

Research Article

Heavy Metal Pollution in Kingtom and Granville Dump Sites in Freetown, Sierra Leone

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Abstract

The studies reported here were undertaken as part of a wider environmental study on the level of heavy metal pollution in the Kingdom and Granville dumpsites in Freetown. The use of the Kingdom and Grandville dumpsites to grow edible crops without checking the level of metal toxicity created concern to undertake such research with a view to ascertain a healthy environment for the growing of crops. Two sets of samples, one from each dumpsite, were taken for analysis. Soil, water, and plants (cassava and krain krain) were tested for Pb, Zn, Ni, and Co. The geological surveys tested physical parameters like pH, temperature, and electrical conductivity. The soil samples were collected at a depth of 10 cm by an auger, and water samples from up, middle, and down river/lagoon and plants of two widely grown varieties were analyzed using the principles of atomic absorption spectrophotometry. The levels of Pb, Zn, Ni, and Co obtained exceeded the recommended WHO permissible standards. The present study has been of short duration, but the data could serve as a baseline for more investigations that give a more complete picture of the seasonal patterns in the level of pollution of heavy metal in the Kingdom and Granville dumpsites. It will be helpful to the Ministry of Health and Sanitation to create policies or legislation on the use of these nearby streams, dump sites, and their immediate environments. It will also help the Ministry of Education to create mass pollution awareness in the school curriculum and society, and therefore, the researcher recommends that community people should prevent overloading, that is, sort for heavy and light debris, and ensure safe waste distribution management.

Keywords

Physicochemical, Heavy Metals, Kingdom, Granville, Dumpsites, WHO Standard, Krain-krain, Cassava Leaves

1. Introduction

Food safety is a global concern since foods are poisoned and rendered unwholesome in many circumstances, with sources as diverse as the toxins themselves [24]. Vegetable consumption on a regular basis is one of the possible health-improving practices; hence, vegetables are regarded as an important part of the human diet. People all around the world have recently begun to consume fresh vegetables rather than

red meat in order to lower the occurrence of chronic diseases such as diabetes, cancer, cardiovascular disease, and other age-related ailments [23].

Vegetables are important for human nutrition and health, especially as sources of vitamin C, folic acid, a mineral, niacin, thiamine, and pyridoxine, as well as for their biochemical role and antioxidative properties [1]. Pollution and con-

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tamination of the human food chain have become unavoidable as human activity grows, particularly with the use of contemporary technologies. One of the most critical areas of food quality assurance is heavy metal contamination in food [12, 17, 19]. As a result of greater knowledge of the risk that toxic metals represent to food-chain contamination, international and national food-quality rules have cut the maximum allowable quantities of toxic metals in food [23].

This study, therefore, will assess the level of concentration of heavy metals, namely, nickel (Ni), cobalt (Co), zinc (Zn), and lead (Pb), in some commonly consumed vegetable samples like *Manihot esculenta* (cassava leaves) and *Corchorus olitorius* (Krain Krain), which were all obtained at local marketplaces in Freetown.

By the standard definition of a dumpsite (a waste dump site characterized by an engineered piping network to transfer leachates, covering, a base liner, etc.), there are no dumpsites in Freetown, as the above is completely absent. However, there are officially two main open dumpsites, namely the Kingtom and Granville Brook in Freetown. In addition, there are several transit points (transfer stations) unevenly distributed across the capital. Waste management in Freetown is plagued with several problems. Part of the problems is hazardous waste [13]. Waste management at both sites could generally be described as crude, uncontrolled, and unacceptable according to modern methods of handling waste. The lack of finance, logistics, and technological inadequacies and poor management at national and local levels have resulted in poor environmental hygiene with its associated health consequences in and around the site. The solid waste management in Freetown relates to the institutional and legislative framework of waste management in the city. To illustrate, the legal framework for waste management in Freetown is old and inconsistent. One of the main existing texts in effect is the Public Health Ordinance. It has still not been reviewed since 1978. However, over the years, there have been continued changes in the institution responsible for leadership of waste management.

It has moved from the Ministry of Health and Sanitation (MOHS) to the Freetown City Council (FCC), then the Ministry of Youth and Sports. A decade ago, the responsibility was handed over to the FCC. Presently, waste management is currently jointly managed by the Environmental Health Division (EHD) of the Ministry of Health and Sanitation, “Klin Salone” (a private Non-Governmental Organization—NGO), the Freetown Solid Waste Management Company (FSWMC), and the Freetown Municipal Council, although only “Klin Salone” is the one actively involved in the day-to-day collection and disposal services.

This current organization of waste collection was established by the FCC in 2006 [14] with the support of an international waste consulting firm—GTZ—and the World Bank. The FSWMC was created in the framework of an emergency phase operation for waste management. Regarding solid waste environmental laws, there is a duplication between the

FCC and the MOHS. Besides the National Health Policy published in October 2002 and the MOHS’s draft Environmental Health Policy developed as an addendum to the latter, there is no clear policy on medical waste in Sierra Leone. In general, both dumpsites receive all categories of waste (i.e., general and domestic, hospital, industrial, and hazardous waste) [9]. Waste management at both sites could generally be described as crude, uncontrolled, and unacceptable according to modern methods of handling waste. The lack of finance, logistics, and technological inadequacies and poor management at national and local levels have resulted in poor environmental hygiene with its associated health consequences in and around the site. The absence of waste cover and the proximity of residents to dumpsites allow for easy rampant scavenging on waste heaps for valuable recyclable materials [16, 18].

In a study to determine the environmental health impacts on residents around the vicinity of the Granville dumpsite, FAO [8] showed that the site contributes to diseases such as malaria, chest pain, diarrhea, and cholera suffered by residents. In an earlier study on both the Kingtom and Granvillebrook dumpsites, Hingston *et al.* [16] and Frazer-Williams *et al.* [10] reported that dumpsite leachates and runoff pollute nearby streams, estuarine waters, and the Rokel River. Their studies showed that higher levels of nickel, cobalt, zinc, and lead compared to World Health Organization (WHO) values were found in both soil samples and vegetables at the sites. Similar findings have been reported elsewhere.

For instance, Akobundu [2] reported leaching of heavy metals from the Aladimma dumpsite of Imo State, Nigeria, to groundwater. Results of physical, chemical, and biological analysis of raw water from boreholes collected close to refuse dumps in Benin City showed that these wastes produce leachates that percolate into the groundwater. Open burning is also a public health concern to residents around dumpsites, as the resulting greenhouse gases (CH_4 , CO, etc.) contaminate the air and cause respiratory problems [3, 15]. Ronnie and Frazer-Williams [22] reported higher levels of polycyclic aromatic hydrocarbons (PAHs), carbon monoxide (CO), and suspended particulate matter (SPM) relative to World Health Organization (WHO) guidelines around the Granville Brook dumpsite. Such a high level is a public health risk.

As a result of the foregoing, concerns about the impact of these two dumpsites on the health of the residents in Freetown are increasing. Another concern expressed by residents is the fact that the Granville Brook dumpsite is located along the Bai Bureh road, which visitors to the country sometimes use when they first enter the country. This view, with utmost dismay, is wrongly placed for visitors. Many have even argued that both dumpsites should be relocated to the outskirts. However, for such a decision to be made, officials must be well informed with facts and data that will guide them in decision-making. As such, assessing the relative health and environmental hazards posed by the Kingtom and Granville dumpsites could help prioritize, plan, and initiate their reha-

bilitation or relocation [6].

In Sierra Leone there is a growing concern over the non-sanitary storage, collection, and disposal of solid waste within the Freetown Municipality. This concern emanated from the blighting and evil-smelling characteristics exhibited by waste. Most often, the river/lagoon around these dumpsites are used for irrigation by gardeners, washing by people, and fishing purposes. A GOPA report in 1994 [14] on the levels of hazardous metals. In Freetown, inhabitants of areas around the dump site have resorted to the use of the dump site for agricultural purposes, and there is this idea of scavenging recyclable materials without prior check on the heavy

metal contents. The fact that these sites are within intensive agricultural pressure justifies the need to constantly check on toxicity.

This research aimed to analyze heavy metals using the quantitative and qualitative determinants of lead, zinc, cobalt, and nickel as potentially hazardous metals at the Kingdom and Granville Dump Sites, and the specific objectives are as follows: to analyze soil samples from Dump Sites, to analyze water samples from the river/lagoon near the Dump Site, and to analyze leaves from edible cassava and crain-crain plants grown on the Dump Site.

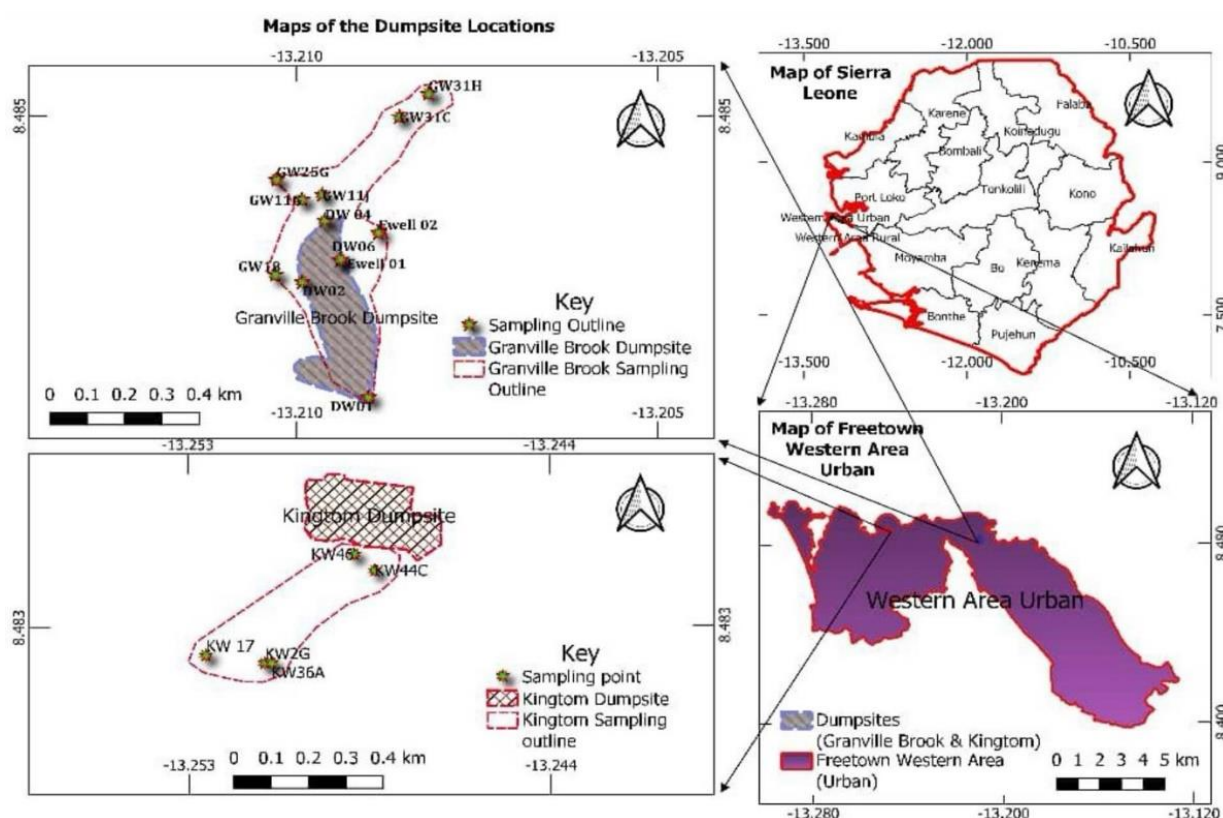


Figure 1. Map showing study areas (Source: Author, 2025).

2. Data and Methods

2.1. Study Area

Kingtom Dump Site came into existence in the 1940s and is situated in the central west of Freetown at Kingtom. This dump site is bordered on the south by Ascension Town Road, on the north and northeast by the Kingtom community, and on the west by the bay. The western side of the dump site is bordered by an embankment. The area between the embankment, the southern ascending slope leading to the Ascension Town Road, and the dump site forms a kind of lagoon, with

ships and cars wrecked out of the water surface. (Figure 1).

The following different demarcations due to the existing duration with the dumpsite and a fourth lagoon basement can be described. An old part located north and south of the dump road adjacent to the Kingdom Cemetery, a recently developed area south and west of the main road and east of the lagoon, a recent dump area to the south of the equipment garage, and a portion showing the area covered by the Kingdom Lagoon with mass deposits of debris on the basement. A weighing bridge is at the entrance control, located just at the gateway.

Grandville Dumpsite is located at the eastern part of Free-town and was set up in March 1991. The setting up of this second dump site was aimed at improving the efficiency of

waste collection. The Granville dumpsite is situated east of Freetown in the deep valley cut off by the Granville Brook. The valley runs south-southwest to north-northeast and is bordered in the south by a 27-meter-high embankment of the Waterloo Road. The site shows three solid waste disposal areas (Figure 1) and a fourth area, which shows the area covered with water. A small plain dumpsite at the southeast side of the culvert, a fill dumped towards the western side from the dump access road. This fill has a very steep slope towards the bottom of the valley, with a dumpsite extending from the northern end of the main dump road and bordered by the Granville Brook River in the west and a settlement on the east side. An area depicting the watercourse of the Granville Brook River with a vast deposit of eroded sediments. Entry to the Granville Dumpsite is only feasible through the southern side via the New Freetown–Waterloo Road. There is a non-functional weighing bridge at the entrance control near the junction. The surface of the southwestern area of the dumpsite marked (1) level but has no cover. Residents have small gardens here and have bordered them with small dams made of coarse litter. The dump area marked (3) was in use from September 1993 until September 1994 but was deserted due to operational mistakes. Hence, skipping waste was either done on the dump access road or the overfilled dump areas.

2.2. Sampling Areas and Points

The dumpsite is partitioned into three plots. The filling of these plots is systematic, with one filled after the other until a level is reached, when the whole process of filling begins all over again. For both the Kingtom and Granville dumpsites. The plots marked three (3) areas are the most recent, and those marked one (1) are the relatively old ones. The plots are adjacently placed with the same boundaries. Their areas are approximately within 600 m² and 800 m²; the research focuses on soil, water, and plant samples. The samples were collected in batches; for batch 1, a total of 18 bulk samples were collected, that is, nine from each dumpsite. Four soil samples, two soil samples, and three water samples. For batch 2, there were no water and plant samples, so there were a total of 8 bulk soil samples for batch 3. One soil sample was taken from each plot since the wastes are dumped at different times, and one more from the river or lagoon base-ment to account for some leached metals to obtain a representative sample.

The water samples were also taken at three different points: one up-river/lagoon, one middle-river/lagoon, and one down-river/lagoon, because of the relative intake of leachates. The labeling of the samples is shown blown on the table.

Table 1. Name of Sampling site and acronyms.

Name of Sampling sites	Acronyms
Kingtom Soil Sample from plot (1)	KSS ₁
Kingtom soil sample from plot (2)	KSS ₂
Kingtom soil sample from plot (3)	KSS ₃
Kingtom soil sample from plot (4)	KSS ₄
Kingtom cassava leaves from plot (2)	KCL
Kingtom Krain-Krain leaves from plot (2)	KKKL
Kingtom up lagoon water samples	KUL
Kingtom Middle Lagoon Water sample	KML
Kingtom down lagoon water sample is labelled KDL	KDL

Note: Numbers are used to assign the plot number. The same denotation was used for Granville dumpsites with G replacing K, and R replacing L for river and not a lagoon.

2.3. Collection and Treatment of Samples

The first set of samples (soil, plant, and water) were collected on the 25th and 27th of November 2024 at the Kingtom and Granville dumpsites, respectively. Batch two was collected between January and February 2025, batch three was collected between February and March 2025, and

batch four was collected between March and April 2025.

With the aid of a 10 cm gauge soil auger consisting of a half-section of steel with sharp edges connected to a 1 m extension rod, a set of four soil samples from both the Kingtom and Granville dumpsites were collected. Having connected the soil auger, it was carefully and indiscriminately inserted into different points. At each point of insertion, a spatula was used to take a reasonable quantity of the scooped

soil. After mixing, followed by quartering, some portions were placed into labeled, locked polythene bags. This is to prevent the entering of foreign materials.

For the plant samples, a stainless-steel knife was used in sample collection; the leaves of cassava and krain-krain were separately plucked, wiped, and air-dried for 5 days at room temperature. Water samples were collected using beakers from the upper, middle, and lower portions of the lagoon and river of the Kingdom and Granville dumpsites, respectively. The water samples collected were placed or kept in tightly stoppered polythene containers.

In the laboratory, the soil samples were air-dried at room temperature for 5 days after eliminating pebbles, bottles, and large-sized particles. They were then ground and sieved through 0.25 mm sieves after oven drying at 105 °C. The samples were placed in petri dishes and preserved in a cupboard awaiting analysis.

The plant samples were dried at 70 °C for 48 hours, followed by grinding in a stainless mill to avoid contamination by trace elements. The powdered sample was obtained by

passing the samples through a 0.1 mm sieve. Immediately after grinding, the powdered samples were thoroughly mixed, packeted in polythene bags, and stored under dry and cool conditions.

The water samples were acidified with analytical reagent grade HNO₃ at the time of collection at pH < 2; this was confirmed with the use of a pH meter just after taking the pH readings. The samples were then kept at room temperature until the following physicochemical tests were conducted.

2.4. Preparation of Standard Solutions

Standard calibration of solutions for each metal to be determined was prepared in situ prior to aspiration into the Atomic Absorption Spectrophotometry (AAS) from the stock metal 1000 ppm solution. In five one-liter volumetric flasks containing 100 ml concentrated HCl for Zn, Co, and Ni and 100 ml conc. HNO₃ for Pb, that were added to 100 ml conc. HCl in volumetric flasks in preparing the standard solutions.

Table 2. Showing Heavy Metal Calibration Standards.

Stds	Pb		Zn		Ni		Co	
	ml	ppm	ml	ppm	ml	ppm	ml	ppm
1	5.0	5.0	0.9	0.9	1.0	1.0	0.1	0.1
2	10.0	10.0	1.5	1.5	3.0	3.0	0.3	0.3
3	15.0	15.0	2.25	2.25	5.0	5.0	0.5	0.5
4	20.0	20.0	3.0	3.0	7.0	7.0	0.8	0.8
5	25.0	25.0	3.2	3.2	10.0	10.0	1.0	1.0

2.5. Analytical Procedures for Each Parameter

2.5.1. Physical Parameters

pH and Temperature

For the measurements of pH and temperature, the HACH Electronic pH meter was used. The calibration of this equipment was done using the requested buffer solutions prepared by dissolving the appropriate buffer in 100 ml of distilled water. This buffer solution covered pH values ranging from 4.00 to 9.00 to break out the expected pH values of both water and soil samples.

Sample solutions were prepared by dissolving 20 g air-dried samples in 50 ml of distilled water. The solutions were then stirred for 10 minutes prior to the pH meter electrode. The pH values of each sample solution were recorded in replicate, and this has been shown to be very accurately repro-

ducible. Mills C. F. [21], Gogra et al. [13], and Akobundu A N. [2].

Electrical Conductivity

With the aid of the MEL conductivity, the electrical conductivities were measured by immersing the parallel electrodes of the meter into 250 ml water solutions in a beaker. Prior to insertion, the electrodes were rinsed with the solution to be analyzed to avoid dilution. By using the adjuster on the meter, the values were read with ease.

2.5.2. Chemical Parameters

Pb Zn Ni and Co in the soil, plant and water samples *Soil Samples*

At the starting of the digestion process, 50 ml of distilled water was added to the accurately weighted 1.0 g of finely ground soil samples in a digestion tube with three boiling chips in each of the tubes. This was then followed with the addition of 50 ml of an HC/HNO₃ 3: 1 mixture. The tubes

were then heated to concentrate the samples to an end volume of about 5 ml. The tubes were then cooled, and 1 ml of 30% H_2O_2 was added, and the digestion process continued for 10 minutes, and this was done twice. The tubes were also cooled, followed by further addition of 3 ml of 30% H_2O_2 and digested for 10 minutes. 20 ml of water and 10 ml of the HCl mixture were added and were heated to boil. The flasks were cooled and transferred to a 50 ml volumetric flask and were filled up to the mark after cooling to room temperature. They were then mixed and left overnight for sedimentation. The solutions were then aspirated into the AAS. Fred Kvius EE 095/972 [11].

A hollow cathode lamp for the desired metal was installed in the instrument, and the wavelength dial was set according to specifications. The bandwidth for each sample was set according to the manufacturer's specification, and the instruction allowed it to warm up for 30 minutes aspiration for maximum performance. Standards Were aspirated and periodically checked during a run. A blank that had been digested in a manner like that of the samples using the same reagents was run between each sample to verify baseline stability.

Plant Samples

25 ml of HNO_3 was added to each of the accurately

weighed 1.0 g of finely ground plant samples in a digestion tube with three boiling chips in each of the tubes. The tubes were then heated to concentrate the sample to about 5 ml. The tubes were cooled, 1 ml of 30% H_2O_2 was added, and the destruction process continued for 10 minutes. The tube was also cooled, followed by further addition of 3 ml of 30% H_2O_2 , and digested for 10 minutes, and 25 ml of distilled water was transferred to a 50 ml volumetric flask and filled up to the mark, mixed, and left to settle.

Water Sample

Prior to analysis, the entire samples were acidified to $\text{pH} < 2$ with concentrated HNO_3 . During analysis, 250 ml aliquots of the well-mixed sample were transferred to 500 ml beakers. 5 analyses, HNO_3 , and a few boiling chips were added. The samples were heated on a Bunsen burner in a cupboard until the volume was reduced to 25 ml. The solution was heated again with the addition of conc. HNO_3 until digestion was completed as shown by the clear solution. Thereafter, the samples were cooled and then filtered to remove silicates and the insoluble materials that would clog the atomizer of the AAS, and the volume was adjusted to 50 ml each. The solutions were then ready for aspiration into the AAS, as was done with soil and plant samples.

3. Results and Discussion

3.1. Results

Table 3. Physical parameter of soil samples in Kingtom Dumpsite (Batch1).

Location	Sample	Temperature	pH
Kingtom Dumpsite	KSS ₁	46	5.4
	KSS ₂	50	5.8
	KSS ₃	42	6.0
	KSS ₄	44	6.1

Table 4. Physical parameter of soil sample in Granville Dumpsite (Batch1).

Location	sample	Temperature	pH
Granville Dumpsite	GSS ₁	36	7.3
	GSS ₂	34	7.0
	GSS ₃	38	7.5
	GSS ₄	31	6.8

Table 5. Physical parameters of water samples in Kingtom Dumpsite (Batch1).

Location	Sample	Temp (°C)	pH	Electrical Conductivity (s/cm)	Total Dissolved Solids (TDS) Mg/1
Kingtom Dumpsite	KUL	38	5.5	15,000	10,500
	KML	35	5.3	15,400	10,780
	KDL	29	5.1	16,667	11,667

Table 6. Physical parameters of water samples in Granville Dumpsite (Batch1).

Location	Sample	Temp. °C	pH	Electrical Conductivity (s/cm)	Total Dissolved Solids (TDS) (Mg/1)
Kingtom Dumpsite	GUR	28	7.2	2,083	1,458
	GMR	26	7.4	2,040	1,428
	GDR	25	7.7	2,000	1,400

Table 7. Calibration Absorbance Readings of known concentration of selected metal ions (Batch1).

Std	Lead		Zinc		Nickel		Cobalt	
	Conc (ppm)	ABS unit	Conc (ppm)	ABS unit	Conc (ppm)	ABS unit	Conc (ppm)	ABS unit
Blank		0.00		0.00		0.00		0.00
1	0.5	0.002	0.90	0.377	1.00	0.035	0.10	0.004
2	5.0	0.1211	1.50	0.607	3.00	0.109	0.30	0.013
3	10.0	0.3772	2.25	0.887	5.00	0.187	0.50	0.023
4	15.0	0.6220	3.20	1.242	10.00	0.374	1.00	0.047
5	25.0	0.994	3.20	1.242	10.00	0.374	1.00	0.047

Note: Absorbance Standard solution = Absorbance Reading - Absorbance of Bank

Table 8. Absorbance's of the Aspirated soil sample solutions from kingtom Dumpsite (in absorbance units) (Batch 1).

location	sample	Pb	Zn	Ni	Co
Kingtom Dumpsite	Blank	0.00	0.00	0.00	0.00
	KSS ₁	0.914	1.232	0.066	0.025
	KSS ₂	0.934	1.156	0.063	0.023
	KSS ₃	0.903	1.213	0.064	0.033
	KSS ₄	0.991	1.004	0.032	0.014

Table 9. Absorbance's of Aspirated soil sample from Granville Dumpsite (in absorbance unit) (Batch1).

Location	Sample	Pb	Zn	Ni	Co
Granville Dumpsite	Blank	0.00	0.00	0.00	0.00
	GSS ₁	0.531	1.161	0.034	0.033
	GSS ₂	0.529	1.180	0.081	0.032
	GSS ₃	0.498	1.121	0.082	0.030
	GSS ₄	0.495	1.085	0.110	0.034

Table 10. Absorbance's of the Aspirated water sample solutions from lagoon of kingtom Dumpsite (in absorbance units) (Batch1).

location	sample	Pb	Zn	Ni	Co
Kingtom Dumpsite	Blank	0.00	0.00	0.00	0.00
	KUL	0.039	0.083	0.117	0.025
	KML	0.037	0.076	0.102	0.020
	KDL	0.043	0.012	0.108	0.034

Table 11. Absorbance's of the Aspirated water sample solutions from nearby stream of Granville Dumpsite (in absorbance unit) (Batch1).

location	Sample	Pb	Zn	Ni	Co
Granville Dumpsite	Blank	0.00	0.00	0.00	0.00
	GUR	0.002	0.042	0.010	0.004
	GUR	0.001	0.035	0.050	0.002
	GDR	0.0029	0.0478	0.030	0.001

Table 12. Absorbance of the Aspirated plant sample solutions from Kingtom Dumpsite (in absorbance units) (Batch 1).

Location	Sample	Pb	Zn	Ni	Co
Kingtom Dumpsite	Blank	0.00	0.00	0.00	0.00
	KCL	0.013	0.041	0.001	0.008
	KKKL	0.006	0.076	0.003	0.004

Table 13. Absorbance of the Aspirated plant sample solutions from Granville Dumpsite (in absorbance units) (Batch1).

location	sample	Pb	Zn	Ni	Co
Granville Dumpsite	Blank	0.00	0.00	0.00	0.00
	GCL	0.011	0.069	0.008	0.007
	GCCL	0.003	0.038	0.014	0.005

Referring to the standard calibration graphs obtained by plotting absorbances against concentrations, the unknowns were carefully read. The concentrations of the metals in dry soil, dry plants, and water in plants per milliliter were calculated. Tables 3 to 13 show the calculated values in mg/kg weights and in parts per million.

According to the procedure, 1 g of dry soil and plant sample was made into a 50 ml solution, and values read from calibration curves were in parts per million, whereas WHO

recommended conversion to be carried out.

For instance:

$$36.5\text{ppm} = 36.5\text{mg/l}$$

$$36.5\text{mg} \dots \dots \dots > 1000\text{ml}$$

$$* \text{mg} \dots \dots \dots > 50\text{ml}$$

$$* = \frac{50 \times 36.5\text{mg}}{1000} = 1.825\text{mg}/50\text{ml}$$

$$> 1.88225\text{mg}/1.0\text{g dry soil}$$

$$> 1.825\text{mg} \times 10^3 \text{ mg/kg soil}$$

Table 14. Levels of metals in Dry soil (mg/kg) at the kingtom Dumpsite (Batch1).

Location	Sample	Pb	Zn	Ni	Co
Kingtom Dumpsite	KSS ₁	1,825	158	80	28
	KSS ₂	1,875	145	78	26
	KSS ₃	1,805	155	75	38
	KSS ₄	1,905	125	40	16

Table 15. Levels of metals in dry soil (mg/kg) at the Dumpsite (Batch1).

Location	Sample	Pb	Zn	Ni	Co
Granville Dumpsite	GSS1	1075	145	41	37
	GSS2	1050	150	110	36
	GSS3	1000	130	112	34
	GSS4	950	138	150	39

Table 16. Levels of metals in water sample from stream at the Kingtom Dumpsite (Batch).

Location	Sample	Pb	Zn	Ni	Co
Kingtom Dumpsite	KUL	1.50	0.45	2.5	0.8
	KML	1.30	0.11	2.3	0.45
	KDL	1.10	0.05	2.4	0.78

Table 17. Levels of metals in water sample from nearby stream at the Granville Dumpsite (ppm) (Batch1).

Location	Sample	Pb	Zn	Ni	Co
Granville Dumpsite	GUR	0.20	0.02	0.03	0.10
	GMR	0.01	0.04	0.028	0.08
	GDR	0.04	0.06	0.05	0.05

Table 18. Levels of metals in cassava and Krain-Krain dry ground level (mg/kg) at the Kingtom Dumpsite (Batch1).

Location	Sample	Pb	Zn	Ni	Co
Kingtom	KKL	25.6	4.6	0.6	7.0
Dumpsite	KKKL	19.2	7.0	1.8	5.0

Table 19. Levels of metals in cassava and Krain-Krain dry ground levels (mg/kg) at the Granville Dumpsite (ppm)(Batch).

Location	Sample	Pb	Zn	Ni	Co
Granville	GKL	22.5	7.0	8.6	9.0
Dumpsite	GKKL	17.0	1.85	15.1	6.0

3.2. Discussion

pH Values

Table 3 to Table 6 shows the pH value for the Kingtom and Granville dumpsites. pH values range from 5.1 to 7.5. The pH values of water samples and soil samples are comparable in both sites. The range is slightly lower than the permissible recommended WHO value of 6.5 to 8.5 for drinking water, and this indicates that it is within the WHO permissible value. The result is with the consent of previous researchers such as Bona [4] and Kanu [17]. This slight acidity is due to the presence of a heavy metal load in the soil. This acidity may facilitate the corrosivity of water, leaching more acids than affects the taste of water. The soil samples from Kingtom, with pH 5.4 to 6.1, are relatively more acidic than those from Granville, in the range of 6.8 to 7.5. The reason being the rate of meal dumping in the kingdom is greater than in Granville. The levels of acidity or alkalinity affect the mobility of metals in the soil. From the result, one would expect more leaching at Kingtom than in Granville.

The water sample from Granville shows natural to slightly alkaline pH values from 7.2 to 7.7, whilst those from Kingtom show slight acidic pH values of 5.1 and 5.5. This might be attributed to the relatively even distribution of organic matter, which has the tendency of contributing to the acidity of the watercourse by partial dissociation of the organic acids they may contain. There is no distinct variation along the lagoon, that is, up lagoon (5.5), middle lagoon (5.5), and down lagoon (5.1) at the Kingtom Dumpsite; the same applies for upriver (7.2), middle river (7.4), and downriver (7.7) at the Granville Dumpsite.

Electrical conductivity and Total dissolved Solids

Table 6 shows the EC and TDS in water samples of the Kingtom and Granville dumpsites. The electrical conductivity (EC) value of the lagoon water at Kingtom is shown to be extremely high, with values recorded for lower, middle, and

upper portions as 16,667 S/cm, 15,400 S/cm, and 15,000 S/cm, respectively, compared to the recommended WHO permissible guideline value of 10-100 S/cm for drinking water. Those for the upper (2,083 s/cm), middle (2,400), and lower (2,000 s/cm) portions of the Granville River are also higher than recommended WHO permissible values but are less than those from the Kingdom Dumpsite. This extremity of EC values can be the ions, their total dissolved solid (TDS), as was noted for the EC values for both dumpsites. This high EC is evident in high levels of metals in soil and water.

Lead

Table 14 and Table 15 show the value for Pb in the soil of the Kingtom and Granville Dumpsite with a mean value of 1,01924 mg/kg. The high Pb content in the kingdom can be attributed to the immense anthropogenic input of solid wastes containing Pb. Furthermore, the high value of Pb at the kingdom may be due to the age of the dumpsite or the rate of water dumped as opposed to the value in the Granville Dumpsite. The value of lead obtained is far above the recommended WHO threshold of 0.01 ppm and 0.01 mg/kg.

From Table 17, the level of Pb in the upper course of the Kingtom lagoon was 1.5 ppm, whilst at Granville the same variation was observed with 0.2 ppm, 0.01 ppm, and 0.04 ppm values for the upper, middle, and lower courses, respectively. A mean value of 0.0870.05 ppm was noted for Granville water samples. It can be inferred that the upper courses of the lagoon/river are closely located to the dumpsite as compared to the courses that facilitate a concentration gradient of leaching metals.

Table 18 and Table 19 indicate the level of metals in the edible portions of two widely grown plant species, cassava and Krain-Krain leaves. Pb in cassava leaves for both Kingtom (25 mg/kg) and Granville (22.5 mg/kg) is much greater than the levels of lead in Krain-Krain leaves for both Kingtom (19.2 kg/mg) and Granville Dumpsite (17.0 kg/mg). This may be due to variation in the metal uptake by the plant

or possible biomagnification within the plant. Here Pb is shown to be high with a mean value of 22.159 mg/kg. Maximum tolerable intake indicated by the joint FAO/WHO Expert Committee on Food Additives provisionally recommended that the weekly intake of Pb should not exceed 0.025 mg/kg of body weight per week for adults, children, and infants. [5]. According to Kanu [17], his values are less than any of the results listed above; this might be probable because he carried out his research in the rainy season, and more leaching could have taken place. It could also be a result of the area of sampling/point of collection.

Zinc

Table 14 and Table 15 show values for Zn in the soils of the Kingdom and Granville Dumpsite. Kingdom Dumpsite shows a mean value of 146 mg/kg, and that of Granville Dumpsite is 141 mg/kg. These two values are comparable. The value obtained for Zn from soil for both dumpsites surpasses the permissible WHO-recommended guideline value (3 mg/kg).

Zn levels in the ground leaves of cassava and Krain-Krain shown in Table 18 and Table 19 manifest a different pattern, with Krain-Krain leaves (7 mg/kg) having a concentration value exceeding that in cassava leaves (4 mg/kg) at Kingdom Dumpsite, but at Granville Krain-Krain leaves (1.85 mg/kg) having a value less than that in cassava leaves. (7 mg/kg). Zinc intake as the structure of metal enzymes as indicated by a decline in erythrocyte zinc activity [15]. Table 16 and Table 17 show levels of zinc from waters around the dumpsite in the range of 0.02 to 0.45 mg/l, the value of Zn at the Kingdom Dumpsite lagoon (0.05-0.45 mg/l).

Nickel

Table 14 and Table 15 show values for Pb in the soils of the Kingdom and Granville Dumpsite. Soils from Granville Dumpsite show levels of Ni (41-150 mg/kg) to be much higher, with a mean value of 10,311.4 mg/kg, than those from Kingdom Dumpsite (40-80 mg/kg), with a mean of 688.2 mg/kg. These values may be correlated with the pH value recorded; since Granville Dumpsite depicts nearly natural pH values (6.8-7.3), a situation that may curtail the leaching of metals. Nonetheless, the kingdom situation with slight acidic pH values (5.4-6.1) enhances the leaching of metals, thus reducing the concentration of metals within the soil. The figures noted for Ni differ from the recommended WHO permissible standard of 0.02 mg/kg. Nickel in the ground Krain-Krain leaves from both Kingdom (1.8 mg/kg) and Granville Dumpsite (15 mg/kg) are usually higher than nickel in the ground cassava leaves of both Kingdom (0.6 mg/kg) and Granville (8 mg/kg). A safe range of population intake for Ni is not proposed due to data scarcity. Nonetheless, available information indicates that most monastic animals have a Ni requirement of less than 0.2 mg/kg of diet [24]. Thus, if animals' data is extrapolated to humans, it is reasonable to suggest a basal Ni requirement of less than 0.1 mg daily for adults. The fact that oral doses as low as 0.6 mg Ni gave positive skin reactions in some Ni-sensitive individ-

uals suggest that the threshold level of toxicity can be quite low in specific situations [20].

The water sample analyzed from the kingdom and the Granville Dumpsites river shows a value within the range of 0.025-2.5 mg/l, which surpasses the guideline values established by WHO for drinking water (0.02 mg/l). The nickel values recorded for the Kingdom Dumpsite lagoon at the upper course (2.5 mg/L), middle course (2.3 mg/L), and lower course (2.4 mg/L) are greater than those obtained at the upper course (0.03 mg/L), middle (0.028 mg/L), and lower course (0.05 mg/L) of the Granville Dumpsite river/stream. As the figures depict, an inverse variation was observed from Kingdom to Granville; the upper course shows higher Ni concentrations than the lower course. This is not the case at Kingdom, with the lower course being more loaded than the upper course [7].

Cobalt

Table 14 shows the value for cobalt in the kingdom and the Granville Dumpsite. Soil samples scooped from those dumpsites show the level of cobalt to be relatively lower in comparison with the levels of Pb, Ni, and Zn. Soil from the Kingdom Dumpsite records levels of Co in the range of 16-38 mg/kg that lie below the record range of Co values at Granville Dumpsite, 34-39 mg/kg.

Even though most experimental indications show that Co has proven to be less troublesome, the continued increase in the concentration of Co from previous studies to this one must be a cause for concern. At both the Kingdom (7 mg/kg) and Granville (8 mg/kg) dumpsites, the level of cobalt in cassava leaves surpasses the level of cobalt in Krain-Krain leaves of both Kingdom (5 mg/kg) and Granville (6 mg/kg). This might be due to the difference in the ability of the plant to translocate the heavy metals from the root to the leaves and the fruits. Spiral availability of the heavy metals (i.e., accessibility to the roots) and considerable differences in their root morphology are contributing factors to this difference [20].

Water sample records Cobalt to be more concentrated at the Kingdom Dumpsite lagoon (0.45-0.78 mg/l) in comparison to Cobalt levels recorded for the river adjacently located to the Granville Dumpsite (0.05-0.1 mg/l). Factors like age of dumpsite, quantity of waste dumped, drainage or rate of leaching, pH, and a lot of other factors will help to explain the trend.

4. Conclusion

The overall pH, Zn, Ni, and Co within the scooped soils of the dumpsite, plants grown on the sites, and water from the nearby river/lagoon as recorded surpassed the recommended WHO guide value, leaving one to conclude that these sites are unhygienic for gardening. Although cobalt and zinc are micronutrients to plant species, the detected value overpoises the threshold value, thus posing some toxic tendencies after bioaccumulation, bioconcentration, or biomagnification

within the plants.

Lead and nickel are not trace nutrients for crops. Even at very low concentrations, lead, in particular, is deleterious to plants. The high value recorded for these metals is even more likely to be a threat to the use of these dumpsite sites for gardening. It is also time that a significant fraction of the metals tends to build up in pliable parts of some plants. Added to those faults, lead or nickel may destroy crops at much lower

concentrations than those that are injurious to human health [5].

Nevertheless, it does not absolutely mean that the dumpsite should be totally out of bounds for gardening, as the determination of all toxic parameters, like hazardous materials, bacteria, and other metals, should be carried out before such proclamations are made. Therefore, the researcher's recommendations are summarized in the table below:

Table 20. Summary of recommendations and specific action points.

No	Recommendation Focus	Specific Actions
1	Control of Pollution Sources	Identify and restrict particular sources, such fuel combustion, brake wear, and leachate from municipal and industrial waste.
2	Waste Management and Infrastructure	Enhance fundamental waste management by implementing engineered landfills equipped with liners and leachate collection systems to avert groundwater contamination.
3	Augmented Surveillance and Monitoring	Create a long-term, ongoing groundwater monitoring program that includes seasonal sampling (dry versus wet seasons) in the vicinity of the dumpsites.
4	Site Remediation and Risk Assessment	Perform a thorough risk assessment and, depending on the level of contamination, put containment measures in place (such as capping and vertical barriers).
5	Strict Enforcement and Policy	Enforce and strengthen environmental laws to prevent improper waste management and unlawful dumping.

Abbreviations

AAS	Atomic Absorption Spectrophotometry
CH ₄	Methane
CO	Carbon Monoxide
Co	Cobalt
Cr	Chromium
Cu	Copper
EC	Electrical Conductivity
EHD	Environmental Health Division
FCC	Freetown City Council
Fe	Iron
FSWMC	Solid Waste Management Company
GDR	Granvillie Down River
GDR	Granvillie Down River
GMR	Granvillie Medium River
GMR	Granvillie Medium River
GSS ₁	Granvillie Soil Sample 1, 2, 3 and 4
GSS1	Granvillie Soil Sample from plot (1)
GSS2	Granvillie Soil Sample from plot (2)
GSS3	Granvillie Soil Sample from plot (3)
GSS4	Granvillie Soil Sample from plot (4)
GUR	Granville Upper River
HCl	Hydrochloric Acid

HNO ₃	Nitrate
HNO ₃	Nitric Acid
KCL	Kingtom Cassava Leaves from Plot (2)
KDL	Kingtom Down Landfill
KDL	Kingtom Down Lagoon Water Sample is Labelled KDL
KKKL	Kingtom Krain-Krain Leaves from Plot (2)
KML	Kingtom Medium Landfill
KML	Kingtom Middle Lagoon Water Sample
KSS ₁	Kingtom Soil Sample from Plot (1)
KSS ₂	Kingtom Soil Sample 1, 2, 3 and 4
KSS ₂	Kingtom Soil Sample from Plot (2)
KSS ₃	Kingtom Soil Sample from Plot (3)
KSS ₄	Kingtom Soil Sample from Plot (4)
KUL	Kingtom Up Lagoon Water Samples
KUL	Kingtom Upper Landfill
KUL	Kingtom Upper Landfill
MOHS	Ministry of Health and Sanitation
Ni	Nickel
PAHs	Polyaromatic Hydrocarbons
Pb	Lead
SPM	Suspended Particulate Matter
TDS	Total Dissolved Solid
WHO	World Health Organization
Zn	Zinc

Author Contributions

David Conteh: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft

Sahr Emmanuel Lebbie: Supervision, Validation, Funding acquisition, Resources, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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