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The Impact of Solid Waste Leachates on Soil and Edible Plants within Unlined Dumpsite in Awka, Anambra State

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Abstract Heavy metals from non-sanitary dumpsites have significantly polluted the environment and their measurement in environment is necessary to develop health management strategies. The concentrations of heavy metals such as lead, mercury, zinc, cadmium, chromium, arsenic, iron, nickel, cobalt, selenium, copper were studied using Atomic absorption spectrophotometry on soil and vegetable samples such as *Telfairia occidentalis, Talinum triangulare* and *Amaranthus hydridus* from unlined dumpsite in Awka. Sixteen upstream and sixteen downstream (control) samples were collected during the rainy season for four months. The heavy metals concentrations in the upstream site were higher than the downstream site, which was attributed to mobility of metals from dumpsites to farmlands through leaching. The concentrations of heavy metals in vegetable samples in both sites were above the permissible limits specified by WHO/FAO standards. The estimated daily dietary intake, health risk index and target hazard quotient showed that the vegetables poses public health related risks to the human population residing within the dumpsite environment. It is concluded that the use of unlined dumpsites can increase the environmental and public health problems of the inhabitants.

Keywords Heavy metals, Dumpsite, Pollution

1. Introduction

Wastes are generated universally and are as a result of human activities [1]. The difficulties encountered with solid waste and its management has been the focus of environmental attention [2]. Rapid urbanization, industrialization, and consequent neglect of solid waste management in developing cities is a global phenomenon and Nigeria is not left out [3,4,5].

In Nigeria, like in other developing countries, open dump systems are the only available option for solid waste disposal in the cities [6]. Open dumps are the oldest and most common disposal method of solid wastes [7]. In developing countries open dumpsites are preferred, due to low budget and non-availability of trained workers for waste disposal [8].

Soil pollution by leachates from surrounding waste dumps has been recognized for a long time [9,10,11]. Studies have shown that soil and plants can be polluted due to poorly designed waste disposal facilities [6]. The prevalence and levels of heavy metals, and other physicochemical constituents in sewage-impacted segment of the ecosystem is encouraged by anthropogenic activities like indiscriminate dumping of sewage and unregulated sewage standard treatment processes [12]. Contaminants like Cd, Cu, Ni, Pb and Zn can alter the soil chemistry and have an impact on the organisms and plants that depends on the soil for their nutrition [13].

The trees absorb these toxins through their root system which retards growth rates and consistently results to death [14]. Recent studies have shown that waste dumpsites can transfer significant amounts of toxic and persistent metals into the soil [15]. Eventually these heavy metals are adsorbed by plant parts and get incorporated into the food chain [16]. However the rate of metal uptake by crops could be influenced by factors such as metal species, plant age and plant part [17]. Consumption of vegetables is an important pathway for the intake of essential nutrients. There is an inherent tendency of plants to take up toxic substances including heavy metals that are subsequently transferred along the food chain [18].

Over the last few years, growing awareness of food safety has stimulated research concerning the risks associated with consuming foods contaminated by heavy metals [19,20]. Contamination of vegetables through contaminated land causes a lot of health concerns to the public. Studies have shown that high levels of heavy metals can cause cancer and non–cancer health effects to humans through consumptions via vegetables intakes [20]. Furthermore, the consumptions of heavy metals contaminated food can seriously deplete some essential

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nutrients in the body, causing a decrease in immunological defences, intrauterine growth retardation, impaired psycho-social behaviour, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer [19,21].

Unlined dump practices because of its cost effectiveness have become the most favourable choice particularly in Anambra State [22]. This study therefore hopes to determine the impacts of solid waste leachates on soil and edible plants within selected unlined dump site at Awka in Anambra State. The transfer factor, estimated daily intake, health risk and target hazard quotient will be used to elucidate the results.

2. Materials and Method

2.1. Site Description

Agu-Awka dump site is situated along Ring Road Junction, Awka in Awka South L.G.A. of Anambra State. The dumping site is located at latitude 6°13'05.2''N and longitude 7°05'30.2''E.

Figure 1. GPS map of dumpsite

2.2. Vegetable Collection and Preservation

Vegetable samples were collected at the upstream location which is close to the dumpsite and also from the downstream location between 100-120 m far from the dumpsite which serves as the control site. Samples were all collected within a farmland. Different edible plant samples such as *Telfairia occidentalis, Talinum triangulare* and *Amaranthus hydridus* were collected for four months during wet season. They were then packed into clean polythene bags for laboratory preparation. The vegetables were washed with distilled water and air dried at room temperature.

Composite samples of each plant were formed and then pulverized to fine powder using a blender. Ground plant samples were then collected in labeled polythene bags and were placed in a desiccator awaiting laboratory analysis.

2.3. Soil Sample Collection and Preservation

Soil samples were collected at the upstream location which is close to the dumpsite and also from the downstream location between 100-120 m far from the dumpsite which serves as the control site. Samples were all collected within a farmland for four months wet and three months dry seasons. Sixteen soil samples were collected at each sampling location at a depth of 30cm and were combined together in a stainless steel bowl to form a composite sample. The samples were transported to the laboratory in a cooler with crushed ice.

The soil samples were air-dried, after drying, visible remains of debris were removed. The dried samples were crushed into fine particles using a pestle and mortar and sieved through a 2 mm sieve. The fine samples were stored at 4°C until further analysis.

2.4. Digestion of Vegetable for Heavy Metals Analysis

2 g of the vegetable samples was weighed into a crucible. It was heated in a muffle furnace for 3hrs at 550°C and allowed to cool in a desiccator. Sample was boiled for one hour with 20ml of HNO_3 in a conical flask. It was made up to 50 ml with deionized water and filtered with filter paper. The filtrate was used for metal analysis using Varian AA240 Atomic Absorption Spectrophotometer.

2.5. Digestion of Soil Samples for Heavy Metals Analysis

2 g of the soil samples was weighed into a crucible. It was heated in a muffle furnace for 3hrs at 550°C and allowed to cool in a desiccator. Sample was boiled for three hours with 20ml of HNO_3 in a conical flask. It was made up to 50 ml with deionized water and filtered with filter paper. The filtrate was used for metal analysis using Varian AA240 Atomic Absorption Spectrophotometer.

2.6. Transfer Factor of Heavy Metals

Transfer factor (TF) is the ratio of the concentration of heavy metal in a plant to the concentration of heavy metal in soil. The heavy metal transfer from soil to the vegetables was calculated as follows [23].

$$TF = Conc(plant)/Conc(soil) \quad (1)$$

2.7. Estimated Daily Dietary Intake

The estimate daily intake (EDI) of the metals (Ag, Fe, Hg, Mn, Zn, Sn, As, Ni, Pb, Cr, Co, Cd and Cu) from each vegetable in this study were calculated using the following equation [24].

$$EDI = CMv \times DIv / BAW \quad (2)$$

Where CM_V = Concentration of metal in plant, DI_V = Daily intake of vegetables (400 g) [25], BAW=Body average weight, 80 kg for Adult [26].

2.8. Health Risk Index

The Health Risk Index (HRI) was computed as the ratio of estimated exposure of tested vegetables and oral reference dose by using following equation [27].

$$EDI = EDI / ORD \quad (3)$$

Where, EDI and ORD represent estimated daily intake of metal and oral reference dose, respectively.

2.9. Target Hazard Quotient and Hazard Index

Target hazard quotients (THQ) were used to assess the human health risks associated with heavy metal contamination of selected vegetables grown in the study area. The target hazard quotient (THQ) was calculated using the equation [28].

$$THQ = EF \times ED \times DI \times CM / ORD \times BW \times AT \quad (4)$$

Where EF = Exposure frequency (350 days/year); ED is the exposure duration = 20 years for adult; AT= Average exposure time for non-carcinogens (365 days/year X ED; DI = daily intake of vegetables (400 g); CM = concentration of metal. The oral reference dose (RfD) is an estimate of daily exposure to human population that is likely to be without an appreciable risk of deleterious effect during life time. The oral reference dose (RfD) (mg/kg/day) used were: Zn (0.3), Sn (0.0005), As (0.0003), Pb (0.0004), Fe (0.7), Ni (0.02), Mn (0.014), Cr (1.5), Co (0.03), Ag (0.0005), Cd (0.001), Hg (0.0004), Cu (0.04) [29]. If the THQ is less than 1, the exposed population is unlikely to experience obvious adverse effects. If the THQ is equal to or higher than 1, there is a potential health risk, and related interventions and protective measures should be taken.

2.10. Hazard Index (HI)

The hazard index from the consumption of different vegetables species *Amaranthus hydridus, Telfairia occidentalis* and *Talinum triangulare* obtained from the study area was given by the equation below [30].

$$HI = \sum THQ \quad (5)$$

2.11. Statistical Analysis

The recorded data were subjected to paired t-test and correlation analysis to analyse the study variables using IBM SPSS statistics software version 23.

3. Results and Discussion

Mean Heavy Metals for Vegetables.

Table 1 showed the mean average results of heavy metal concentration displayed for the three vegetables (*Amaranthus hydridus, Telfairia occidentalis*, *Talinum triangulare*). The upstream heavy metal concentrations were higher than the downstream metal concentration which was the control. This was attributed to the closeness of the vegetables to the dumpsite which contributed to the high metal concentrations of the vegetables. The leachates from the dumpsites pollute the soil with heavy metals which the plants absorb to the edible parts of the plant. The rate of metal uptake by the vegetables could have been affected by other factors such as plant age, plant species, soil pH, nature of soil and climate and this in turn would affect the content of heavy metal observed [17].

The concentrations of nickel also ranged from 0.25 – 1.02 mg/kg. Ni deficiency can cause liver disorder [31]. High concentration of nickel can lead to health risks [32]. Cadmium concentrations recorded ranged from 0.25 to 0.70 mg/kg which was above the WHO/FAO permissible limit of 0.20 mg/kg for edible plants [33]. The high cadmium concentrations at both sites might be as a result of the burning of e-waste containing cadmium–nickel batteries [32]. High cadmium concentrations can cause acute and chronic poisoning, adverse effect on kidney, liver, vascular and the immune system [34].

Table 1. Heavy metal results of vegetables

Metals (mg/kg)	***Amaranthus hydridus***		***Telfairia occidentalis***		***Talinum triangulare***	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Zn	5.29	2.50	4.52	3.27	5.96	3.55
Sn	0.11	0.03	0.09	0.04	0.08	0.03
As	0.13	0.06	0.11	0.05	0.13	0.07
Pb	0.77	0.27	0.67	0.26	0.73	0.31
Fe	8.47	5.63	8.99	5.36	9.33	6.39
Ni	1.02	0.25	0.96	0.29	0.75	0.27
Mn	8.65	2.29	4.92	2.39	6.00	2.89
Cr	0.58	0.23	0.96	0.26	0.62	0.27
Co	0.48	0.14	0.39	0.19	0.44	0.14
Ag	0.04	-	0.07	0.01	0.09	0.05
Cd	0.60	0.25	0.61	0.25	0.70	0.27
Hg	0.12	0.05	0.13	0.09	0.11	0.05
Cu	0.38	0.21	0.47	0.17	0.46	0.21

Lead concentrations ranged from 0.26 to 0.77 mg/kg. Values of 0.26 mg/kg and 0.27 mg/kg recorded in the downstream were the only values below the WHO/FAO permissible limit of 0.30 mg/kg for edible plants [33]. The high concentrations of Pb in plant from the site could be attributed to the burning of lead-containing products like scrap metals and batteries [32]. Similarly, the concentration of Cu ranged from 0.17 to 0.38 mg/kg for both site. High levels of copper can cause hair and skin decolouration and dermatitis [35]. Concentrations of Zn ranged from 2.50 mg/kg to 5.96 mg/kg for both sites. Zinc is a required body nutrient and becomes toxic to plants only at high concentrations.

The concentrations of Arsenic ranged from 0.05 to 0.13 mg/kg. Cr metal concentration ranged from 0.23.to 0.96 mg/kg. The mercury level of the vegetables ranged from 0.05-0.13 mg/kg. The iron level also ranged from 5.36 to 9.33 mg/kg. The average heavy metal values indicated a strong positive correlation between upstream and downstream vegetable species studied in both sites. The p-values for the average heavy metal values for vegetable species were all significant (P <0.05). The vegetable species in the upstream and downstream had a strong positive correlation with the upstream and downstream of the soil.

The uptake of heavy metals by plants occurs during the vegetative period as a result of leaching of metal [36]. The presence of toxic heavy metals in the soil results in the bio-accumulation of these metals into plant tissues [37].

Heavy metals for soil

Figure 2 and 3 showed wet and dry season's average mean heavy metals soil results. The downstream values were predominantly lower than the upstream values. It was attributed to the closeness of the upstream soil to the point source (dumpsites). The order of maximum concentration followed this order for wet season for upstream: Mn > Fe > Zn > Hg > Ni > Cr > Cd > Sn > Pb > As > Cu > Co > Ag, downstream followed this order Fe > Mn > Zn > Hg > Cr > Ni > Pb > Sn > Cd > Cu > As > Co > Ag. Dry season followed this order for upstream: Fe > Mn > Zn > Hg > Ni > Cd > As > Pb > Sn > Cr > Cu > Co > Ag, while for downstream, the concentration followed this order: Fe > Mn > Zn > Hg > Cd > Ni > As > Cu > Pb > Sn > Cr > Co > Ag.

The correlation analysis of the average heavy metals for soil indicated a strong positive correlation between upstream and downstream values for wet and dry seasons. The variation of average heavy metal values for soil upstream and downstream for wet and dry seasons showed that it was significant. This implies that the upstream has higher concentration of heavy metals when compared with the downstream. The heavy metals of upstream and downstream of soil significantly correlated positively with the three vegetable species studied for both locations.

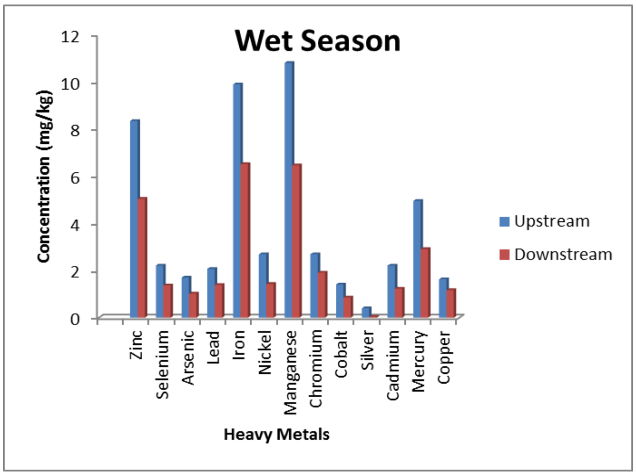

Figure 2. Average heavy metal results of soil for wet season

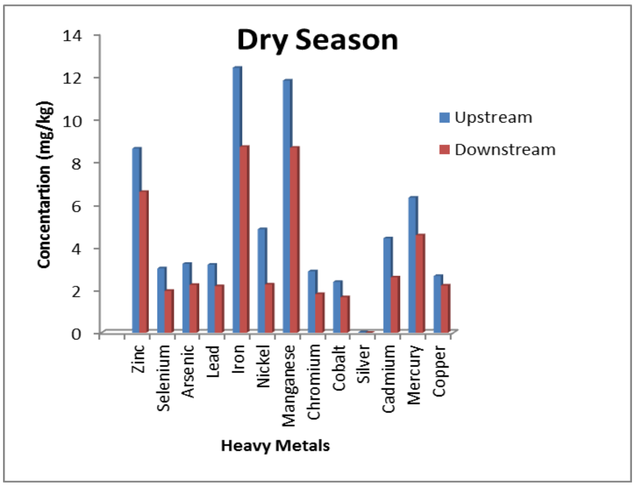

Figure 3. Average heavy metal results of soil for dry season

Transfer factor of vegetables

Table 2 showed the average transfer factor for wet season. Iron had the highest transfer factor for both sites across the three vegetables studied. The total average transfer factor of the vegetables studied followed the same trend for upstream and downstream: *Talinum triangulare* > *Telfairia occidentalis* > *Amaranthus hydridus.*

The upstream sites recorded the highest values virtually for all the studied vegetables. It was attributed to the level of contamination of the sites due to high mobility of heavy metals in the soil from the leachates which are closer to the dumpsites. Variations in transfer factor among different vegetables may be attributed to differences in the concentration of metals in the soil and differences in element uptake by different vegetables [38]. Higher transfer factors indicate higher possibility of plants to absorb metals [39]. However, low transfer factor showed strong adsorption of the metals to soil colloids [40].

Estimated daily dietary intake of vegetables

Table 3 showed the values of the estimated daily dietary intake (EDI) of the heavy metals through the consumption of different vegetables species (*Amaranthus hydridus, Telfairia occidentalis, Talinum triangulare),* for both sites. Zinc, chromium, cobalt, iron, nickel, silver and copper EDI values were lower than the oral reference dose (RfD) for the vegetables. The value of EDI for Sn was only higher in the upstream site of *Amaranthus hydridus* with value of 0.0006 mg/kg/day.

Arsenic, lead and cadmium values were all higher than the RfD value for both sites. The value of 0.0003 mg/kg/day observed for downstream of *Amaranthus hydridus* and *Telfairia occidentalis* was the only value within limit for mercury. Manganese EDI observed values for upstream were higher than the RfD limit for the three vegetables, while the downstream values were lower except for downstream of *Talinum triangulare,* which had a value of 0.0145 mg/kg/day. Mercury EDI values for downstream of *Amaranthus hydridus* and *Talinum triangulare* were the only values lower than the RfD value of 0.0004 mg/kg/day.

The EDI values for upstream sites were higher than the EDI for the downstream sites for all the vegetables studied for both locations. This was attributed to leaching of dumpsite as a result of rainfall, which plants absorbed into their leaves. The estimated daily intake of metals depends on concentrations of heavy metals in edible portions of the vegetables and the vegetable species [17]. The consumption of these vegetables posed high health risk to the local population when they enter the human body [31].

Table 2. Transfer factor of vegetables

	Amaranthus hydridus		***Telfairia occidentalis***		***Talinum triangulare***	
Metals	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Zn	0.64	0.54	0.55	0.72	0.72	0.77
Sn	0.05	0.02	0.04	0.03	0.04	0.02
As	0.08	0.06	0.06	0.05	0.07	0.07
Pb	0.37	0.19	0.32	0.19	0.36	0.22
Fe	0.86	0.85	0.9	0.8	0.94	0.96
Ni	0.38	0.18	0.35	0.2	0.29	0.2
Mn	0.8	0.36	0.45	0.39	0.56	0.46
Cr	0.22	0.12	0.36	0.14	0.23	0.14
Co	0.35	0.17	0.29	0.23	0.32	0.17
Ag	0.09	-	0.68	0.36	0.66	1.41
Cd	0.27	0.21	0.28	0.21	0.32	0.23
Hg	0.02	0.02	0.03	0.03	0.02	0.02
Cu	0.24	0.19	0.3	0.15	0.3	0.18
$\sum TF$	4.37	2.9	4.62	3.49	4.83	4.85

Table 3. Estimated daily dietary intake

	Amaranthus hydridus		***Telfairia occidentalis***		***Talinum triangulare***	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Zn	0.0265	0.0125	0.0226	0.0164	0.0298	0.0178
Sn	0.0006	0.0002	0.0005	0.0002	0.0004	0.0002
As	0.0007	0.0003	0.0006	0.0003	0.0007	0.0004
Pb	0.0039	0.0014	0.0034	0.0013	0.0037	0.0016
Fe	0.0424	0.0282	0.045	0.0268	0.0467	0.032
Ni	0.0051	0.0013	0.0048	0.0015	0.0038	0.0014
Mn	0.0433	0.0115	0.0246	0.012	0.03	0.0145
Cr	0.0029	0.0012	0.0048	0.0013	0.0031	0.0014
Co	0.0024	0.0007	0.002	0.001	0.0022	0.0007
Ag	0.0002	-	0.0004	0.0001	0.0005	0.0003
Cd	0.003	0.0013	0.0031	0.0013	0.0035	0.0014
Hg	0.0006	0.0003	0.0007	0.0005	0.0006	0.0003
Cu	0.0019	0.0011	0.0024	0.0009	0.0023	0.0011

Health risk index of vegetables

Table 4 showed the values of the health risk index (HRI) of the metals through the consumption of different vegetables species (*Amaranthus hydridus, Telfairia occidentalis, Talinum triangulare).* The values of the HRI were greater than 1. The upstream values were greater than the downstream values. Thus, the health risk index as a result of estimated daily intake of heavy metals daily consumption of vegetables from both sites is of potential health risk to the local population living around the dumpsite environment.

Target hazard quotient and hazard index of vegetables

Table 5 showed the values of the target hazard quotient (THQ) of the metals through the consumption of different vegetable species (*Amaranthus hydridus, Telfairia occidentalis* and *Talinum triangulare).* The THQ values were less than 1 (THQ <1) for Cu, Co, Cr, Ni, Fe, Ag, Mn, Zn, and greater than 1(THQ >1) for Pb and Cd. Selenium values were greater than 1 for the upstream sample of *Amaranthus hydridus* and less than 1 for the other plant samples. Arsenic recorded values of 0.9589 for *Amaranthus hydridus* and 0.7991 for *Telfairia occidentalis* which were less than 1, while the other values were greater than 1.

Mn values were higher than 1 for the upstream samples for the three plants and less than 1 for the downstream samples. Mercury value of 0.5993 recorded for downstream of *Amaranthus hydridus* and *Talinum triangulare* were lower than 1, while the other values were higher than 1. THQ ≥1 signified considerable health risk to the population, while THQ < 1 signified negligible risk to the population. Lead possessed the highest THQ of all the metals in both sites. The upstream values had the highest THQ for both sites. The hazard index (HI) values for the studied vegetables showed the risk level (HI > 1).

Table 4. Health risk index of vegetables

	Amaranthus hydridus		***Telfairia occidentalis***		***Talinum triangulare***	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Zn	0.0883	0.0417	0.0753	0.0547	0.0993	0.0593
Sn	1.2	0.4	1	0.4	0.8	0.4
As	2.3333	1	2	1	2.3333	1.3333
Pb	9.75	3.5	8.5	3.25	9.25	4
Fe	0.0606	0.0403	0.0643	0.0383	0.0667	0.0457
Ni	0.255	0.065	0.24	0.075	0.19	0.07
Mn	3.0929	0.8214	1.7571	0.8571	2.1429	1.0357
Cr	0.0019	0.0008	0.0032	0.0009	0.0021	0.0009
Co	0.08	0.0233	0.0667	0.0333	0.0733	0.0233
Ag	0.4	-	0.8	0.2	1	0.6
Cd	3	1.3	3.1	1.3	3.5	1.4
Hg	1.5	0.75	1.75	1.25	1.5	0.75
Cu	0.0475	0.0275	0.06	0.0225	0.0575	0.0275
HRI	21.81	7.97	19.417	8.4818	21.015	9.7459

Table 5. Target hazard quotient and hazard index

	Amaranthus hydridus		***Telfairia occidentalis***		***Talinum triangulare***	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Zn	0.0845	0.04	0.072	0.0523	0.095	0.0567
Sn	1.0548	0.2877	0.863	0.3836	0.767	0.2877
As	2.0776	0.9589	1.758	0.7991	2.078	1.1187
Pb	9.2295	3.2363	8.031	3.1164	8.75	3.7158
Fe	0.058	0.0386	0.062	0.0367	0.064	0.0438
Ni	0.2445	0.0599	0.23	0.0695	0.18	0.0647
Mn	2.9623	0.7842	1.685	0.8185	2.055	0.9897
Cr	0.0019	0.0007	0.003	0.0008	0.002	0.0009
Co	0.0767	0.0224	0.062	0.0304	0.07	0.0224
Ag	0.3836	-	0.671	0.0959	0.863	0.4795
Cd	2.8767	1.1986	2.925	1.1986	3.356	1.2945
Hg	1.4384	0.5993	1.558	1.0788	1.318	0.5993
Cu	0.0455	0.0252	0.056	0.0204	0.055	0.0252
HI	**20.534**	**7.252**	**17.977**	**7.701**	**19.653**	**8.699**

The HI for vegetable species had a range of 7.252 – 20.534. The HI recorded high values at the upstream sites than the downstream sites, which were due to high contamination of sites with heavy metals. The HI of the vegetables studied decreased in the order for upstream: *Amaranthus hydridus* > *Talinum triangulare* > *Telfairia occidentalis*, while downstream followed this order: *Talinum triangulare* > *Telfairia occidentalis* > *Amaranthus hydridus*.

Thus, consumption of vegetables from both locations is of potential health risk to the local population living around the dumpsite environment through intake of heavy metals contained in both plants being consumed. Therefore, it is urgent to take proper measures for the reduction of the polluted metals in this area to save the population from non-cancer health risks.

4. Conclusions

The study revealed that the concentrations of heavy metals considered were higher at upstream sites than the downstream sites due to leachate runoff. Leachates from the dumpsite led to the accumulation of heavy metals in soil and consequently into the vegetables. Heavy metals concentrations varied among the tested vegetables which reflect the differences in their uptake capabilities and their further translocation to edible portion of the plants. The results obtained from this work revealed that the vegetables from the study site are not suitable for human consumption. Therefore, constant monitoring on the level of heavy metals in the soil should be checked, so as to prevent possible build-up of metals in the soil and plants as a result of bioaccumulation.

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