumulate in the body when these vegetables are consumed. This study was conducted to determine the level of some heavy metals in vegetables, soil and irrigation waste water along Asikolaye stream, Kaduna. A total number of 18 soil samples, 24 water samples and 18 vegetables were randomly collected and analysed for Lead, Cadmium, Zinc, Iron and Copper using atomic absorption spectrophotometer. Trace amount of Lead was found in spinach soil while high concentration of Lead exceeding maximum permissible limit (MPL) of World Health Organisation (WHO) was observed in cabbage soil and lettuce soil. However, low concentration of Cadmium, Zinc, Iron and Copper were observed in the analysed soil samples. Irrigation waste water were found to contain high level of Pb, Cd and Fe exceeding MPL of WHIO. Furthermore, Vegetables were found to contain high level of Pb and Cd exceeding the MPL set by WHO while Zn, Fe and Cu were found in low concentration. It was concluded that Vegetables cultivated at Asikolaye farm are unwholesome for consumption because they contain some heavy metals that are toxic to the body.**

**Keywords: Irrigation, Agrochemicals, Unwholesome**

## 1. Introduction

Waste water can be described as any household effluent consisting of black water (excrete, urine and associated sludge) and gray water (kitchen and bathroom waste water). Waste water re-use has also spread to areas below urban centers as a replacement for clean water used for irrigation (Scott *et al*., 2004). In most cities in Nigeria, waste water is also used for the irrigation and cultivation of vegetables in dry season because of the scarcity of clean water (Wajahat *et al.,* 2006; Aljaloud, 2010). During dry season, the use of waste water to irrigate farm land provides a lot of vegetables (like spinach, tomato, onion, lettuce, carrot and cabbage, among others) and thus a means of subsistence for many citizens (Sarkin-Noma *et al.,* 2013). The amount of waste water produced from domestic, industrial and commercial sources has increased with population, urbanization, improved living conditions and economic growth.

Soil is one of nature's essential and useful resources, which has complex functions that are beneficial to both human and other living organisms (Addis and Abebaw, 2014). It also serves as a method of filtering, buffer storage, transformation and thus protects the global ecosystem from the harmful effects of environmental contaminants (Sumithra *et al.,* 2013).

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In all industrialized areas of the country, soil contamination has become a serious problem. Soil is equally regarded as the ultimate sink for pollutants released into the environment (Shokoohi *et al*., 2009). There have been increasing attentions in the last few decades in both developing and developed countries on the environmental problem of soil pollution associated with heavy metals (Wu *et al*., 2014). This is assisted by the unorganized increasing urban expansion, industrial developments coupled with inadequate waste management, which causes significant alterations in the physical environment and increases accumulation of municipal waste. Soil which enables growing of plant and human activities is mostly affected. Urban areas are known for high level of industrial activities which generate more pollutants. Soil is a vital resource for sustaining basic human needs, quality food supply and a livable environment and it serves as a sink and recycling factory for both liquid and solid wastes (Oyedele *et al.,* 2008).

Heavy metals refer to any metal element whose density is relatively high and even at low concentration is toxic or poisonous. The consequences of contamination of heavy metal (embracing metalloids) are of great concern, especially in the agricultural production system (Kachenko and singh, 2006). The consumption of vegetables accumulated with heavy metals has adverse effect in the human body. Each metal has particular indication of its harmfulness. However, it has been documented that the following typical signs are linked to gastrointestinal (GI) disorders, diarrhea, stomatitis, tremor, hemoglobinuria causing stool rust-red color, ataxia, paralysis, vomiting and convulsion, depression, and pneumonia and respiratory disease (Asfaw *et al.,* 2013).

Vegetables are tender edible shoots of plants and spices that are eaten whole or partly, raw or cooked as a complement to starch foods. Vegetables which are an essential part of the human diet, are important edible crops and they are extremely nutritious and as important source of carbohydrates, vitamins and fibres as well (Hu *et al.,* 2013). Because of the presence of mineral elements such as calcium, iron, sulfur, potassium and vitamins such as vitamin A, B and C, they play an important role in maintaining good health. They help to provide strong bone, teeth and protect the body from diseases. They also act during digestion as neutralizing agents for the formation of acidic substances. The study is aimed to determine the level of some heavy metals in soil where vegetables were cultivated, the vegetables (lettuce, cabbage and spinach) and the waste water used for irrigating the vegetables.

## 2. Materials and Methods

### 2.1 Study Area

#### 2.1.1 Sampling Area

The study was conducted in Asikolaye of Kaduna South Local Government Area of Kaduna State in Northern part of Nigeria. It lies within latitude 10034’30” N and longitude 70 22’ 30’’ E. At the bank of the stream are vegetable farms in which farmers use the water for irrigation especially during dry season. Household waste are also dumped close to the stream, as a result the stream has turned into a dumpsite thereby polluting the water used for irrigation in terms of colour, odour and taste.

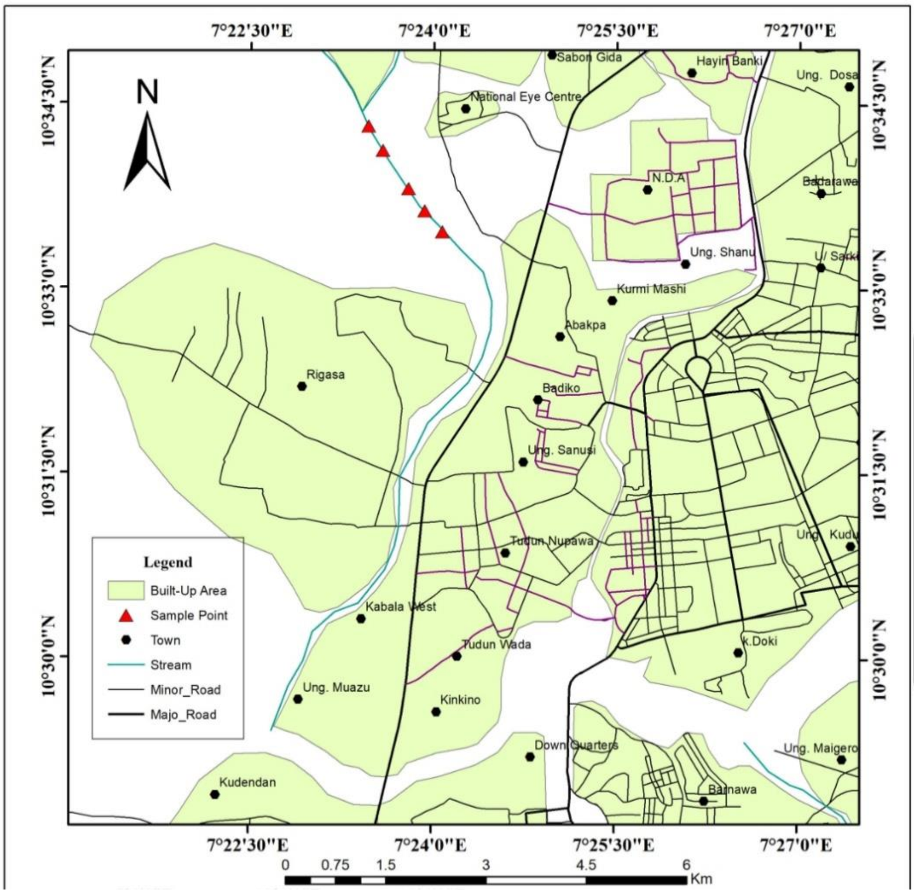


Figure 1: Map of study area showing sampling points

Source: Kaduna Geographic Information Service. (KADGIS,2021)

### 2.1.2 Soil Sample Collection

The soil that was used to grow the vegetables were randomly collected from the location. Soil samples were collected for six months (from January to December, 2020). A total of 18 soil samples (6 from each farm where vegetables were cultivated) were collected. An auger of 0-15cm depth was used to collect the soil. The soil sample was then placed in clean plastic bag, labeled and transported to the laboratory for analysis

### 2.1.3 Soil Digestion

In the laboratory, the soil samples were air dried and pounded to powdery form using a pestle and mortar. Method of soil digestion were adopted from Association of Official Analytical Chemist (1984). The sample was sieved with a 2mm sieve. The soil sample (1g) was weighed into a digestion flask. Concentrated nitric acid (20ml) was added and the mixture was heated using hot plate. After heating, it was allowed to cool and 30 ml of distilled water was added and filtered with Whatman filter paper and a digest was obtained. The digest was made up to 50 ml solution with distilled water and kept for analysis.

### 2.1.4 Water Sample Collection and Preservation

The procedure for water sample collection and analysis was adopted from American Public Health Association (APHA, 2005). Three sampling points 200 meters apart were established along the stream. Sampling point A was the downstream and it is the first point of water collection. Sampling point B was midstream, 200 meters away from point A, while sampling point C was upstream and which is also 200 meters from sampling point B. Control sample was collected from a well water which was 500m away from the study area. Sample containers were thoroughly washed with detergent, rinsed with water followed by distilled water before soaking in 5% nitric acid for about 24 hours. Water sample was collected from each of the three sampling points by simple scooping using plastic bucket on monthly basis for six months. Collected water sample was poured into the washed 2-litre polypropylene container.

### 2.1.5 Water Sample Preparation

The samples were digested according to Standard methods for the examination of water and wastewater, American Public Health Association (APHA, 2005). Each sample was thoroughly mixed, 20ml was transferred into a conical flask, 10ml concentrated nitric acid was added and brought to slow boiling before evaporating on a hot plate to lowest volume (5-10ml). Concentrated nitric acid was added as necessary until digestion was complete as shown by light colour clear solution. The digest was filtered into 50ml volumetric flask and made up to the mark. The digest was then used for the heavy metal analysis.

### 2.1.6 Sample Collection and Treatment of Vegetables

The vegetables analyzed are spinach, cabbage and lettuce. Samples were collected from (January to December, 2020), from three different farms in the site at each visit. Sample collection was done during dry season because irrigation of vegetables was mostly done during that period. Each sample was randomly handpicked, wrapped in a big brown envelope and labeled. In the laboratory, each sample was washed with tap water and thereafter with distilled water and then dried in an oven at 80°C (Larry and Morgan, 1986). At the end of the drying, the oven was turned off and left overnight to enable the sample cool to room temperature. Each sample was grounded into a fine powder, sieved and finally stored in a 250 cm3 screw capped plastic jar appropriately labeled.

### 2.1.7 Digestion Procedure of Vegetable Sample

Method of wet digestion was adopted from American Public Health Association (APHA, 2005). Digestion and analysis Duplicates of each vegetable sample were weighed (0.2 g) into digestion flasks and treated with concentrated 10 ml HNO3 and 5 ml H2SO4. A blank sample was also prepared using 10 mL of HNO3 and 5 mL of H2SO4 into empty digestion flask (Sahito et al., 2002). The flasks were heated for 2h on an electric hot plate (HP 220, UTEC Products Inc., and Albany N.Y., USA) at 80–90 °C before the temperature was raised to 150 °C at which the samples were made to boil. Concentrated HNO3 and H2SO4 were further added to the sample (3–5 mL of each was added occasionally) and digestion continued until a clear solution was obtained. The solution was allowed to cool and then filtered with Whatman 's No. 42 filter paper. It was then transferred quantitatively to a 50 mL volumetric flask topped up to the mark with deionized water. The digested 50 mL filtrate solution was transferred into an acid rinsed polyethylene sample container with label for analysis.

### 2.1.8 Analysis of Samples

The digests were used for determination of heavy metals (Pb, Cd, Zn, Fe and Cu) using the Atomic Absorption Spectrophotometer (AAS) model AA 220 at Ahmadu Bello University, Zaria, Nigeria. Each digest was determined in triplicates.

### 2.2 Data Analysis

Concentrations of heavy metals obtained from the analysis were expressed as mean ± SD (standard deviation) using SPSS 17.0. One-way ANOVA was used to compare means among treatments and differences resulting in $p < 0.05$ were considered significant.

## 3. Results and Discussions

The mean concentration of heavy metals in waste water used for irrigating the vegetables were shown in (Table 4.1). The concentration of Pb, Cd and Fe in waste water used for irrigation were found to have exceeded the maximum permissible limit set by WHO/FAO as standard in water while that of Zn and Cu were below MPL. The concentrations of Pb, Cd, Zn, Fe and Cu in waste water ranged from 0.128-0.224, 0.05-0.081, 0.134-0.395, 1.554-1.838 and 0.006-0.028 mg/l respectively.

The concentration of Pb in cabbage soil, lettuce soil and spinach soil were 2.019 ± 0.51, 2.473 ± 0.417 and 0.481 ±0.6 mg/kg. Concentration of Cd in cabbage soil, spinach soil and lettuce soil were 0.08±0.06, 0.092 ±0.05, 0.098±0.05 and have not exceeded the maximum permissible limit of 0.2 mg/kg set by WHO/FAO. The concentrations of Zn were 0.788±0.67, 1.306 ±1, and 0.078±0.001 in cabbage soil, spinach soil and lettuce soil respectively and were observed to be below the Maximum permissible limit of 5-10.0 set the WHO/FAO. The concentrations of Fe and Cu in all the vegetables soil analysed were also below the MPL set by WHO/FAO. The concentrations of Fe were 6.578±546, 4.071 ±4.58 and 4.074±4.03 mg/kg while that of Cu were 0.105±0.11, 0.081±0.12 and 0.087±0.11 mg/kg.

The concentrations of heavy metals in the vegetables irrigated with waste water were shown in Table (4.4). Pb and Cd were found to be above Maximum permissible limit set by WHO/FAO while Zn, Cd and Fe were observed to be below the standard set by WHO/FAO. The concentrations of heavy metals in the vegetables ranged from 0.347-0.940, 0.375-0.714, 0.509-1.596, 2.618-4.92 and 0.028 -0.096 mg/kg for Pb, Cd, Zn, Fe and Cu respectively.

Table 1: Mean Concentration (mg/l) of Heavy Metals in Waste Water used for Irrigation

| Heavy metals | Point 1 | Point 2 | Point 3 | Control | WHO/FAO |
|---|---|---|---|---|---|
| Pb | 0.224± 0.23 $^{a}$ | 0.128±0.2 $^{a}$ | 0.212±0.34$^{a}$ | 0±0$^{b}$ | 0.01 |
| Cd | 0.068±0.05$^{a}$ | 0.05 ±0.05$^{a}$ | 0.081±0.07 $^{a}$ | 0.1±0 | 0.02 |
| Zn | 0.395±0.94$^{a,b}$ | 0.137 ±0.29$^{b}$ | 0.134±0.25$^{b}$ | 0.07±0.2 | 5.0 |
| Fe | 1.383±1.23$^{b}$ | 2.209 ±1.81$^{b}$ | 1.554±0.93$^{b}$ | 0±0$^{a}$ | 0.3 |
| Cu | 0.006±0.01$^{a, b}$ | 0.28±0.03$^{b}$ | 0.28±0.04$^{b}$ | 0.063-0.4$^{a}$ | 2.0 |

Values are presented as mean± standard deviation (SD)

Values with different superscript across a row are significantly different

Pb = Lead, Cd = Cadmium, Zn = Zinc, Fe = Iron, Cu = Copper

Table 2: Mean Concentrations (mg/kg) of Heavy Metals in soil where the Vegetables were cultivated

| Heavy metals | Cabbage soil | Spinach soil | Lettuce soil | WHO/FAO Standard |
|---|---|---|---|---|
| Pb | $2.019\pm 0.51^{b}$ | $0.481\pm0.6^{a}$ | $2.473\pm0.417^{b}$ | 1.0-7 |
| Cd | $0.08\pm0.06^{b}$ | $0.092\pm0.05^{b}$ | $0.098\pm0.05^{b}$ | 0.2 |
| Zn | $0.788\pm0.67^{a}$ | $1.306\pm1^{a,b}$ | $0.078\pm0.001^{a}$ | 5-10.0 |
| Fe | $6.578\pm5.46^{a}$ | $4.071\pm4.58^{a}$ | $4.074\pm4.03^{a}$ | 15.0 |
| Cu | $0.105\pm0.11^{b}$ | $0.081\pm0.12^{b}$ | $0.087\pm0.11^{b}$ | 0.6-6.0 |

Values are presented as mean± standard deviation (SD)

Values with different superscript across a row are significantly different

Pb = Lead, Cd = Cadmium, Zn = Zinc, Fe = Iron, Cu = Copper

Table 3: Mean Concentrations (mg/kg) of Heavy Metals in Vegetables Irrigated with Waste water

| Heavy metals | Cabbage | Lettuce | Spinach | WHO/FAO Standard |
|---|---|---|---|---|
| Pb | $0.347\pm 0.35^{a}$ | $0.514\pm0.244^{a}$ | $0.940\pm0.301^{a}$ | 0.3 |
| Cd | $0.375\pm0.100^{a,b}$ | $0.608\pm0.211^{a,b}$ | $0.714\pm0.203^{a}$ | 0.2 |
| Zn | $1.022\pm1.33^{a}$ | $0.509\pm0.509^{a}$ | $1.596\pm1.05^{a}$ | 6.0 |
| Fe | $2.618\pm1.27^{a}$ | $4.92\pm4.86^{a,b}$ | $2.671\pm2.23^{b}$ | 42.5 |
| Cu | $0.028\pm0.04^{b}$ | $0.061\pm0.06^{b}$ | $0.096\pm0.09^{b}$ | 4.0 |

Values are presented as mean± standard deviation (SD)

Values with different superscript across a row are significantly different

Pb = Lead, Cd = Cadmium, Zn = Zinc, Fe = Iron, Cu = Copper

**4. Discussion**

The study conducted at Asikolaye vegetable Farms, have shown that some of the selected vegetables, soil and water contain variable concentration of different heavy metals. Pb and Cd are anthropogenic metals i.e without human activity they are normally not abundant in water or soil (Al-Turaki and Helal, 2004). The concentration of Pb, Cd and Fe in waste water were high and have exceeded their respective permissible limit threshold. While that of Cu and Zn were found in trace amount and well below MPL threshold. Udiba et al., (2014), reported of high concentration of Cadmium in river Galma as a result of high industrial activity that is taken place near the river. Population explosion, rapid urbanization, industrial and technological expansion, waste generation from domestic and industrial sources have rendered many water bodies unwholesome and hazardous to man and aquatic organisms. Contamination of irrigation water by heavy metals can be attributed to the availability of waste containing metals at the dumpsite that leached into the water.

Trace amount of Cd, Zn, Fe and Cu were observed in soil where the vegetables were cultivated and they were below the permissible limits set by WHO/FAO in agricultural soil. However, Pb was observed to be high and have exceeded the MPL in cabbage and lettuce soil only, with the exception of spinach soil which was also found in trace concentration. The low level of Cd, Zn, Fe and Cu that was observed in the soil is an indication of non-existence of any industrial activity and other activities that can introduce high amount of heavy metals into the soil like metal production, battery production, mechanic workshops, location of the farm far away from express roads where automobile exhaust can serve as a major source of heavy metals. Kananke et al., (2014), reported that agricultural soil effluents discharged from mechanical workshops and industrial activities can serve as source of soil pollution.

The trace amount of the metals found in the soil can be as a result of fertilizers and manure application, agrochemicals and also irrigation with water contaminated with waste from dumpsite at the study area. In a similar study conducted by Ocholi (2012), he reported that Cd, Cr, Mn, Pb and Zn were present in experimental plots or soil but have not exceeded their various permissible limits. This may be as a result of fertilizer application that was used and irrigation with untreated water. In a similar report conducted at Ille-Ife, Nigeria by Ayodele and Gaya, (2008), the authors reported that vegetable soil was enriched with Zn, Cu and Cd which were still within tolerable limit with the exception of lead which has a high value exceeding MPL. Cadmium is more mobile than other elements and retained less strongly by soil (Lokeshwari and Chandrappa, 2006).

The difference in heavy metals concentration observed in the vegetables may be related to the absorption capacity variations of these vegetables and their translocation capacity (Gupta et al., 2013). Leafy vegetables are known to readily absorb heavy metals from water and soil higher than root vegetables. The concentration of Pb in the vegetables have exceeded the permissible limit set by FAO/WHO. High level of Pb in vegetables can be closely related to polluted irrigation water, fertilizers, agrochemicals and pollution from vehicle exhaust (Ukpong et al., (2013); Mohammed and Folorunsho (2015), reported that heavy metals are contained in pesticides, herbicides and fertilizers applied on agricultural land. This is in agreement with the work of Muazu et al., (2010), who reported of high level of Pb in lettuce irrigated with waste water in Challawa Kano State. Odai et al., (2008), also recorded high level of heavy metals in vegetables grown in waste disposal area in Kumasi, Ghana. This contradicts the work of Ibrahim et al., (2020), the authors reported of low concentration of Pb in spinach irrigated with waste water in Tudun Wada, Zaria of Kaduna State. Lead is a non-essential element and has no known advantage to the body. It is known to gather in the body and cause different health problems. It spoils the normal role of the brain. It can cause severe blood effects, dysfunctions of the reproductive system, damage to the gastrointestinal tract, the central and peripheral nervous systems in adults (Rubio et al., 2005).

The mean concentration of cadmium in cabbage, lettuce and spinach respectively have exceeded the maximum permissible limit (MPL) set by WHO for cadmium in fresh vegetables. Cadmium is one of the heavy metals that has no known importance in animal body and also in plants and. It was noticed that plants can absorb heavy metals from organic and inorganic manure (decomposing waste on dumpsites). Cadmium is a contaminant in chemical fertilizer, manure and sewage sludge (Galadima and Garba, 2012). Cd is easily taken up and translocated to shoots of plants and may lead to chronic cadmium toxicity in human (Mumba et al., 2008). Girmaye (2014), in his studies also finds Pb and Cd in spinach and lettuce in high concentration beyond MPL in Melka Hida, Ethiopia. The high level of heavy metals found in some fruit and vegetables could be closely related to the pollutants in irrigation water, farm soil, pesticides or pollution from vehicle exhaust (Kashif et al., 2009). Olayinka et al., (2014), reported that high concentration of heavy metals in vegetables are mostly due to the materials contained in dumpsites which can contaminate irrigation water. Cadmium can affect the kidney, cause damage to skeletal system and induce cancer in humans (He et al., 2005). Cadmium can cause liver failure and kidney dysfunction when they accumulate in the liver and kidney. Eating food or drinking water with high cadmium concentration causes vomiting and diarrhea, while continues exposure can cause irreversible damage to the lungs (Udiba et al., 2013).

Zinc is an essential element which is required by the body in trace amount for normal growth and developments. The concentration of Zn in vegetables does not exceed the maximum permissible limit set by WHO/FAO. This concentration is good for normal biological function of zinc in the human body.

Iron is an essential element that is needed by the body in trace amount and its deficiency causes anaemia. Trace concentration of Fe was found in the vegetables and were all below MPL of WHO/FAO.

Copper acts as a biocatalyst required for body pigmentation because it is an essential micronutrient. Most plants contain the amount of Cu that is needed by the body but their concentrations can elevate by organic fertilizers. The concentration of Cu in cabbage, lettuce and spinach were by far below the MPL set by WHO/FAO for heavy metals in fresh vegetables. In a similar study by Lawal and Audu (2011), in Jakara area of Kano State, the authors recorded high copper concentration in spinach.

**5. Conclusions and Recommendation**

The present findings establish that there is high concentration of Pb, Cd and Fe in water used for irrigation which have exceeded the maximum permissible limit set by WHO for irrigation water while Cu and Zn were within acceptable limits. Contamination of irrigation water in the study area can be from waste containing metals from the dumpsite like tins, cans, vehicle parts of different corrosion that are dumped close to the stream and leached into the water body. Contamination can also come from sewage runoff from the farm and households close to the water body. Lead (Pb) was present in high concentration exceeding maximum permissible limit in cabbage soil and lettuce soil, whereas trace amount of Pb was observed in spinach soil which is below maximum permissible limits. The high contamination by Pb may be as a result of agrochemicals and organic manure from the dumpsite that were usually applied by farmers as fertilizers. However, in cabbage, spinach and lettuce soil, low concentrations of Cd, Zn, Fe and Cu were observed and they were below the recommended permissible limit set by WHO and FAO. In the observed vegetables, Pb and Cd were present in cabbage, spinach and lettuce. However, Zn, Fe and Cu were only found in trace concentration in the vegetables. The high concentrations recorded in the vegetables may be as a result of contamination from irrigation water, fertilizers and agrochemicals. Hence, these vegetables may be liable to cause sickness related to Pb and Cd. It is therefore recommended that farmers should be enlightened against the use of manures from dumpsites because they are contaminated with heavy metals and find a better alternative. As the dumpsite directly affects the quality of water in that area, household waste in that should be properly managed or disposed to counter further contamination.

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