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CADMIUM FROM SLUDGE AND EFFLUENT FROM GIMBOKI SEWAGE TREATMENT PLANT ACCUMULATES IN THE VEGETABLE *TELFAIRIA OCIDENTALIS*

By

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DECLARATION

I, **Hlupo Munyaradzi P**, hereby declare that I am the sole author of this dissertation. I authorize Midlands State University to lend this dissertation to other institutions or individuals for the purpose of scholarly research.

Signature ………………………………

Date …………………………………

APPROVAL

This dissertation entitled "Cadmium from sludge and effluent from Gimboki Sewage Treatment Plant accumulates in the vegetable *Telfairia occidentalis*" by **Hlupo Munyaradzi P,** meets the regulations governing the award of the degree of Applied Biosciences and Biotechnology of the Midlands State University, and is approved for its contribution to knowledge and literal presentation.

Supervisor ………………………………………

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ABSTRACT

Use of sewage sludge and effluent in cultivation of crops and vegetables is a common practice in Zimbabwe. However, high concentrations of heavy metals such as Cadmium (Cd) in sewage sludge and effluent does not only result in environmental contamination, but may lead to elevated heavy metal uptake by crops, which may affect food quality and safety. The current study aimed to investigate if high concentration of Cd in sludge and effluent from Gimboki Sewage Treatment Plant translates into high concentration of Cd in the leaves of the vegetable *Telfairia occidentalis*. A total of 20 vegetable samples were analysed for presence of Cd using an Atomic Absorption Spectrophotometer (AAS). *Telfairia occidentalis* leaves grown under a combination of sludge and effluent had the highest Cd concentration of 24 ± mg kg^{-1}, which was 100 times higher than the EEC (European Economic Commission Regulation) permissible limit of 0.2 mg kg^{-1}. This was followed by leaves of plants grown under effluent only with 6.92 ± mg kg^{-1}, which also exceeded EEC permissible limit by 35 times. Remarkably, *T. occidentalis* leaves of plants grown with neither sludge nor effluent did not have any detectable Cd concentration. It can be concluded that high concentrations of Cd in sewage effluent and sludge led to accumulation of Cd in pumpkin leaves thereby compromising the quality and safety of the vegetables for human consumption. I therefore recommend that farmers at Gimboki Sewage Treatment Plant should desist from using sludge and effluent for manuring and watering their crops.

DEDICATION

I dedicate this dissertation to my lovely parents who have made me come this far and for being an inspiration that they are in my life. Without their support l would not have been where l am today.

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“If any of you lack wisdom, let him ask of God that giveth to all men liberally and upbraideth not; and it shall be given him”. The Holy Bible (James 1:5). First and Foremost l would like to thank the Almighty God for giving me every opportunity that He has, for taking me this far in life, for His mercy and Grace endures forever. I thank Him for blessing me with Dr. T. Muteveri (my Academic supervisor), Mr V. Tamirepi and Mr. T. Pashi (my WRL supervisors). I am most grateful for their suggestions, assistance, support and patience during the course of this study.

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CHAPTER ONE: INTRODUCTION

1.1. General introduction

Cadmium is a rare but widely dispersed heavy metal found naturally in the environment (Schulze *et al.*, 2002). Heavy metals like Cadmium (Cd) are introduced into sewage systems through effluent from manufacturers of Cd-containing products such as NiCd batteries and pigments (ATSDR 1999). Other sources of Cd in sewage systems include weathering and erosion of soils and bedrock, mining, plating, atmospheric deposition, direct discharge from industrial operations and leakage from landfills and contaminated sites (Muller and Anke, 1994; Sorme and Lagerkvist, 2002; Akpor, 2014).

Cadmium and other heavy metals are concentrated in sludge due to their association with settlable solids during primary and secondary treatment processes (Jern, 2006). The persistence of Cd in wastewater is due to its non-biodegradability (Jern, 2006). Cadmium like other heavy metals occurs in high concentration in sludge and effluent in developing countries owing to the ineffectiveness of treatment processes that are used in developing countries (Sorme and Lagerkvist, 2002). A high concentration of Cd in effluents and sludge is a cause for concern because of the inherent risk of heavy metal toxicity to soil, plants and humans (Al-Musharafi *et al.*, 2012). At present, large amounts of sewage sludge are being generated and stockpiled in several waste water treatment plant premises around the world and agricultural application is being considered as a future viable option of disposal (Deribachew *et al.*, 2015).

Accumulation of Cd in agricultural soils through application of sludge (used as manure) and effluent (used to water crops) does not only result in soil contamination but may also lead to accumulation in crops thereby affecting food quality and safety (Hughes, 1985; Muchuweti *et al.*, 2006; Khan *et al*., 2008; Arora *et al.*, 2008). Food chain contamination is one of the most important pathways for the entry of Cd into the human body. Evidence is accumulating that leafy vegetables manured by sludge and watered by sewage effluent, accumulate higher amounts of metals including Cd than those grown in uncontaminated soils (Muhammad *et al*., 2008). Cadmium accumulation in plants depends on plant species. Efficiency of different plants in absorbing Cd is evaluated by either plant uptake or soil to plant transfer factors (Antil, 2011; Deribachew *et al.*, 2015).

Cadmium has no known use to the human body and is very toxic even at low levels (Khan *et al*., 2008). It can affect nearly all systems in the human body including cardiovascular, reproductive, urinary, the central nervous system and even the brain by inducing neuron cell death resulting in decreased attention and memory loss (Deribachew *et al.*, 2015). Other potential health risks caused by Cd include high blood pressure, bone damage (Itai-Itai), damage to prostate function and increased testosterone levels and this therefore result in reduced sperm production, sleep apnea, development of larger breasts, increased risk of heart diseases etc. (Deribachew *et al.*, 2015 and Livestrong, 2018). The exposure to Cd also causes cancers and affects the unborn before they even join this world. Cadmium can cross the placenta and accumulate in fetal tissues and prenatal exposure. It is also a threat to the developing brain and results in reduced birth weight and birth size. In children, Cadmium affects the renal and dopaminergic systems (Khan *et al*., 2008).

The intake of vegetables is an important path of heavy metal toxicity to human beings (Khan *et al*., 2008). Consumption of leafy vegetables poses a persistent risk of uptake of heavy metals. Therefore, monitoring heavy metals in crops is important for safety assessment of human health (Khan *et al*., 2008). Against this background, it was necessary to determine if Cd in sludge and effluent at Gimboki Sewage Treatment Plant accumulates in the leaves of *Telfairia occidentalis*, a popular vegetable to the local people.

1.2. Problem of statement

Sludge and effluent at Gimboki Sewage Treatment Plant (GSTP) contain high concentrations of heavy metals including Cd (Unpublished EMA report, 2017). Despite the high levels of heavy metals in the sludge and effluent, farmers use them for manuring and watering their crops and vegetables such as *Telfairia occidentalis* near GSTP. There is a possibility that Cd accumulates in the vegetable *Telfairia occidentalis* (Mapanda *et al.*, 2007) and cause health problems to the consumers of the vegetable. Currently it is not known whether these heavy metals accumulate in the crops and vegetables and pose a threat to the consumers.

1.3. Justification

This study aims to provide information on whether Cd accumulates in the vegetable *Telfairia occidentalis* that is either watered by effluent or watered by effluent and manured with sludge. If Cd is accumulating in vegetables, farmers should be advised to desist from using effluent and sludge to water their vegetables. On the other hand, if there is no accumulation of heavy metals, farmers can continue to freely use effluent and sludge for watering and manuring vegetables.

1.4. Objectives

The main objective of this study was to determine if the vegetables that are watered by effluent or vegetables watered by effluent and manured by sludge at Gimboki Sewage Treatment Plant, accumulate high concentrations of Cadmium using *T. occidentalis* as an example. To achieve this objective, the following specific objectives were addressed: (1) to determine concentration of cadmium in *T. occidentalis* leaves grown under different combination of sludge and effluent, (2) to compare concentration of cadmium in *T. occidentalis* leaves with the recommended concentration in vegetables and (3) to infer on health safety.

CHAPTER TWO: LITERATURE REVIEW

2.1. Heavy metals

Heavy metals refer to any metal of relatively high density (specific gravity greater than about 5) or of high relative atomic weight (Vogel, 1989). Examples of heavy metals include cadmium, lead, arsenic, chromium, mercury, manganese among others. These heavy metals are natural constituents of the Earth's crust and cannot be degraded or destroyed, therefore they are persistent in all parts of the environment (Mishara *et al.*, 2010).

Heavy metals, in small amounts, enter the human body via food, drinking water and air. Moreover, some heavy metals are required in small amounts (nutritionally essential for a healthy life) in living organisms and these are particularly trace elements such as iron, copper, cobalt, manganese, molybdenum, and zinc and excessive levels of these can be damaging to the organisms (Muchuweti *et al.*, 2006). These trace elements, or some form of them, are commonly found naturally in foodstuffs, in fruits and vegetables, and in commercially available multivitamin products (Muchuweti *et al.*, 2006).

Heavy metals can therefore be described as any metallic element having a relatively high density and is toxic or poisonous at low concentrations. Human activities such as mining affect the natural geological and biological distribution of heavy metals through pollution of soil, air and water (Adrienne *et al.*, 2008). Humans also alter the chemical forms of heavy metals released to the environment and such alterations often affect a heavy metal's toxicity by allowing it to bioaccumulate in plants and animals, bioconcentrate in the food chain or to even attack specific organs of the body (Deribachew *et al.*, 2015). Bioaccumulation is defined as an increase in the concentration of a metal in a biological organism over time, compared to the normal concentration in the environment. A number of metals accumulate faster in living things any time they are taken up and stored than they are broken down (metabolized) or excreted (Muchuweti *et al.*, 2006).

In addition, some heavy metals such as cadmium, mercury and lead are toxic metals that have no known vital or beneficial effect on organisms and their accumulation over time in human bodies or even animals can cause serious illness (Khan *et al.*, 2008). Since heavy metals are stable and persistent environmental contaminants, they cannot be degraded or destroyed and therefore they tend to accumulate in the soil, sewage water and sediments (Mishara *et al.*, 2010).

2.1.1. The occurrence of heavy metals in nature

Metals exist in the environment either in the solid, liquid or gaseous state. They can also exist as individual elements, as organic and inorganic compounds and their movement between environmental reservoirs may or may not involve changes of state (Adrienne *et al*., 2008).

The original source of all metals is the geosphere except for those that enter the atmosphere from space in the form of meteorites and cosmic dust. Metals may be present in minerals, glasses, and melts within the geosphere and occur as dissolved ions and complexes, colloids, and suspended solids in the hydrosphere (Mishara *et al*, 2010). In addition, in the atmosphere, metals may be present as gaseous elements and compounds and as particulates and aerosols (Nriagu, 1989). Particulate and gaseous metals may be inhaled whereas the solid and liquid (aqueous-phase) metals may be ingested or absorbed, thereby entering the biosphere. In addition of the geosphere being the original source of all terrestrial metals, it may also represent a sink for metals (Nriagu, 1989). The hydrosphere and atmosphere also constitute sinks for metals, however, from a geological perspective, they are more likely to be considered as agents of transport (Adrienne *et al*., 2008).

2.1.2. Cadmium

Cadmium is a phytotoxic heavy metal that inhibits plant growth parameters including respiration, photosynthesis, water and nutrient uptake (Adrienne *et al*., 2008). Cadmium and its components travel through soil but its mobility depends on several factors such as amount of organic matter and pH, which vary depending on the local environment. Cadmium binds strongly to organic matter becoming immobile in the soil and is taken up by the plant then eventually the heavy metal enters the food chain (Alloway, 1990).

Once taken up by the plant, cadmium reduces the rate of root growth, new cell production, induces oxidative stress in cells and inhibits the ant oxidative enzyme activities (Adrienne *et al*., 2008). In addition, Cd, has a low mobility in most clay soils (Burton 2006 and Asante-Duah, 1993). Furthermore, Cd induces changes in plants at all biochemical, physical and genetic levels which are responsible for the reduction in the growth of plants, leaf or root necrosis, leaf chlorosis, and ultimately plant death occurs (Khan *et al*., 2008).

Cadmium together with mercury is used in the manufacture of primary and secondary household cell batteries. When these batteries are disposed of in a landfill they usually are buried together with municipal solid waste (MSW) with variable moisture content and improper disposal of industrial cadmium onto the earth's surface has significant dangerous effects on human health (FAO 1990 and Hardoy *et al*, 2001). When ingested especially through the food chain, Cd affects the internal organs of the body and these include the cardiovascular, reproductive organs, the kidneys, eyes, the central nervous system and the brain.Damage of these can be acute resulting from over-exposure at a high concentration or chronic caused by accumulation in the liver and renal cortex(Adrienne *et al*., 2008).

2.2. Sludge

Sewage sludge is defined as the residual, semi-solid material that is produced as a by-product during sewage treatment of municipal wastewater (EPA, 1999).

Amount of sludge that is produced is proportional to the amount and concentration of wastewater treated and it also depends on the type of wastewater treatment process used (EPA, 1999). Total sludge production from a wastewater treatment process is the sum of sludge from primary settling tanks (if they are part of the process configuration) plus excess sludge from the biological treatment step. Sludge production is expressed as kg of dry solids produced per ML of wastewater treated; one mega litre (ML) is 10^3 m^3 (Khan *et al*., 2008).

Sewage sludge can be classified into two classes which are class A and class B. Class A consists of sludge that is typically dried and pasteurized and is also known as exceptional quality (Boyd, 2011). Class B consists of all the sludge that has not been classified as exceptional quality. This class typically consists of undigested and volatile sludge. Both these classes may still contain radioactive or pharmaceutical wastes (Boyd, 2011). Moreover, both these classes also contain sludge that is composed of both inorganic and organic materials, heavy metals, large concentrations of some plant nutrients, much smaller concentrations of numerous trace elements and organic chemicals and some pathogens. The compositions of these vary considerably depending on the wastewater composition and the treatment processes used (EPA, 1999).

2.3. Effluent

Sewage effluent is the water that is produced as a by-product during sewage treatment of municipal wastewater (EPA, 1999).

Treated sewage effluent (TSE) has tremendous potential in supplementing the ever-growing water demand. Effluent can be effectively recycled for both potable and non-potable purposes, provided it meets specific water quality requirement and type of application (Boyd, 2011). In addition, generation of treated wastewater is cheaper and consumes lower energy when compared to desalinated water. Wastewater effluent however contains a wide range of pathogens and other pollutants including chemicals of emerging concerns and heavy metals. It might also contain abundance presence of pharmaceuticals, personal care products (PPCPs) and endocrine disrupting chemicals (EDCs) that could pose a severe threat to public health (Boyd, 2011). It is therefore important that wastewater effluents are adequately treated and monitored to ensure a safe supply and reuse of treated effluents in the industrial and agriculture sectors to reduce the demand on desalinated water (EPA, 1999).

2.4. Telfairia occidentalis

Telfairia occidentalis is a tropical plant that is mostly grown in West and southern Africa as a leaf vegetable and for its edible leaves and seeds. The common names for this plant include fluted pumpkin, fluted gourd, muboora (in the Shona language, ugu (in the Igbo language), and ikong-ubong (in the Efik/Ibibio language). *Telfairia occidentalis* is a member of the Plant Kingdom, Cucurbitaceae family and under the genus *Telfairia*, (Akoroda, 1990).

2.4.1. Structure, Nutritional Content, Cultivation, Uses

Fluted gourd fruit is quite large ranging from about 16–105 cm (6.3–41.3 in) in length, and an average of 9 cm in diameter. In both the pistillate and staminate varieties, *T. occidentalis* flowers grow in sets of five, with creamy-white and dark red petals, contrasting with the light green colour of the fruit when young, and yellow when ripe and also dioecious flowering is most common in the fluted gourd, (Akoroda, 1990).

Telfairia occidentalis is widely used for consumption due to its high nutritional value and is considered an oil seed. The *T. occidentalis* leaves contain a high amount of antioxidants and hepatoprotective and antimicrobial properties, the fluted gourd is high in oil (30%), and the shoots of *T. occidentalis* contain high levels of potassium and iron, while seeds are composed of 27% crude proteins and 53% fats (Badifu and Gabriel, 1993). In Zimbabwe, the leaves are mainly used as vegetables and can be eaten with pap (sadza).

The *T. occidentalis* is mostly grown vertically on trestle-like structures and is allowed to spread flat on a field. Growing the gourd flat has a beneficial outcome in the suppression of weeds, especially when intercropped with a tall, upright plant such as maize. Furthermore, the growing period usually begins in April or May when seeds are planted, the first leaves and shoots can be harvested after a month and can be collected every two–four weeks thereafter (Emebiri and Nwufo, 1990). The seeds are planted directly into the soil, typically in groups of three as a way to increase output in a case of a failed germination. The fruit is then harvested between October and December. Though dependent upon soil type, fluted gourd is able to ratton and subsequently produce many flushes of fruit over long periods (Akoroda, 1990). Highest degree of success to ratton occurs in well-drained soils. The seeds are housed in another greater covering or hard shell which protects them from harm. It can also survive drought and can retain its life in the root even after many years and is a creeping plant and grows well if staked with bamboo sticks (Emebiri and Nwufo, 1990).

Main use of *Telfairia occidentalis* is as a leaf, fruit and seed vegetable. Its tender shoots, succulent leaves and immature seeds are cooked and consumed as a vegetable. The leaves can also be used alone or together with okra (Okoli *et al.*, 1983). They can be cooked with fish, meat and tapioca. The immature seeds are cooked or roasted or can be fermented for several days and eaten as a slurry. Moreover, the fruit pulp with young seeds is occasionally made into marmalade or the fruit can just be boiled and eaten (Akoroda, 1990). The mature seeds cannot be consumed directly because they have a high content of anti-nutrients but their fat and oil may be extracted, the seed cake is suitable for fortifying foods and the seed oil serves as cooking oil and for margarine production (Badifu and Gabriel, 1993). Seeds can also be used to produce flour that can be used for high-protein breads (Giami, 2003). In addition, the rind and pulp of the fruit of fluted pumpkin can be used as fodder for livestock and leaf juice can be used by pregnant women and patients suffering from anaemia as it strengthens the blood and can be used for other medicinal purposes such as to treat sudden attack of convulsion, malaria and playing a vital and protective role in cardiovascular diseases. The *T. occidentalis* stems are also macerated to produce fibres that are used as a sponge (Nwanna and Emem, 2008).

CHAPTER THREE: MATERIALS AND METHODS

3.1. Study site

This study was done at Gimboki Sewage Treatment Plant, which is located about 12 km to the south of Mutare City. Farmers at Gimboki grow maize, yams, sugar-cane and pumpkins (*Telfairia occidentalis*) within the sewage plant premises, using both sludge and effluent to fertilize and water their crops, respectively.

3.2. Experimental design

This study was a field-based manipulative study in which Cd concentration was the response variable and the different treatment combinations constituting the predictor variable. The treatments consisted of: (1) the control in which vegetables were grown on beds with the natural local soil and watered with tap water, (2) treatment 1 in which vegetables were grown on bed with natural local soil and watered with effluent, and (3) treatment 2 in which vegetables were grown on a bed fertilized with sludge and watered with effluent (Table 3.1). *T. occidentalis* seeds were cultivated in each bed with five replicates per bed.

Table 3.1: Treatments used in the study

Treatment	**Description**	**number of replicates**
Control	natural local soil + tap water	5
Treatment 1	Effluent only + natural local soil	5
Treatment 2	Effluent + sludge + natural local soil	5

3.3. Sampling and sample preparation

The soil, sludge, effluent and tap water were first analyzed for Cd concentration to ascertain the source of Cd. The area was divided into three equal beds, which were randomly assigned to serve as a control, treatment 1 or treatment 2. Each bed was cultivated as a monoculture for *T. occidentalis.* The control bed had no effluent nor sludge and was watered with tap water.

Treatment 2 bed was watered with sewage effluent. Treatment 3 bed was watered with sewage effluent and manured with sewage sludge.

Six holes were made in each bed before two *Telfairia occidentalis* seeds were planted at a depth of 5 cm in each hole. The plants were thinned soon after germination so that there were five plants per bed. After 38 days a total of 20 pumpkin leaves (five leaves from each bed) were harvested for analyses for Cd concentration.

3.4. Sample digestion

3.4.1 Plant digestion

3.4.1.1 Pre-treatment of samples

The collected vegetable samples were washed thrice with distilled water to remove dust particles. The leaves were air-dried. The dried samples were ground into fine powder and stored in polyethylene bags until acid digestion.

3.4.1.2 Sample preparation

Sample were prepared for digestion at Midlands State University, Gweru in the Biotechnology Laboratory. A mass of 1 g of each of the vegetable samples was taken into separate 50 ml volumetric flasks before 10 ml of conc. HNO_3 was added into each flask. The mixture was evaporated on a hot plate in a fume cupboard until the brown fumes disappeared giving white fumes. The samples were then made up to 50 ml mark with distilled water. After addition of distilled water, the mixture was filtered through what-man filter papers. The digested samples were then stored in bottles ready for further analysis.

3.4.2 Soil and sludge digestion

Soil and sludge samples were digested at Midlands State University, Gweru in the Biotechnology Laboratory. The total Cd in soil was digested using aqua-regia. To 1 g of dry soil, 10 ml of aqua regia solution was added and digested near to dryness on a hot plate. The process was repeated three times before 1 ml HNO_3 was added. The mixture was made up to the 50 ml mark with distilled water. The samples were filtered through a filter paper and stored ready for analysis.

3.5. Laboratory analysis for cadmium

All the samples were analysed for Cd concentration at Mimosa Mine Laboratories in Zvishavane using the Agilent Technologies 200 Series AA AAS 03 Atomic Absorption Spectrophotometer (Mimosa Laboratories, Zvishavane, Fig 3.4).

Fig 3.4: Atomic Absorption Spectrophotometer

3.6. Data analysis

Cadmium concentration was compared across the three treatments using one way ANOVA in SPSS Version 21. In addition, one sample t-tests were performed in the R-software to test whether Cd concentration in vegetables exceeded the EEC (European Economic Commission Regulation) permissible limit of 0.2 mg kg^{-1}

CHAPTER FOUR: RESULTS

4.1. Cadmium concentrations in soil, water, effluent and sludge

Cadmium was detected in both sludge, with a concentration of 20.5 mg kg^{-1}, and effluent, with a concentration of 0.18 mg l^{-1}. It was remarkable that Cd was undetectable in the soil and tap water (Table 4.1).

Table 4.1 Cadmium concentration in the components used

Component	**Cadmium concentration**
Tap water	N.D
Soil	N.D
Sewage effluent	0.18 mg l^{-1}
Sewage sludge	20.5 mg kg^{-1}

<u>KEYWORDS</u>: N.D: *not detectable,* Cd: *Cadmium*

4.2. Cadmium concentration in pumpkin leaves (*Telfairia occidentalis*)

Cadmium was not detectable in vegetables grown in the control bed (with neither effluent and nor sludge). Vegetables exposed to a combination of sludge and effluent had about three times higher Cd concentration (24 ± 5.11(SD) mg kg^{-1}) than those exposed to effluent only (6.92 ± 2.80(SD) mg kg^{-1}). Moreover, Cd concentration in pumpkin leaves from bed 1 (control) did not exceed the EEC threshold of 0.2 mg kg^{-1} . Cadmium concentration in vegetables in bed 2 (effluent only) was significantly above the EEC permissible limit (one sample t-test: $p = 0.003$). Similarly, Cd concentration in vegetables in bed 3 (sludge + effluent) significantly exceeded the EEC permissible limit (one sample t-test: $p = 0.00$).

Table 4.2 Cadmium uptake by *Telfairia occidentalis* (pumpkin leaves) in mg kg^{-1}

Control (soil+ tap water)	Treatment 2 (soil+ effluent)	Treatment 3 (soil+ sludge+ effluent)
ND	4.35	19
ND	10	31
ND	9.5	22.5
ND	4	20
ND	6.75	27.5
Mean ± SD	6.92±2.80	24±5.11

CHAPTER FIVE: DISCUSSION, CONCLUSION and RECCOMMENDATIONS

5.1. Discussion

5.1.1. Concentration of cadmium in soil, tap water, sludge and effluent

The fact that Cd was not detected in the soil in which the pumpkin seeds were planted and in tap water found at GSTP is important in that it indicates that the only plausible sources of Cd were effluent and sludge.

Cadmium was detected in both treated sewage sludge and effluent with sludge having a mean concentration of 20.5 mg kg^{-1} and effluent 0.18 mg l^{-1}. Cadmium concentration in the treated sewage sludge and effluent led to the pollution of the soil then consequently the pumpkin leaves. Vegetables tend to absorb Cd from contaminated soils since Cd binds strongly to organic matter becoming immobile in the soil and available for absorption (Al Jassir *et al.*, 2005). The mean values for sludge and effluent, 20.5 $mgkg^{-1}$ and 0.18 mg l^{-1}, respectively, exceeded the EEC safety threshold of 0.1 mg kg^{-1} and that of EMA (0.01 mg l^{-1}) suggesting that the sludge and effluent at GSTP are unsuitable for use in agriculture. Accumulation of Cd in soils has phytotoxic effects on the pumpkin leaves and expose consumers to health problems such as brain damage and cancer (Khan *et al*., 2008). Sewage sludge and effluent should therefore not be used for agricultural practices due to the high levels of heavy metals, instead, farmers should shift to other alternatives, for example compost manure for manuring crops and tap water for watering crops.

5.1.2. Concentration of cadmium in pumpkin leaves (*Telfairia occidentalis*)

Pumpkin leaves from the control bed did not contain detectable Cd meaning that any accumulation of Cd in the treatments could be attributed to effluent or sludge or both. Vegetables that were irrigated by sewage effluent had Cd concentration of 6.9 mg kg^{-1}, exceeding the EEC permissible limit of 0.2 mg kg^{-1} for crops and vegetables. Cadmium concentration in the vegetables exposed to sewage effluent and sludge also exceeded the EEC permissible limit having a mean of 24 mg kg^{-1}. These findings are similar to those of Mohammed-Rusan *et al*., (2007), who attributed elevated levels of heavy metals including Cd in vegetables to irrigation with poor quality wastewater. Similarly, Singh and Kumar (2006) found a positive correlation between heavy metal load in irrigation wastewater and high concentration of heavy metals in vegetables. Results in this study suggest that the high concentration of Cd in effluent and sludge is translating into high concentration of Cd in vegetables exposed to effluent and sludge.

5.2. Recommendations

This study has shown that Cd accumulates in pumpkin leaves exposed to effluent or sludge or both to levels that exceed EEC permissible limit posing a great risk to consumers. Therefore, sludge and effluent from GSTP should not be used in agriculture, especially for irrigating vegetables. In light of these findings, I recommend that farmers at GSTP should desist from using sludge and effluent for manuring and watering their crops respectively. Farmers should instead shift to other safer kinds of manure such as compost manure, and water crops with tap water.

5.3. Conclusion

In vegetables watered with effluent only, pumpkin leaves contained Cd concentration that was thirty five times higher than the EEC permissible limit of 0.2 mg kg^{-1} for leafy vegetables. The pumpkin leaves watered with effluent and fertilised with sludge had Cd concentration about 100 times higher than EEC permissible limit. It can be concluded that high concentrations of Cd in sewage effluent and sludge led to accumulation of Cd in pumpkin leaves (*Telferia occidentalis*), compromising the quality and safety of the vegetables for human consumption. These results suggest that the practice of watering vegetables with effluent and fertilising them with sludge at GSTP is causing high health risk to the consumers of the vegetable. I therefore recommend that farmers at GSTP should desist from using sludge and effluent for manuring and watering their crops respectively. Farmers should instead shift to other safer kinds of manure such as compost manure and water crops with tap water.

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APPENDIX

Table 4.3: comparison of Cd concentration across all the three treatment groups.

Test of Homogeneity of Variances

Concentration of Cadmium in Pumpkin Leaves(*Telfairia occidentalis*)

Levene Statistic	df1	df2	Sig.
12.066	2	12	.001

ANOVA

Concentration of Cadmium in Pumpkin Leaves(*Telfairia occidentalis*)

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1526.021	2	763.011	67.422	.000
Within Groups	135.803	12	11.317		
Total	1661.824	14			

Multiple Comparisons

Dependent Variable: Concentration of Cadmium in Pumpkin Leaves(*Telfairia occidentalis*)

Tukey HSD

(I) treatments	(J) treatments	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
soil+tapwater	soil+effluent	-6.92000*	2.12762	.018	-12.5962	-1.2438
	soil+effluent+sludge	-24.00000*	2.12762	.000	-29.6762	-18.3238
soil+effluent	soil+tapwater	6.92000*	2.12762	.018	1.2438	12.5962
	soil+effluent+sludge	-17.08000*	2.12762	.000	-22.7562	-11.4038
soil+effluent+sludge	soil+tapwater	24.00000*	2.12762	.000	18.3238	29.6762
	soil+effluent	17.08000*	2.12762	.000	11.4038	22.7562

*. The mean difference is significant at the 0.05 level.

Concentration of Cadmium in Pumpkin Leaves(*Telfairia occidentalis*)

Tukey HSD[a]

Treatments	N	Subset for alpha = 0.05		
		1	2	3
soil+tapwater	5	.0000		
soil+effluent	5		6.9200	
soil+effluent+sludge	5			24.0000
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 5.000.

Means Plots

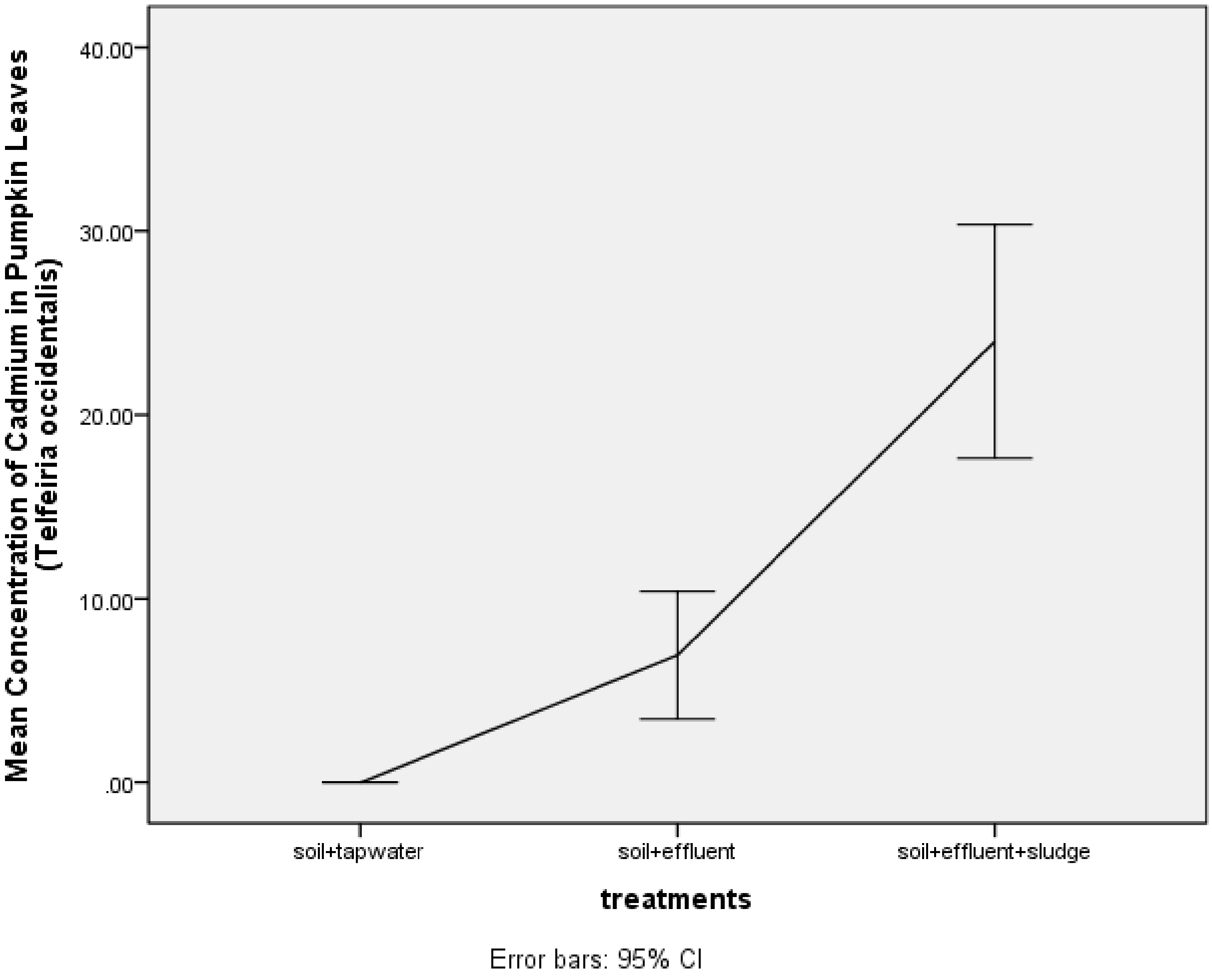

Fig 4.4 Comparison of cadmium concentration in pumpkin leaves (*Telfairia occidentalis*) with the recommended Cd in vegetable leaves (EEC: 0.2mg/l) using one sample t-test in Spss.

R.OUTPUTS

Control

=c(0,0,0,0,0)

> t.test(x,alternative="greater",mu=0.2)

One Sample t-test

data: x

t = 0, df = 4, p-value=1

alternative hypothesis: true mean is greater than 0.2

95 percent confidence interval:

NaNNaN

sample estimates:

mean of x

0

Effluent only

x=c(4.35, 10, 6.75, 4, 9.5)

> t.test(x,alternative="greater", mu=0.2)

One Sample t-test

data: x

t = 5.3714, df = 4, p-value = 0.002901

alternative hypothesis: true mean is greater than 0.2

95 percent confidence interval:

4.252933 Inf

sample estimates:

mean of x

6.92

Sludge+ effluent

```
x=c(19,20,22.5,27.5,31)
> t.test(x,alternative="greater",mu=0.2)

        One Sample t-test

data:  x
t = 10.412, df = 4, p-value = 0.0002403
alternative hypothesis: true mean is greater than 0.2
95 percent confidence interval:
19.12697 Inf
sample estimates:
mean of x
       24
```