Research Journal of

Environmental Toxicology

ISSN 1819-3420

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS **Research Journal of Environmental Toxicology**

ISSN 1819-3420
DOI: 10.3923/rjet.2020.16.25

Research Article
Heavy Metal Concentrations in Leachates and Crops Grown Around Waste Dumpsites in Sekondi-Takoradi in the Western Region of Ghana

Robert Agbemafle, Samira Elsie Aggor-Woananu, Olivia Akutey and John Kwesi Bentum

Department of Laboratory Technology, College of Agriculture and Natural Sciences, School of Physical Sciences, University of Cape Coast, Ghana

Abstract
Background and Objective: Accumulation of heavy metals in waste dumpsites affects soils and release concentrated leachate to the environment which further enters the food chain. Heavy metals accumulation results in serious health and environmental problems because of poisonous effects of these metals on plants and potential health implications to humans and animals consuming such vegetables from these dumpsites. The objective of this study was to assess the concentrations of 5 heavy metals (Cadmium, zinc, lead, chromium and copper) in leachates and crops grown around four selected waste dumpsites in the Sekondi-Takoradi Metropolis of the Western region of Ghana. **Materials and Methods:** Leachates and crops samples were collected from the selected dumpsites, digested and the heavy metals concentrations were determined by using Atomic Absorption Spectroscopy (AAS). **Results:** The mean concentrations of the heavy metals in the leachates and the crops grown at the selected dumpsites were found to be high as compared to Food and Agriculture Organization (FAO) and World Health Organization (WHO) permissible limits. Zinc and copper concentrations were higher in leachates from Essipong waste dumpsite. **Conclusion:** Zinc and copper were the most abundant heavy metals in most of the crops from the selected dumpsites. Heavy metals concentrations in crops must be monitored regularly since the detrimental effects of heavy metal pollution manifest many years after exposure.

Key words: Heavy metals, leachates, waste dumpsites, groundwater, Sekondi-Takoradi Metropolis, heavy metal pollution

Citation: Robert Agbemafle, Samira Elsie Aggor-Woananu, Olivia Akutey and John Kwesi Bentum, 2020. Heavy metal concentrations in leachates and crops grown around waste dumpsites in Sekondi-Takoradi in the Western region of Ghana. Res. J. Environ. Toxicol., 14: 16-25.

Corresponding Author: Robert Agbemafle, Department of Laboratory Technology, College of Agriculture and Natural Sciences, School of Physical Sciences, University of Cape Coast, Ghana Tel: +233244151461

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Fast and relatively unorganized urban expansion and industrial development doubled with insufficient waste management have a significant effect on the physical environment and increase the accumulation of municipal waste. One of the most critical concerns of urbanization in Ghana is the management of waste (solid, liquid and toxic). Some cities in the developing countries do not have proper solid waste regulation as well as proper disposal facilities for toxic or radioactive waste.

Heavy metals accumulation persistently exists in waste dumpsites at environmentally dangerous level[1]. This results in serious health and environmental problems because of the poisonous effects of these metals in plants and potential health implications to humans and animals consuming such vegetables[2]. According to Albores *et al.*[3], municipal waste may increase concentration of heavy metals in soil and ground water. This may have consequences on the host soils, crops and human health[4]. This indicates that the environmental impacts of municipal waste are largely influenced by their heavy metal contents.

The damage of environment with regards to heavy metals come from various sources which can be grouped into urban-industrial aerosols, liquid and solid wastes from animal and man, mining industries and agricultural chemicals[5]. Heavy metals are mostly present in electronic wastes especially copper from wires, chromium, nickel, zinc, cadmium and lead, including other metals and elements that are rare on earth. High air emissions or leaked liquids result in significant amounts of metals that are concentrated in landfills or dispersed in the environment after recycling[6].

Waste dumpsites which have been abandoned are used considerable as fertile grounds for cultivating vegetables though research has shown that the vegetables are capable of accumulating significant levels of heavy metals from contaminated and polluted soils[6].

The decomposition of organic materials in municipal solid wastes by micro-organisms produces a hazardous liquid known as leachate and its volume is influenced by surface and ground water and excess rain water passing through the waste layers. Landfill leachates are mostly composed of organic matter, inorganic macro-components and heavy metals. The dispersion of heavy metals in landfill leachate has indicated that significant portion of them is linked to waste derived dissolved organic matter. Research in landfill have revealed that leachate is of specific interest because it has potentially harmful heavy metals[7] and the current trend in municipal waste management and disposal practices may give rise to heavy metal implications on soils and groundwater[8].

Moreover, dumpsites create health hazard even to a passer-by and those living near the sites. This is as a result of unpleasant smell emitting from the activities of micro-organisms on the organic waste. Unchecked burning of solid waste creates serious environmental pollution which is detrimental to the health of solid waste workers and pickers. Toxic and hazardous wastes when burnt with addition to solid waste like asbestos fibre may introduce potential carcinogenic fibre to the smoke plume[9].

Landfill sites are considered a major threat to ground water resources, either through waste materials coming into contact with ground water under flow or through infiltration from precipitation[10]. The land fill solid waste often releases products that contaminate the water moving through the deposit as well as liquids containing several different organic and inorganic compounds that sit at the bottom of the deposit and seep into the soil affecting its physical and chemical properties[11]. Monitoring of heavy metals in leachates and crops grown around waste dumpsites can facilitate the recommendation of suitable management practices to these dumpsites.

The aim of this study was to assess the level of contamination of heavy metals in leachates and crops grown around waste dumpsites in Sekondi-takoradi, Western region of Ghana.

MATERIALS AND METHODS

Study area: The study was conducted in Kojokrom, Effiakuma, Ntankoful and Essipong in the Sekondi-Takoradi Metropolis, Western region of Ghana from May, 2018 to July, 2019. Map of study area is shown in Fig. 1. Sekondi-Takoradi is located between latitudes 4°52'30"N and 5°04'00"N and longitudes 1°37'00" W and 1°52'30"W. Bounded to the North of the metropolis is the Mpohor-Wassa district, to the south by the Gulf of Guinea, to the west by the Ahanta West district and to the east by Shama district. The metropolis happens to be the smallest district in the region with a land area of 385 km^2. However, it is the most populated district. The metropolis is strategically located in the South-western part of the country, about 242 km to the west of Accra the capital city and approximately 280 km from the La Côte d'Ivoire in the west.

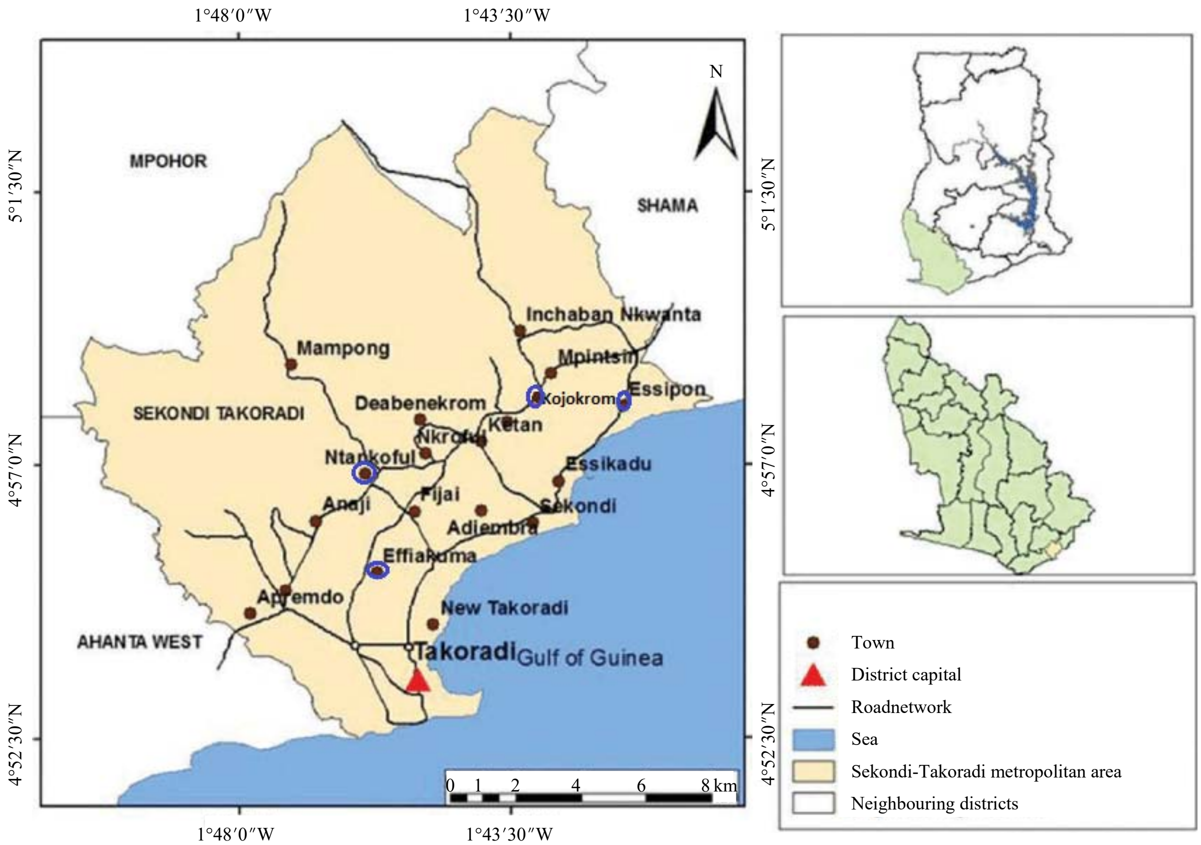

Fig. 1: Map of the study area
Source: GIS and Cartography Unit of University of Cape Coast[12]

The population of Sekondi-Takoradi Metropolis, according to the 2010 population and housing census is 559,548 representing 23.5% of the region's total population. Generally, the Metropolis does not experience severe weather conditions. The climate of the Metropolis is equatorial with an average annual temperature of about 22°C experienced between January and March. Rainfall is bi-modal with the major season occurring between March and July and the minor season occurring between August and November. The mean annual rainfall is about 1,380 mm, covering an average of 122 rainy days[13].

Sampling

Leachate sampling: Leachates were collected at various points from each waste dumpsite and composited to give a true representative of each site. The leachates were collected into 1 L pre-cleaned high density polyethylene bottles. These bottles were washed thoroughly with detergent, rinsed several times with distilled water and soaked in 10% HNO_3 overnight and finally rinsed with distilled water. The pH conductivity and temperature were measured *in situ* using a portable meter and recorded at the sampling site using Nisso pH meter and conductivity meter (PC 450), respectively. Each leachate sample was acidified with 2 mL concentrated 65% HNO_3. Collected samples were labelled accordingly and stored in a cooler containing ice cubes according to the standard method of APHA[14] and later transported to the Department of Chemistry, University of Cape Coast, for analysis. At the laboratory, the samples were stored in a refrigerator at 4°C until analysis.

Crops sampling: At the Effiakuma waste dumpsite ayoyo leaves (*Corchorus olitorius*), kontomire (*Colocasia esculenta*), pawpaw (*Carica papaya*) and plantain (*Musa paradisiaca*) were the dominant crops grown around the site. Dominant crops grown at the Essipong dumpsite were pawpaw, plantain and kontomire. Those grown at Kojokrom dumpsite were plantain and kontomire and that of Ntankoful waste dumpsite were pawpaw, plantain, orange *(Citrus sinensis)* and turkey berries (*Solanum torvum*). Medium aged crop samples were taken from different sampling positions and composited for each waste dumpsite. The crops were kept in separate zip-locked plastic bags, labelled accordingly and kept in box and transported to the laboratory for analysis.

Chemical reagents: Chemicals and reagents used were of analytical grade. They included 65% nitric acid (Fluka Garanie, Sweden), 37% hydrochloric acid, (BDH Prolabo, France) distilled water standard solutions purchased from Agilent Technologies, USA.

Cleaning of glassware: All apparatus were initially washed with detergents then soaked in 10% nitric acid for overnight then washed thoroughly. They were rinsed with aqua regia followed by tap water and then rinsed in distilled water. The glassware was then dried in a hot oven at 105°C.

Sample preparation: The crop samples were thoroughly washed with tap water to remove any dirt and soil particles from the surface and subsequently rinsed with distilled water. The samples were cut into pieces with a stainless steel knife and dried in an oven at 80°C for 48 h. The dried samples were ground in a stainless steel blade blender, transferred into air-tight plastic bags and stored in a desiccator until further analysis.

Acid digestion of leachate and crop samples

Leachate digestion: Fifty milliliters of the well-mixed leachate sample was transferred into a beaker which was previously acid washed. Two milliliters of concentrated nitric acid and 5 mL of concentrated HCl were added. The sample was covered with watch glass and heated on a hot plate at 95°C until the volume was reduced to 15-20 mL. The sample was allowed to cool and the beaker walls and the watch glass were washed down with distilled water, filtered by using Whatman filter paper into a 100 mL volumetric flask and diluted to the mark using distilled water[15].

Crops digestion: Conventional aqua regia (i.e., solution of HCl and HNO_3 with ratio of 3: 1) digestion was employed. This was performed in 250 mL glass beaker covered with watch glasses. A well-mixed sample of 1.0 g was digested in 12 mL aqua regia on a hot plate at 95°C and evaporated to near dryness. The sample was allowed to cool, diluted with 20 mL of 2% nitric acid and transferred into a 100 mL volumetric flask by using a Whatman No. 42 filter paper and diluted to 100 mL with distilled water[16].

Preparation of metal standard solutions: Calibration curves for each of the selected metals (copper, chromium, lead, zinc and cadmium) were prepared by using standard solutions. These standards prepared by dilution from 100 mg L^{-1} stock solution were as follows: 0.05, 0.1, 0.5, 1.0, 2.0 and 5.0 mg L^{-1} for cadmium and zinc, 0.1, 0.5, 1.0, 2.0, 5.0 and 10.0 mg L^{-1} for copper, chromium and lead. Calibration curves were drawn for Cd, Zn, Cu, Cr and Pb by plotting absorbance versus metal ion standard concentration.

Determination of heavy metals: The Atomic Absorption Spectrophotometer (AAS) (SHIMADZU AA-7000, Japan) was used for the determination of concentration of the metal ions present in the samples by reading their absorbance and comparing it on the respective standard calibration curve. Three replicate determinations were carried out on each sample and same analytical procedure was employed for the determination of elements in digested blank solutions and for the spiked samples.

Limit of detection: The limit of detection for the heavy metals Cd, Cu, Pb, Zn and Cr was found to be 0.003, 0.01, 0.015, 0.002 and 0.01 mg L^{-1}, respectively.

Quality control and quality assurance: Precautions were taken to ensure the reliability of results. The samples were carefully handled to avoid any external influences that could interfere with the integrity of the result. Blank and replicate samples were analyzed and compared to actual values obtained. Before the analysis, equipment was calibrated by using appropriate standards. Triplicate determination of the samples was made and data presented as mean. All glassware and plastic bottles were soaked overnight in 10% (v/v) nitric acid and rinsed with distilled water and dried before use[17]. Distilled water was used in the preparation of samples and deionized water was used in the preparation of reagents. The digestion method and atomic absorption spectroscopy analysis were validated by recovery method. One gram of randomly selected ground crop samples was spiked with known concentrations of heavy metals each run in with the AAS. This was followed by the digestion of the spiked samples and determination of metal concentration by using AAS.

Data presentation and statistical analysis: The obtained data were analyzed by using Microsoft Excel and Graph Pad prism version 7. Results were expressed as mean±standard deviation. Using ANOVA, the means were compared to determine whether there were significant differences in the heavy metals concentrations in the leachates and crops from the sampling sites.

RESULTS

Physicochemical properties of leachates from the selected waste dumpsites: The data related to the various physicochemical parameters (pH, Electrical Conductivity (EC) and temperature) in leachates from the selected waste dumpsites is presented in Fig. 2a-c. The leachates from these sites were neutral to basic as the mean pH values for Kojokrom, Essipong, Effiakuma and Ntankoful were 7.14, 8.06, 7.40 and 8.16, respectively. Electrical Conductively (EC) values show different results amongst the four dumpsites. The highest value was obtained at the Ntankoful waste dumpsite with mean value of 7.01 mS cm^{-1} whereas, the lowest value was obtained at the Kojokrom waste dumpsite with the value of 0.31 mS cm^{-1}. The highest value of temperature was obtained at the Effiakuma whereas, the lowest value was obtained at Kojokrom waste dumpsite (Fig. 2c).

Heavy metals concentrations in leachates from the selected waste dumpsites: The mean concentrations of cadmium, zinc, lead, chromium and copper in the leachates sampled from the selected waste dumpsites in the Sekondi-Takoradi Metropolis are shown in Table 1.

There were significant differences in the heavy metal concentrations of the leachates from the various waste dumpsites. The minimum and maximum mean concentrations of cadmium in leachates were 0.03 and 0.10 mg L^{-1} from Kojokrom and Essipong waste dumpsites, respectively. Leachates from Effiakuma and Ntankoful waste dumpsites recorded the same concentrations for cadmium (0.05 mg L^{-1}). The minimum and maximum mean concentrations of zinc in leachates were 0.20 and 5.48 mg L^{-1} from Kojokrom and Essipong waste dumpsites, respectively. Mean lead concentrations in the leachate samples from Kojokrom and Essipong waste dumpsites were the same. The minimum and maximum mean concentrations of chromium in leachates were 0.38 and 0.55 mg L^{-1} from Essipong and Effiakuma waste dumpsites, respectively. The minimum and maximum mean concentrations of copper in leachates were 0.17 and 0.90 mg L^{-1} from Effiakuma and Essipong waste dumpsites, respectively.

Relationship between heavy metals in leachates and crops from the selected waste dumpsites: The concentrations of cadmium, zinc, lead, chromium and copper for leachates and corresponding crops from each waste dumpsite are presented in Table 2-5. The concentrations of heavy metals in the crops analyzed differed from one dumpsite to another and varied

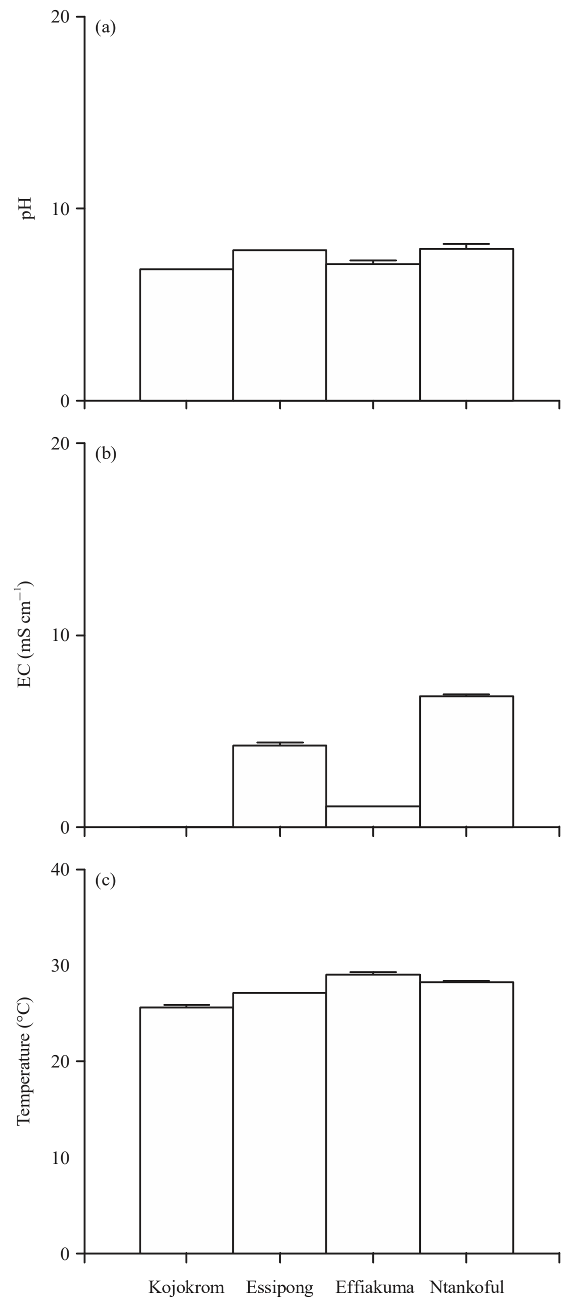

Fig. 2(a-c): Mean values of physicochemical properties, (a) pH, (b) EC and (c) Temperature of leachates from the various waste dumpsites

from one species of crop to the other. The crops contained higher concentrations of heavy metals as compared to the leachate with the exception of copper which was below the detection limit in plantain sampled from Kojokrom dumpsite (Table 2). The most abundant metals found in kontomire from this site were zinc and copper which were 673.52 and 263.84 mg kg^{-1}, respectively.

Table 1: Concentration (Mean±SD) of heavy metals (mg L^{-1}) in leachates among the sampling sites

Heavy metals	Kojokrom	Essipong	Effiakuma	Ntankoful	p-value
Cd	0.03±0.03[a]	0.10±0.03[b]	0.05±0.01[a]	0.05±0.01[a]	0.022
Zn	0.20±0.03[a]	5.48±0.45[b]	2.67±0.25[c]	4.23±1.37[d]	0.000
Pb	4.97±0.02[a]	4.97±0.01[a]	5.11±0.02[b]	5.35±0.18[b]	0.003
Cr	0.39±0.02[a]	0.38±0.05[a]	0.55±0.07[b]	0.43±0.05[a]	0.015
Cu	0.41±0.06[a]	0.90±0.10[b]	0.17±0.04[a]	0.88±0.30[c]	0.001

Mean values with different superscript along the row are significantly different ($p<0.05$)

Table 2: Concentration (Mean±SD) of heavy metals in leachate (mg L^{-1}) and crops (mg kg^{-1}) in Kojokrom dumpsite

Samples	Cd	Zn	Pb	Cr	Cu
Leachate	0.03±0.03	0.20±0.03	4.97±0.02	0.39±0.02	0.41±0.06
Kontomire	1.13±0.09	673.52±175.04	33.64±7.38	12.70±0.67	263.84±6.76
Plantain	0.47±0.05	11.72±2.77	18.00±0.16	12.98±0.84	BDL
p- value	0.000	0.000	0.001	0.000	0.000

BDL: Below detection limit

Table 3: Concentration (Mean±SD) of heavy metals in leachate (mg L^{-1}) and crops (mg kg^{-1}) in Essipong dumpsite

Samples	Cd	Zn	Pb	Cr	Cu
Leachate	0.10±0.03	5.48±0.45	4.97±0.01	0.38±0.05	0.90±0.10
Kontomire	0.53±0.14	335.41±207.65	26.20±3.72	11.29±3.19	243.47±5.80
Plantain	0.17±0.07	33.75±13.12	33.18±1.63	7.76±1.24	55.02±2.72
Pawpaw	1.63±0.80	39.66±0.28	18.90±0.90	9.32±0.86	4.12±0.84
p- value	0.006	0.014	0.000	0.000	0.000

Table 4: Concentration (Mean±SD) of heavy metals in leachate (mg L^{-1}) and crops(mg kg^{-1}) in Effiakuma dumpsite

Samples	Cd	Zn	Pb	Cr	Cu
Leachates	0.05±0.01	2.67±0.25	5.11±0.02	0.55±0.07	0.17±0.04
Ayoyo leaves	0.92±0.10	405.33±50.26	BDL	9.07±0.56	133.04±4.73
Kontomire	0.53±0.14	217.36±27.67	BDL	0.52±0.25	1443.31±8.80
Pawpaw	1.34±0.21	123.93±20.21	8.69±1.37	10.41±2.06	1213.76±2.46
Plantain	1.44±0.16	43.52±8.68	19.41±1.36	3.29±1.01	157.14±9.38
p-value	0.000	0.000	0.000	0.000	0.000

BDL: Below detection limit

Table 5: Concentration (Mean±SD) of heavy metals in leachate (mg L^{-1}) and crops (mg kg^{-1}) in Ntankoful dumpsite

Samples	Cd	Zn	Pb	Cr	Cu
Leachates	0.05±0.01	4.23±1.37	5.35±0.18	0.43±0.05	0.88±0.30
Pawpaw	0.86±0.35	161.08±25.18	5.76±1.70	2.77±1.63	1708.67±14.55
Turkey Berry	0.78±0.32	62.65±14.88	34.17±3.63	14.82±1.96	12.75±1.53
Plantain	2.93±0.46	20.16±8.13	1.28±0.31	11.45±1.19	BDL
Orange	1.28±0.32	22.37±0.86	21.24±0.72	5.65±1.06	BDL
p-value	0.000	0.001	0.000	0.000	0.000

BDL: Below detection limit

Table 6: RMC for wastewater/leachate and permissible limits for vegetables

Heavy metals	RMC for wastewater/leachate (mg L^{-1})	Permissible limit for vegetables (mg kg^{-1})
Cadmium (Cd)	0.01	0.2
Zinc (Zn)	2.00	99.0
Lead (Pb)	5.00	0.3
Chromium (Cr)	0.10	2.3
Copper (Cu)	0.20	73.0

RMC: Recommended maximum concentration

From Table 3, it was observed that the concentrations of heavy metals in the crops sampled from Essipong dumpsite were higher as compared to the leachate sample. Cadmium levels in kontomire and pawpaw exceeded the permissible limit set for vegetables of 0.2 mg kg^{-1} (Table 6) and that of plantain was within the permissible limit.

Table 4 showed concentrations of heavy metals in leachate and crops sampled from the Effiakuma dumpsite. It was observed that the crops contained higher concentrations of heavy metals as compared to the leachate sample with the exception of lead which was below detection limit in ayoyo and kontomire samples and chromium level in kontomire 0.52 mg kg^{-1} was less than that of the leachate sample and within the permissible limit of 2.3 mg kg^{-1} (Table 6).

The crops contained higher concentrations of heavy metals as compared to the leachate with the exception of copper which was below the detection limit in plantain and orange sampled from Ntankoful dumpsite (Table 5). The concentrations of cadmium in the crops sampled exceeded the permissible limit of 0.2 mg kg^{-1} (Table 6).

DISCUSSION

In this study the physicochemical properties and concentration of heavy metals in leachates and crops at waste dumpsites were assessed. The results showed that there were significant differences in the heavy metal concentrations of the leachates from the various waste dumpsites. The pH and conductivity of leachates are indicators of the abundance of dissolve inorganic species or total concentration of ions[18]. The pH of the leachates varies according to the age of the waste dumpsites[19]. The pH of young leachate is less than 6.5 while old landfill leachate[20] has pH higher than 7.5. Initial low pH may be due to high concentration of volatile fatty acids[21]. An increase in pH suggested that a steady state was reached between acid producing processes (e.g., cellulose and lignin degradation) and acid consuming processes (e.g., methane formation) at the landfill[22]. The pH values obtained for the leachates from the study sites are in agreement with pH values of 4.5-9.0 and 6.0-9.0 reported by Christensen and Stegmann[23] and Banar *et al.*[18], respectively. The EC of the leachates from the Essipong and Ntankoful waste dumpsites were within the range of values found in leachate from landfills[24] (2.5-35.0 mS cm^{-1}). The EC of the leachates from Kojokrom and Effiakuma waste dumpsites were within the range 0.007-0.031 mS cm^{-1} reported by Al-Muzaini *et al.*[25], 0.002-0.0342 mS cm^{-1} reported by Banar *et al.*[18], 0.01-0.045 mS cm^{-1} reported by Yoshida *et al.*[26] and 0.531-27.440 mS cm^{-1} reported by Maqbool *et al.*[27].

The mean concentrations of cadmium from all the waste dumpsites were above the recommended maximum concentration of 0.01 mg L^{-1} set for cadmium[28]. The presence of cadmium could be due to the discharge of municipal solid waste at the dumpsites which contain nickel-cadmium batteries, discarded consumer electronic products such as; televisions, calculators, stereos and plastics[29]. Similar ranges have been reported on cadmium by Im *et al.*[30], Chofqi *et al.*[31] and Abu-Rukah and Al-Kofani[32] in leachates 0.018-0.023, 0.0084-0.034 and 0.012-0.52 mg L^{-1}, respectively The mean level of zinc from the Kojokrom dumpsite was within the recommended maximum concentration of 2.0 mg L^{-1} set for zinc[28]. Leachates from the other dumpsites were above this limit. According to Peganova and Eder[33], the presence of zinc in landfill leachates are due to wastes from cosmetics, dyes, dry-cell batteries, fungicides and soaps found at these sites. Sucheckan *et al.*[34] and Chofqi *et al.*[31] also reported zinc concentrations in leachates as 0.175-0.025 and 0.7-0.747 mg L^{-1}, respectively which were within the acceptable limit[28]. The lead concentrations from Effiakuma and Ntankoful leachate samples of 5.11 and 5.35 mg L^{-1}, respectively exceeded the recommended maximum concentration[28] of lead 5.0 mg L^{-1}. The presence of lead in the leachate may be from lead-acid batteries, plastics and rubber remnants, lead foils such as; bottle closures, used motor oils and discarded electronic gadgets including televisions, electronic calculators and stereos[30] at the landfill sites. Chistensen and Stegmann[23] and Yoshida *et al.*[26] reported lead values of 0.0010-5.0 and 0.01-0.18 mg L^{-1} which were within the limit set by World Health Organization. The mean concentrations of chromium from all the waste dumpsites were above the recommended maximum concentration of 0.10 mg L^{-1} set for chromium[28]. The presence of chromium in leachates may be attributed to wastes from electroplating industries, leather tanneries, textile industries and steel industries[35]. Kjeldsen and Christophersen[36], Chistensen and Stegmann[23] and Yoshida *et al.*[26] reported similar values of 0.02-1.5, 0.02-1.5 and 0.14-1.80 mg L^{-1}, respectively for chromium in leachates. Aside the leachate from Effiakuma being below the recommended maximum concentration[28] of 0.20 mg L^{-1}, the levels obtained from the other waste dumpsites were above this limit. According to Momcilovic[37], presence of copper in leachates is due to products of photovoltaic solar cells, plumbing pipes and electrical cables found in these sites. However, levels of copper from all the dumpsites agree with those reported by Kjeldsen and Christophersen[36] and Abu-Rukah and Al-Kofani[32]. They reported levels of copper 0.005-10.0 and 0.04-19.4 mg L^{-1} in leachates, respectively.

The concentrations of heavy metals in the crops analyzed differ from one dumpsite to another and vary from one species of crop to the other. This may be attributed to differential uptake capacity of plants for different heavy metals through roots and their further translocation within the plant parts[38].

The heavy metals concentrations in the crops at Kojokrom dumpsite exceeded the permissible limits for vegetables[39]. High levels of lead in the crops can be attributed to the burning of lead containing products like scrap metals and batteries in waste dumpsite and high level of copper in kontomire can be attributed to continuous dumping of copper-containing electrical gadgets. However, this level is in line with findings of Odai *et al*.[40], who reported cadmium values ranging between 0.68-1.78 mg kg^{-1} on urban waste dumpsites in Kumasi. Nkop *et al*.[41] also reported values of 0.11-0.80 mg kg^{-1} for cadmium in plants grown on waste dumpsites in Nigeria. Nkop *et al*.[41] also reported zinc values ranging between 11.35 and 22.31 mg kg^{-1} in plants grown on waste dumpsites in Nigeria. The cadmium levels in kontomire and pawpaw, however, agreed with the finding of Odai *et al*.[40], who reported values ranging between 0.68-1.78 mg kg^{-1} on urban waste dumpsites in Kumasi.

The zinc levels obtained from plantain and pawpaw were within the permissible limit for vegetables[39] of 99.0 mg kg^{-1}, while that of the kontomire much exceeded the required limit. Zinc is a required nutrient and becomes toxic to plants only at high concentrations. The concentrations of lead and chromium in sampled crops far exceeded the permissible limit of 0.3 and 2.3 mg kg^{-1}, respectively[39]. However, this result was in agreement with values reported for lead ranging between <0.001 and 36.72 mg kg^{-1} in plants on waste dumpsite in Accra[42]. The concentration of chromium in the sampled crops falls within the critical range of 5.00-30.00 mg kg^{-1} given by Radojevic and Bushkin[43] and reported by Agyarko *et al*.[44]. The copper levels in kontomire amongst the crops sampled exceeded the permissible limit[40] of 73.0 mg kg^{-1}. According to Maobe *et al*.[45] high levels of copper can cause metal fumes fever with flu-like symptoms, hair and skin decolouration, dermatitis, irritation of the upper respiratory tract, metallic taste in the mouth and nausea.

The cadmium levels in the sampled crops were above the permissible[39] limit of 0.2 mg kg^{-1}. These levels agreed with findings of Fosu-Mensah *et al*.[42], who reported values of cadmium ranging between 0.25 and 1.64 mg kg^{-1} for vegetation on e-waste in Accra. This result was also in line with the finding of Odai *et al*.[40], who reported values ranging between 0.68-1.78 mg kg^{-1} on urban waste dumpsites in Kumasi. The high concentrations of cadmium might be as a result of the burning of waste containing cadmium–nickel batteries, pigments and paints. Significant concentration of Cd may have gastrointestinal effect and reproductive effect on livestock[46]. Jabeen *et al*.[46] reported that cadmium causes both acute and chronic poisoning, adverse effect on kidney, liver, vascular and the immune system. With the exception of plantain which was within the permissible limit of 99.0 mg kg^{-1} for zinc, the rest of the crops sampled exceeded the required limit. The levels of lead in ayoyo and kontomire were below the detection limit whereas that of pawpaw and plantain exceeded the permissible limit[39] of 0.3 mg kg^{-1}. However, these values are in agreement with values reported for lead ranging between <0.001 and 36.72 mg kg^{-1} in plants on waste dumpsite in Accra[42]. The chromium concentration in kontomire was within the permissible limit[39] of 2.3 mg kg^{-1}, but the others had concentrations which exceeded the required limit. The copper concentrations in all crops sampled exceeded the permissible limit[39] of 73.0 mg kg^{-1} and this can be attributed continuous dumping of copper-containing electrical gadgets.

With the exception of plantain having cadmium concentration of 2.93 mg kg^{-1}, the other crops are in line with findings of Odai *et al*.[40], who reported cadmium values ranging between 0.68-1.78 mg kg^{-1} on urban waste dumpsites in Kumasi. The high concentration of cadmium can be attributed to burning of e-waste containing cadmium-nickel batteries, pigments and paints. Significant concentrations of Cd may have gastrointestinal effect and reproductive effect on livestock[45]. The concentrations of zinc in the sampled crops were within the permissible limit of 99.0 mg kg^{-1} with the exception of the level in pawpaw (161.08 mg kg^{-1}). The concentrations of lead and chromium in the crops exceeded the permissible limit of 0.3 and 2.3 mg kg^{-1}, respectively. However, these values are in agreement with values reported for lead and chromium ranges <0.001-36.72 and 1.08-3.84 mg kg^{-1}, respectively in plants on waste dumpsites in Accra[42]. Agyarko *et al*.[44] also reported critical range of chromium as 5.00-30.00 mg kg^{-1} given by Radojevic and Bushkin[43]. Aside plantain and orange having concentrations of copper below the detection limit, turkey berry was found to be within permissible limit of 73.0 mg kg^{-1} for copper and the concentration of copper in pawpaw exceeded the required limit.

CONCLUSION

The results of this study have demonstrated that leachates and crops from the selected waste dumpsites are contaminated with heavy metals. However, some crops were below the detection limits for copper and lead from Kojokrom, Effiakuma and Ntankoful dumpsites. For all the locations, cadmium and chromium showed values above the acceptable limits for leachates. Zinc and copper levels were also above the acceptable limits for leachates with an exception of Kojokrom and Effiakuma waste dumpsites. Essipong waste dumpsite showed the highest zinc and copper concentrations for the leachate samples. Zinc and copper concentrations were also the most abundant heavy metals found in most of the crops from the selected waste dumpsite.

SIGNIFICANCE STATEMENT

The study discovered high concentrations of heavy metals in the leachates and crops grown at the selected wastes dumpsites in the Sekondi-Takoradi Metropolis in the Western region of Ghana. Consumption of crops from the dumpsites where significantly high concentrations of Cd, Zn, Pb, Cr and Cu were detected poses a threat to human health. The Environmental Protection Agency and Sekondi-Takoradi Metropolitan Assembly (STMA) should collaborate to create awareness on the potential health risks people are exposed to from these waste dumpsites.

ACKNOWLEDGMENT

Authors would like to thank the Research Journal of Environmental Toxicology for publishing this article free of cost and to Karim Foundation for bearing the cost of article production, hosting as well as liaison with abstracting and indexing services and customer services.

REFERENCES

1. Amusan, A.A., D.V. Ige and R. Olawale, 2005. Characteristics of soils and crops' uptake of metals in municipal waste dump sites in Nigeria. J. Hum. Ecol., 17: 167-171.
2. Pillay, A.E., J.R. Williams, M.O. Al-Lawati, S.M.H. Al-Hadabbii, M.H. Al-Hamdi and A. Al-Hamdi, 2003. Risk assessment of chromium and arsenic in date palm leaves used as livestock feed. Environ. Int., 29: 541-545.
3. Albores, A.F., B. Perez-Cid, E.F. Gomes and E.F. Lopez, 2000. Comparison between sequential extraction procedures and single extractions for metal partitioning in sewage sludge samples. Analyst, 125: 1353-1357.
4. Smith, S.R., D.M. Jaffe and M.A. Skinner, 1997. Case report of metallic mercury injury. Pediatr. Emerg. Care, 13: 114-116.
5. Ideriah, T.J.K., F.O. Harry, H.O. Stanley and J.K. Igbara, 2010. Heavy metal contamination of soils and vegetation around solid waste dumps in Port Harcourt, Nigeria. J. Applied Sci. Environ. Manage., 14: 101-109.
6. Robinson, B.H., 2009. E-waste: An assessment of global production and environmental impacts. Sci. Total Environ., 408: 183-191.
7. Abdus-Salam, N., 2009. Assessment of heavy metals pollution in dumpsites in Ilorin Metropolis. Ethiop. J. Environ. Stud. Manage., 2: 92-99.
8. Okoronkwo, N.E., S.A. Odemelam and O.A. Ano, 2006. Levels of toxic elements in soils of abandoned waste dumpsite. Afr. J. Biotechnol., 5: 1241-1244.
9. Oyelola, O.T., A.I. Babatunde and A.K. Odunlade, 2009. Health implications of solid waste disposal: Case study of *Olusosun dumpsite*, Lagos, Nigeria. Int. J. Pure Applied Sci., 3: 1-8.
10. Taylor, R. and A. Allen, 2006. Waste Disposal and Landfill: Potential Hazards and Information Needs. In: Protecting Groundwater for Health: Managing the Quality of Drinking-water Sources, Schmoll, O., G. Howard, J. Chilton and I. Chorus (Eds.)., IWA Publishing, London, UK., ISBN: 1843390795, pp: 339-360.
11. Al-Yaqout, A.F. and M.F. Hamoda, 2003. Evaluation of landfill leachate in arid climate-A case study. Environ. Int., 29: 593-600.
12. GIS and Cartography Unit of University of Cape Coast, 2017. A map of Ghana showing Sekondi-Takoradi Metropolitan area. Department of Geography and Regional Planning of University of Cape Coast, Cape Coast.
13. GSS, 2012. 2010 Population and housing census. Summary Report of Final Results, Ghana Statistical Service, Accra, Ghana.
14. APHA., 1995. Standard Methods for the Examination of Water and Waste Water. 19th Edn., The American Public Health Association, Washington, DC., USA., Pages: 874.
15. US EPA., 1995. SW-846 EPA Method 3050B: Acid Digestion of Sediments, Sludges and Soils in Test Methods for Evaluating Solid Waste. 3rd Edn., 3rd Update; US EPA., Washington, DC.
16. Devêvre, O.C. and W.R. Horwáth, 2001. Stabilization of fertilizer nitrogen-15 into humic substances in aerobic vs. waterlogged soil following straw incorporation. Soil Sci. Soc. Am. J., 65: 499-510.
17. Boadi, N.O., S.K. Twumasi, M. Badu and I. Osei, 2011. Heavy metal contamination in canned fish marketed in Ghana. Am. J. Scient. Ind. Res., 2: 877-882.
18. Banar, M., O. Aysun and K. Mine, 2006. Characterization of the leachate in an urban landfill by physicochemical analysis and solid phase microextraction-GC/MS. Environ. Monitor. Assess., 121: 439-459.
19. Kulikowska, D. and E. Klimiuk, 2008. The effect of landfill age on municipal leachate composition. Bioresour. Technol., 99: 5981-5985.
20. Abbas, A.A., G. Jingsong, L.Z. Ping, P.Y. Ya and W.S. Al-Rekabi, 2009. Review on landfill leachate treatments. J. Applied Sci. Res., 5: 534-545.
21. Bohdziewicz, J. and A. Kwarciak, 2008. The application of hybrid system UASB reactor-RO in landfill leachate treatment. Desalination, 222: 128-134.
22. Chu, L.M., K.C. Cheung and M.H. Wong, 1994. Variations in the chemical properties of landfill leachate. Environ. Manage., 18: 105-117.
23. Chistensen, T.H. and R. Stegmann, 1992. Landfill Leachate: An Introduction. In: Land FIlling of Waste Leachate, Christensen, T.H. and R. Stengmann (Eds.). St. Edmundsbury Press, Bury St. Edmunds, Suffolk, UK.

24. Kjeldsen, P., M.A. Barlaz, A.P. Rooker, A. Baun, A. Ledin and T.H. Christensen, 2002. Present and long-term composition of MSW landfill leachate: A review. Environ. Sci. Technol., 32: 297-336.
25. Al-Muzaini, S., M.U. Beg and K. Muslmani, 1995. Characterization of landfill leachates at a waste disposal site in Kuwait. Envirom. Int., 21: 399-405.
26. Yoshida, M., S. Ahmed, S. Nebil and G. Ahmed, 2002. Characterization of leachate from Henchir El Yahoudia closed landfill. Water Waste Environ. Res., 1: 129-142.
27. Maqbool, F., Z.A. Bhatti, A.H. Malik, A. Pervez and Q. Mahmood, 2011. Effect of landfill leachate on the water quality of the salhad stream in Abbottabad, Pakistan. Int. J. Environ. Res., 5: 491-500.
28. WHO., 2006. World Health Organisation Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Vol. I: Policy and Regulatory Aspects, Vol. II: Wastewater Use in Agriculture, Vol. III: Wastewater and Excreta Use in Aquaculture, Vol. IV: Excreta and Greywater Use in Agriculture. World Health Organization, Geneva.
29. Woodbury, P.B., 1992. Trace elements in municipal solid waste composts: A review of potential detrimental effects on plants, soil biota and water quality. Biomass Bioenergy, 3: 239-259.
30. Im, J.H., H.J. Woo, M.W. Choi, K.B. Han and C.W. Kim, 2001. Simultaneous organic and nitrogen removal from municipal landfill leachate using an anaerobic-aerobic system. Water Res., 35: 2403-2410.
31. Chofqi, A., A. Younsi, E.K. Lhadi, J. Mania, J. Mudry and A. Veron, 2004. Environmental impact of an urban landfill on a coastal aquifer (El Jadida, Morocco). J. Afr. Earth Sci., 39: 509-516.
32. Abu-Rukah, Y. and O. Al-Kofahi, 2001. The assessment of the effect of landfill leachate on ground-water quality-a case study. El-Akader landfill site-North Jordan. J. Arid Environ., 49: 615-630.
33. Peganova, S. and K. Eder, 2004. Zinc. In: Elements and their Compounds in the Environment, Merian, E., M. Anke, M. Ihnat and M. Stoeppler (Eds.)., Vol. 2. Wiley-VCH., Weinheim, Germany, pp: 1203-1227.
34. Suchecka, T., W. Lisowski, R. Czykwin and W. Piatkiewicz, 2006. Landfill leachate: Water recovery in Poland. Filtration Separation, 43: 34-38.
35. Palaniappan, P.L. and S. Karthikeyan, 2009. Bioaccumulation and depuration of chromium in the selected organs and whole body tissues of freshwater fish *Cirrhinus mrigala* individually and in binary solutions with nickel. J. Environ. Sci., 21: 229-236.
36. Kjeldsen, P. and M. Christophersen, 2001. Composition of leachate from old landfills in Denmark. Waste Manage. Res., 19: 249-256.
37. Momčilović, B., 2004. The Copper Group. In: Elements and their Compounds in the Environment: Occurrence, Analysis and Biological Relevance 2nd Edn., Merian, E., M. Anke, M. Ihnat and M. Stoeppler (Eds.)., WILEY-VCH Verlag GmbH & Co. KGaA., Weinheim, pp: 731-750.
38. Yahaya, M.I., S. Mohammad and B.K. Abdullahi, 2009. Seasonal variations of heavy metals concentration in abattoir dumping site soil in Nigeria. J. Applied Sci. Environ. Manage., 13: 9-13.
39. FAO. and WHO., 2001. Food additives and contaminants. Joint Codex Alimentarius Commission, FAO/WHO. Food Standards Programme, ALINORM 01/12A, 1-2892001.
40. Odai, S.N., E. Mensah, D. Sipitey, S. Ryo and E. Awuah, 2008. Heavy metals uptake by vegetables cultivated on urban waste dumpsites: Case study of Kumasi, Ghana. Res. J. Environ. Toxicol., 2: 92-99.
41. Nkop, E.J., A.M. Ogunmolasuyi, K.O. Osezua and N.O. Wahab, 2016. Comparative study of heavy metals in the soil around waste dump sites within University of Uyo. Arch. Applied Sci. Res., 8: 11-15.
42. Fosu-Mensah, B.Y., E. Addae, D. Yirenya-Tawiah and F. Nyame, 2017. Heavy metals concentration and distribution in soils and vegetation at Korle Lagoon area in Accra, Ghana. Cogent Environ. Sci., Vol. 3, No. 1. 10.1080/23311843.2017.1405887.
43. Radojevic, M. and V.N. Bashkin, 2006. Practical Environmental Analysis. Royal Society of Chemistry Publishing Cambridge, UK.
44. Agyarko, K., E. Darteh and B. Berlinger, 2010. Metal levels in some refuse dump soils and plants in Ghana. Plant Soil Environ., 56: 244-251.
45. Maobe, M.A., E. Gatebe, L. Gitu and H. Rotich, 2012. Profile of heavy metals in selected medicinal plants used for the treatment of diabetes, malaria and pneumonia in Kisii region, Southwest Kenya. Global J. Pharmacol., 6: 245-251.
46. Jabeen, S., M.T. Shah, S. Khan and M.Q. Hayat, 2010. Determination of major and trace elements in ten important folk therapeutic plants of Haripur basin, Pakistan. J. Med. Plants Res., 4: 559-566.