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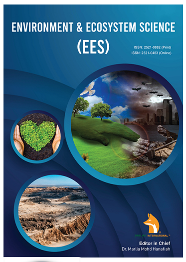

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RESEARCH ARTICLE

ASCERTAINING THE QUALITY OF WATER FOR IRRIGATION AND ITS IMPACT ON VEGETABLE QUALITY: A CASE STUDY ALONG THE BIBINI RIVER IN KUMASI

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ABSTRACT

Farmers in peri-urban areas use diluted wastewater for irrigation. Over time, heavy metals may accumulate in agricultural soils and food crops causing health problems when consumed. Physicochemical, heavy metals (cadmium, lead and chromium) and microbial analysis of water, soil and vegetables were conducted to ascertain the quality of water and vegetables using standard methods. The results of the study showed that the water quality indicators; dissolved oxygen, biochemical oxygen demand and water temperature were not within the recommended standards of Ghana's Environmental Protection Agency. The presence of heavy metals in the water, soil and vegetables were in the order of; soil (1.47 ± 0.017 of cadmium, 0.0019 ± 0.00011 of chromium and 0.541 ± 0.017 of lead) > vegetable (1.472 ± 0.044 of cadmium, 0.0020 ± 0.00010 of chromium and 0.474 ± 0.021 of lead) > water (0.068 ± 0.009 of cadmium, 0.0047 ± 0.00037 of chromium and 0.110 ± 0.014 of lead). Cadmium, chromium and lead concentrations in soil, vegetables and water varied significantly. Cadmium and lead concentrations as well as coliform counts in water and vegetables exceeded Food and Agriculture Organization/ World Health Organization's maximum permissible levels. Soil samples from the control site showed almost negligible concentrations of heavy metals (0.00017 mg/kg of cadmium, 0.00014 mg/kg of chromium and 0.0011 mg/kg of lead) whereas farm sites had heavy metals as a result of long-term wastewater irrigation. Cadmium and lead concentrations in the water and vegetables makes them toxic and microbial populations of faecal coliform in water and lettuce indicated faecal contamination. Therefore, the quality of vegetables produced using the Bibini river is low and unsafe for human consumption.

KEYWORDS

Wastewater irrigation, Water quality, Heavy metals, Faecal Coliform, Vegetable quality.

1. INTRODUCTION

In Ghana, urban and peri-urban agriculture is developing wherever land is available close to streams and drains (Obuobie et al., 2006). In Kumasi for example, informal irrigation, which uses stream water is estimated to cover 11,500 ha, which is twice the total area under formal irrigation in the whole country (Keraita and Dreschel, 2004). Buckets, motorized pumps with hosepipe and surface irrigation are used to fetch, pump and water crops. Surface water used for irrigation is usually of low quality due to human activities which introduces metals and other pollutants into the water (Dyjak, 2018). Generally heavy metal pollution originates from sources like untreated domestic and industrial waste discharges, accidental chemical spills, direct soil waste dumping, and residues from agricultural inputs namely fertilizers and pesticides (Tchounwou et al., 2012; Mico et al., 2006). Bio-accumulation of heavy metals occurs over time after entering the body through food, water or air.

Heavy metals like cadmium, lead and chromium are important environmental pollutants because their presence in water or the soil even in traces can result in serious problems to organisms and humans when they bio-accumulate in the food chain. One of the main routes of exposure to these elements by humans is by ingestion through the food chain (Ejaz et al., 2007). Compared with about 800-1000 farmers practicing wastewater irrigation in Accra, every day, more than 200, 000 urban dwellers eat fast food with contaminated raw vegetables (lettuce and cabbage) in street restaurants. For instance, a survey conducted by International Water Management Institute between 2008-2014 estimated that in the main cities in the country, a total of 800,000 people has the component of raw leafy vegetables in their diet daily (Amoah et al., 2007). Dietary intake of vegetables contaminated with heavy metals may lead to various diseases; exposure to Cadmium may lead to renal and pulmonary diseases such as bronchiolitis, emphysema and alveolitis, Lead may cause a reduced haemoglobin synthesis, malfunctioning of the kidney, joints, reproductive system, cardiovascular system and chronic damage to the central and peripheral nervous system and, high concentration of Chromium may cause mucous membrane ulcerations, perforation of the nasal septum, allergic asthma reactions, skin irritations and bronchial carcinomas (European Union, 2002; Young, 2005; Ogwegbu and Muhanga, 2005; Baruthio, 1992). These afore-mentioned metals are of interest because the main effluent (wastewater) flowing into the river is greywater and they (cadmium, lead and chromium) are metals found in greywater (Donner and Erikson, 2010).

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The extent of contamination depends on several factors including the quality of water used for irrigation. Water quality parameters like pH, temperature and dissolved oxygen affects the availability and solubility of micronutrients or metals for crops consumption (British Columbia Ministry of Environment et al., 1998). Vegetables accumulate heavy metals in their edible and non-edible parts. Although some heavy metals act as micro-nutrients at lower concentrations, they become toxic at higher concentrations. Health risks due to heavy metal contamination have been widely reported (Eriyamremu et al., 2005; Muchuweti et al., 2006). The major contaminants in wastewater also include microbial organisms which severely affect the health of humans as well as the environment (Davies, 2005). In wastewater, the presence of organic matter promotes the breeding of most pathogenic organisms (like bacteria, fungi, viruses and protozoa) which cause a number of water-borne diseases (Jegatheesan et al., 2008).

Majority of pathogenic water-borne microbes responsible for human diseases are from faecal wastes (Kris, 2007). These diseases include typhoid fever, cholera, salmonellosis and hepatitis A. Over the past years, a vibrant vegetable farming where diluted wastewater is used for irrigation has been observed along the Bibini river which passes through KNUST. The lettuce produced is purchased by fast food vendors who use the lettuce in its raw state as salad. This makes it difficult to get rid of faecal coliforms as aside cooking, washing is not a reliable way to remove faecal coliform. Also, heavy metals biomagnify and bioaccumulate on entry into the food chain causing detrimental health effects. This study is aimed at ascertaining the quality of the water used for irrigation and its impact on vegetable quality.

2. Materials and Methods

2.1 Study area

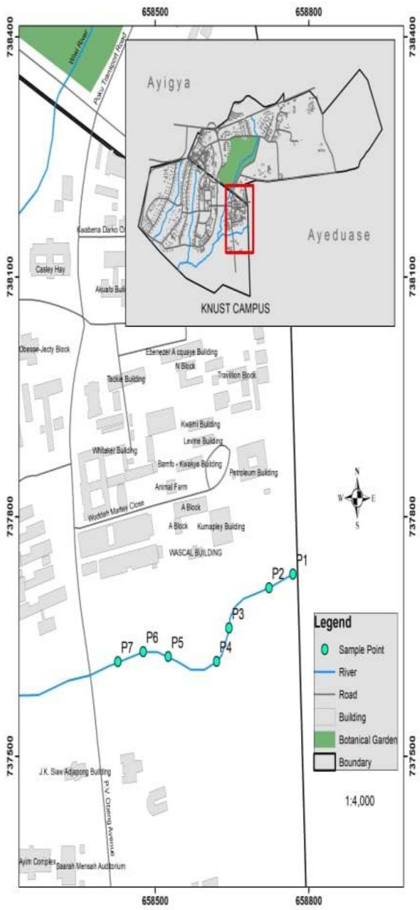

Figure 1: A map of KNUST showing Bibini river

The study was conducted at KNUST which is in the Kumasi Metropolis of Ghana. The Bibini river shown in Figure 1 is found within KNUST and is a tributary of Wiwi river. Bibini river receives effluent from a drain whose surrounding environs consists of a petroleum filling station, cars washing bay, gymnasium, hair salons, greywater drains from adjoining hostels as well as drains from some KNUST engineering laboratories. The focus of the study was on lettuce farms found directly along the Bibini river whose irrigation source is the river and this was because lettuce was the common vegetable on all the farms. The produce (lettuce) from farms along the Bibini river is usually purchased by market women from Kumasi and sometimes Accra in bulk for retail to food vendors, restaurants and also, to other vegetable sellers who buy them in small quantities.

2.2 Water

The dissolved oxygen concentration and water temperature were measured directly in the river from the entry point of the drain into the farm then at every 50 m interval afterwards. Water samples were collected at every point of measurement and taken to the laboratory in sterilized plastic bottles with labels, placed in an ice chest and transported to the laboratory for preparation and analysis using American Public Health Association standard methods (America Public Health Association, 2017). The pH and total dissolved solids were measured within 24 hours and the biochemical oxygen demand obtained after 5 days. This was done once monthly between October, 2019 to December, 2019. A volume of 50 ml of water was acidified with a tri acid mixture of volume 10 ml comprising nitric acid (HNO_3), sulphuric acid (H_2SO_4) and percloric acid ($HClO_4$) in the ratio 1:1:1 and digested on a hot plate in a fume chamber for 30 minutes. The dissolved solution was then allowed to cool after which it was filtered with Whatman filter paper and diluted with distilled water to the 50 ml mark of the volumetric flask. Concentrations of lead (Pb), chromium (Cr) and cadmium (Cd) were determined using an atomic absorption spectrophotometer (AAS) (BUCK Scientific, Model 210 VGP).

2.3 Vegetable

Composite samples of lettuce (50 – 60 days old) were randomly taken from each of the 5 farm sites along the river comprising 20 subsamples from each farm. The lettuce samples were placed in labelled ziplock bags, stored on ice and transported to the laboratory. Lettuce samples were thoroughly washed with distilled water, cut into pieces, mixed up and oven dried at 70-80 °C for 24 hours. The dried lettuce was then ground into fine powder using a stainless-steel blender and sieved with a <2 mm sieve. 2 g of the vegetable was accurately weighed on a balance into an acid washed beaker, acidified with 15 ml of tri acid mixture comprising HNO_3, H_2SO_4 and, $HClO_4$ in the ratio 5:1:1 and digested at 80 °C till the mixture turned transparent (Akan et al., 2009). The solution was set aside to cool and filtered afterwards with a Whatman filter paper into a 50 ml volumetric flask. Distilled water was then used to top up the filtrate till it got to the 50 ml mark. Concentrations of Pb, Cr and Cd were determined using AAS (BUCK Scientific, Model 210 VGP) based on standard methods for the examination of water and wastewater.

2.4 Soil

Composite samples comprising 20 subsamples were randomly taken from each of the 5 farm sites along the river specifically from beds having lettuce on them. 20 subsamples were taken from an adjacent piece of uncultivated land about 26 m away from farming area to serve as control. The soil samples were placed in labelled ziplock bags, stored on ice and conveyed to the laboratory. Soil samples were completely oven dried at 100 °C for 24 hours and ground manually in a ceramic mortar with ceramic pestle till all soil particles excluding stones became fine to decrease subsample variability. The soil was then sieved with a <2 mm sieve and stored in airtight ziplock bags for analysis. 1 g of the soil sample is weighed on a balance, acidified with HNO_3 and HCl in the ratio 1:3 by volume and digested on a hot plate in a fume chamber till the solution turned lighter or straw in colour (Hossner, 1996). The solution was set aside to cool and filtered afterwards with a Whatman filter paper into a 50 ml volumetric flask. Distilled water was then used to top up the filtrate till it got to the 50 ml mark. Determination of concentrations of Pb, Cd and Cr in soil was done using AAS (BUCK Scientific, Model 210 VGP).

2.5 Instrumentation

The basic setup (air pressure = 50 – 60 psi, acetylene pressure = 10 -15 psi and voltage = 208 – 240 V) of the AAS was ensured. The file for the type of analysis and hollow cathode lamps were selected with appropriate wavelengths; Cd at 228.9 nm, Cr at 357.9 nm, Pb at 217.0 nm. A calibration curve was plotted for each of the elements to be analyzed from the stock standards (Buck Scientific). The digested sample solution was analyzed for the elements; Cd, Cr and Pb. The Y in the calibration equation is absorbance of the element and X is the concentration of the element in the sample. X was calculated after substituting the absorbance reading of the sample into the calibration equation. This gave X in terms of mg/L. The total concentration of the element in the sample solution (100 ml) was calculated by multiplying the concentration in mg/L by 0.1 L. This gave the total mass of the element in solution. The percentage amount of the element was found using Equation 2.1 (Wodaie and Abebaw, 2017):

$$Concentration\ (Cd, Pb\ and\ Cr) = \frac{Concentration\ from\ AAS \times Nominal\ value}{Sample\ weight\ (g)} \quad (1)$$

Where:
Nominal volume =100 ml
Sample weight = 1.00g

2.6 Microbial analysis

Total and faecal coliform counts were determined in water and vegetable samples using the most probable number (MPN) following APHA-AWWA-WEF standard methods (American Public Health Association, the American Water Works association, and the Water Environment Federation, 2017). Serial dilutions of 10-1 to 10-10 were prepared by putting 1ml of the sample into 9 ml of sterile distilled water. One millimetre aliquots from each of the tubes were inoculated into 5 ml of MacConkey Broth with inverted Durham tubes and incubated at 35 °C and 44 °C for total coliforms and faecal coliforms respectively for 24 hours. Tubes that showed a change in colour from purple to yellow and had gas collected in the Durham tubes after the 24 hours were identified as positive for total and faecal coliforms. The MPN tables were used to calculate counts per 100 ml of sample. A drop from each of the positive tubes was transferred into a 5 ml test tube of trypton water and incubated at 44oC for 24 hours. Afterwards, a drop of Kovac's reagent was added to the tube containing the trypton water. All tubes that showed development of a red ring after gentle agitation denoted the presence of indole hence was recorded as a presumptive for thermotolerant coliforms (*Escherichia coli*).

2.7 Data analysis

Data was statistically analyzed using analysis of variance with the GenStat statistical package (12th edition). The means were separated using the least significant difference (LSD) at 95% confidence level.

3. Results and Discussion

3.1 Physicochemical parameters of irrigation water

Variables described in this section include dissolved oxygen, temperature, pH, dissolved solids and biological oxygen demand, and represents analysis of samples taken from the entry point of effluent into river (referenced as 0 m) and subsequently after every 50 m interval.

3.1.1 Temperature

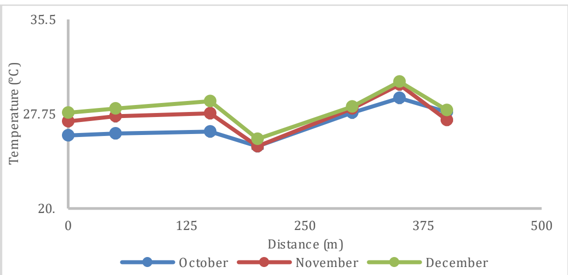

Figure 2: Temperature variations along river

Results of temperature of the irrigation water from various sampling points are presented in Figure 2. From the results, water temperatures for October, November and December ranged from 25.10 to 29.05, 25.10 to 30.15 and 25.70 to 30.40 °C, respectively. Temperatures at all points except the 350 m point were below Ghana's Environmental Protection Agency's maximum limit of 30 °C. Generally, water temperatures differed significantly ($p \leq 0.001$) across the points (Figure 2) and were higher in December than the other months. Precipitation decreased from October (minor rainfall in Ghana) to December and may account for the pattern observed (Figure 2). Consistently, across all months, the lowest and highest temperatures were observed at 200 and 350 m from the reference point. Water temperature was about 4 % or more higher in 350 m than in the other points in all three months. Absence of riparian vegetation around 350 m from the effluent entry point increased solar penetration which correspondingly increased the water temperature at that point. This observation accords with who reported that reduced riparian cover increases average water temperatures (Pusey and Arthington, 2003). Aside the 200 m, the effluent entry point (0 m) had generally lower temperature than all other points. This could be due to atmospheric temperature variations during field measurements as the entry point was the first sampling point at all times (8-9 am). Some aquatic plants were present at the 200 m point which could be responsible for the deflection of sunlight from the water surface resulting in the relatively lower temperature observed at this point. High water temperature enhances chemical and biological reactions that consume oxygen and also, reduces the solubility of oxygen in water (Kundzewicz and Krysanova, 2010).

3.1.2 Biochemical oxygen demand (BOD), Dissolved oxygen (DO) and Total dissolved solids (TDS)

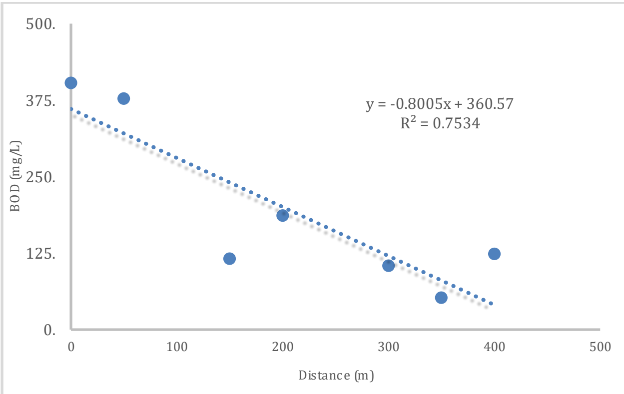

Figure 3: Biochemical oxygen demand variations along river

The biochemical oxygen demand was measured to give a clearer indication of the amount of organic pollution present in the water and the results are shown in Figure 3. BOD measures the amount of oxygen aerobic bacteria use to remove waste organic matter from water through decomposition (United States Environmental Protection Agency, 2012). Biochemical oxygen demand at the points varied from 52.2 to 403.2 mg/L with the lowest and highest BOD observed at the 350 m and reference point, respectively. With the exception of the 350 m point, all points along the river had BOD concentrations exceeding the recommended BOD concentration in irrigation water of 50 mg/L (EPA, Ghana). The level of organic pollution in a river depends on two counteracting mechanisms; pollutant loading and natural cleaning (Wen et al., 2017). This could explain why the reference point contained the highest total dissolved solids (Figure 5) and lowest dissolved oxygen (Figure 4) but had the highest BOD concentration. Increasing distance away from the reference points accounted for about 75 % of the variations observed in BOD (Figure 3) suggesting the effluent was the main source of pollution in the river. Thus, general decrease in pollution away from the reference point resulted in reduction of BOD.

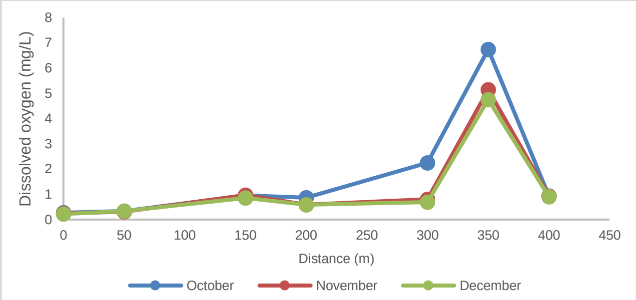

Figure 4: Dissolved oxygen variations along river

Figure 4 represents dissolved oxygen concentrations along the river in October to December. The lowest concentrations of DO in irrigation water were observed at the entry point of effluent or drain (0.27 mg/L) and the highest at 350 m away from the reference point (Figure 4). Except for the distance 350 m and 150 m where a sharp increase in dissolved oxygen were observed, there was a general gradual increase in oxygen concentration along the river. A strong relationship (r = 99 %) existed between dissolved oxygen and distance in November and December (point 150 and 350 m excluded) but not in October which averagely had the highest precipitation (Appendix 1). Oxygen concentrations increased away from the pollution source due to the dilution occurring as effluent moved along the river. Lower dissolved oxygen levels were found at higher polluted zones (zones with high TDS) as high microbial growth gets stimulated and, they use up available dissolved oxygen to break down organic materials (Sirota et al., 2013). According to a study, high water temperature is expected to reduce the concentration of oxygen in water but the highest dissolved oxygen was also found at the 350 m point which had the highest water temperature (Figure 2) (Kundzewicz and Krysanova, 2010).

This can be attributed to the low extent of water pollution (low BOD) which limits biological reactions that require oxygen. The relatively higher dissolved oxygen also observed at the 150 m point can be explained by the presence of aquatic plants at this zone which undergo photosynthesis and release oxygen into the water. Generally, higher DO was observed in October than in November and December from the 200 to 350 m away from the effluent entry point. This could be attributed to the higher precipitation that occurred in October which may have introduced more oxygen into the surface waters. The impact of precipitation however is likely be more prominent in less polluted than more polluted zones. This may account for the higher DO concentrations from the 200 to 350 m points. Concentrations of dissolved oxygen in the reference point and 50 m were generally similar ($p > 0.05$) but were all lower ($p \leq 0.001$) than that found in the other points. The only exception was found between 50 and 200 m in December where dissolved oxygen differences among the two points did not differ ($p > 0.05$). The dissolved oxygen level required in irrigation water is 1 mg/L (EPA, Ghana) hence the water can be said to be of low quality since the oxygen levels are below the standard.

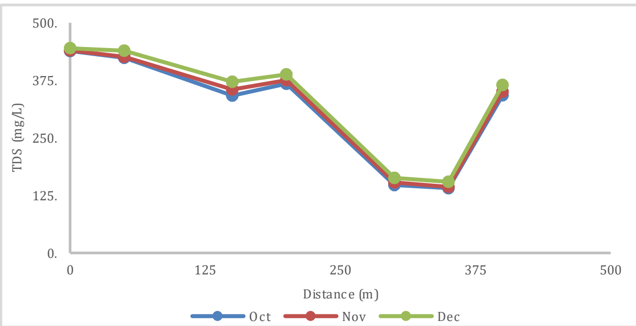

Figure 5: Total dissolved solids variations along river

The total dissolved solids in the water sampled along the river across all the three months are shown in Figure 5. Observation in all three months showed the highest and least TDS concentrations were observed at the reference point and 350 m, respectively. Mean TDS values generally increased from the wetter month (October) to the drier months (November, December) and this finding is similar with observation made (Byamugisha and Ntambi, 2016). The authors reported that TDS normally increases from wet to dry seasons and which was due to low and high evaporation rates respectively. Changes in river discharge affects the river dilution capacity increasing risk of river pollution in periods of reduced climate wetness (Milly et al., 2005; McDonald et al., 2011).

A steady decline in TDS concentration was observed with distance along the river but a sudden increase was detected at 400 m. The sharp rise in TDS 400 m away from the reference point could be linked to presence of another drain that supplies effluents to the river. About 87, 88 and 89 % of the variations found in TDS concentrations were accounted for by distance (400 m excluded) in October, November and December, respectively (Appendix 2). This is because concentration of solids at the entry point of effluent is higher but dilutes as it moves along the river reducing the amounts of solids introduced (Wen et al., 2017). The TDS concentration required for irrigation water is ≤1000 mg/L (EPA, Ghana) and the concentrations measured in the studied sites were well below the standard showing a potential for the water to be used for irrigation purposes.

3.1.3 pH

Fig. 6 displays the pH measured along the river from October through to December ranging from 7.30 -8.19. The pH was alkaline at all points and was generally relatively lower in the wetter month (October) than the drier months (November and December). The highest pH was observed at 200 m away from the reference point across all months and were significantly higher ($p \leq 0.001$) than all other points. This can be as a result of a refuse dump sited close to this point which releases leached materials. Unlike October where the least pH was observed at 350 m away from reference point, in November and December, the least pH values were recorded at the 300 m point from reference.

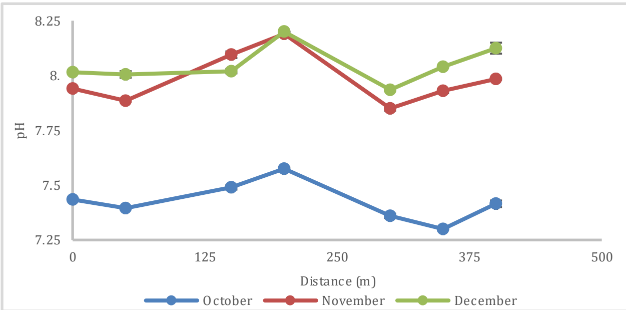

Figure 6: pH variations along river

The generally basic state of the water can be explained by the nature of wastewater released into the river which is largely greywater and contains detergents as well as soap-based products. Another factor that can be responsible for the basicity of the water is anaerobic respiration by microbes resulting in the production of gases like methane and ammonia- these gases are basic in nature and on dissolution into a medium, turns the medium basic (Roychoudhury, 2019). The pH of irrigation water affects the soil pH which also greatly influences the movement and bioavailability of heavy metals for plant uptake (Nigam et al., 2001). Lead solubility decreases with increased pH (Kim et al., 2011). Also, chromium tends to precipitate under neutral to basic pH (Oliveira, 2012). However, cadmium precipitates and has low solubility at low pH (0 to 4) (Zhang et al., 2018). The optimum pH for irrigation water is between 6.0- 9.0 (EPA, Ghana) showing the water pH is suitable for irrigation purposes.

3.2 Heavy metals in irrigation water

The mean concentrations of heavy metals in the river at the various points are described in Table 1. Cadmium, lead and chromium concentrations ranged from 0.025 to 0.113, 0.008 to 0.204 and 0.001 to 0.007 mg/L, respectively. Cadmium concentrations generally increased with distance (r^2 = 70) but a poor relationship exist between distance and, chromium and lead (Appendix 3). Point 1 had the lowest cadmium, chromium and

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lead concentrations and were all significantly lower than all other points ($p < 0.001$). Differences found between cadmium concentration at point 1, 2 and 4 were not significantly different. Point 4, 5 and 7 respectively had the highest lead, chromium and, cadmium concentrations. The concentration Cr in the water was below the permissible values of 0.1 mg/L whereas Cd and Pb exceeded their maximum permissible limits (EPA, Ghana).

Table 1: Heavy metals concentration in irrigation water

Distance(m)	Cd	Pb	Cr
0 (point 1)	0.035±0.0003	0.01±0.0002	0.001±0.00001
50 (point 2)	0.026±0.0065	0.05±0.0024	0.006±0.00032
150 (point 3)	0.081±0.0078	0.09±0.0024	0.003±0.00020
200 (point 4)	0.031±0.0084	0.20±0.0099	0.005±0.00026
300 (point 5)	0.067±0.012	0.15±0.0049	0.007±0.00018
350 (point 6)	0.114±0.0051	0.08±0.0027	0.006±0.00017
400 (point 7)	0.114±0.0079	0.16±0.0041	0.005±0.00026
Lsd(5%)	0.0242	0.02	0.0007
P	<0.001	<0.001	<0.001
EPA Ghana standard	-	≤ 0.1	≤0.1

Cadmium is a rare element which is exclusively derived from ores of zinc (Townshend, 1995) and its presence in water samples could be attributed to the presence of cadmium metals used in manufacturing parts of vehicles such as Ni-Cd batteries. The source of cadmium can also be cadmium substances (zinc containing materials) from road dust which get attached to surfaces of cars and transferred to the car washing bay. Petroleum fuel used in cars can contribute to the cadmium in irrigation water (Anon., 2011). A similar study however, found cadmium in only 1 out of their 3 samples and attributed it to the washing of Ni-Cd batteries at washing bays (Abagale et al., 2013). They attributed the non-detection of cadmium in the other 2 samples to the rarity of cadmium metal hence the low probability of its usage in the manufacturing of vehicle parts. The presence of high concentrations of cadmium in irrigation water poses a threat to the ecosystem as increased cadmium concentrations have been found to increase soil and plant cadmium over time, thereby increasing cadmium flow through the food chain (Zanders et al., 1996).

Lead sources in the irrigation water could be lead paints and car batteries (Divya et al., 2012). At high concentrations, lead in irrigation water can slow down plant cell growth (Pescod, 1992). In humans, lead accumulates in the bones and teeth without necessarily affecting the bones but are stored and released into the bloodstream from where it moves to target organs like the brain. Calcium-deficient people have the tendency to accumulate more lead in their bones resulting in higher lead toxicity (Bradl, 2005). However, in aquatic ecosystems, lead accumulates in the skin, bone, liver and kidney and does not get biomagnified up the food chain rendering it less problematic through this route (Taub, 2004).

3.3 Heavy metals in soil

The respective mean concentrations of lead, chromium and cadmium in the soils ranged from 0.001 to 0.633, 0.0001 to 0.002 and 0 to 1.521 mg/kg (Table 2) with soils sampled from the farm sites having higher cadmium, lead and chromium concentrations than an adjacent uncultivated and non-irrigated piece of land (control). The concentration of the chemicals in the soils along the river were significantly ($p \leq 0.001$) affected by distance although the patterns were inconsistent (Appendix 4). The significantly higher metal concentrations in soil samples than in the uncultivated area indicates that the main source of heavy metals contamination of is long-term anthropogenic activities (Yeketetu, 2017). Although Cd, Cr and Pb were in concentrations below permissible limits of FAO/WHO (Table 2), there were significant differences between metals concentrations ($p \leq 0.001$). The presence of heavy metals in the soil should be of concern because heavy metals in water used for irrigation tend to accumulate in the soils over time where there is a potential that they could become bioavailable for crops consumption (Toze, 2006). Moreover, heavy metal contamination is considered as the foremost indicator of food safety and quality (Marshall, 2004; Radwan and Salama, 2006; Khan et al., 2008). Human and animal consumption of such crops may lead to detrimental effects (like kidney dysfunction) as the metals biomagnify and bioaccumulate on entry into the food chain (Saidi, 2010).

Table 2: Heavy metals concentrations in soil

Sites	Cd	Cr	Pb
1	1.390±0.0168	0.0015±0.00012	0.559±0.029
2	1.517±0.0208	0.0019±0.00035	0.633±0.045
3	1.456±0.0492	0.0021±0.00015	0.501±0.006
4	1.487±0.020	0.0016±0.00015	0.509±0.010
5	1.521±0.023	0.0024±0.00012	0.502±0.011
Control	0.00017±0.000009	0.00014±0.000012	0.0011±0.000012
Lsd (5 %)	0.080	0.00055	0.071
P	<0.001	<0.001	<0.001
FAO/WHO Standard (2001)	≤3	≤50	≤100

3.4 Heavy metals in vegetable

Table 3 and Appendix 6 show the results on the concentration of heavy metals in the vegetables. Concentration of lead at the 5 sites did not differ significantly ($p > 0.05$) but differences were observed for chromium and cadmium concentrations. Metals like cadmium, chromium and lead do not have any known physiological activity in plant growth but are shown to be harmful beyond certain target values (Marschner, 1995; Bruins et al., 2000). Lead concentration in vegetables was above the permissible value given by FAO/WHO (Table 3) at 0.3 mg/kg. This agrees with findings from a study carried out by where lead was found in 100% of vegetable samples irrigated with wastewater and was 1.8- 1.35 times more than the maximum required limit used (Lente et al., 2014). Cadmium levels in the vegetables varied from 1.324 to 1.77 mg/kg in site one and five, respectively and were all above the FAO/WHO (Table 3) standard of 0.20 mg/kg.

Table 3: Heavy metals concentrations in vegetable.

Sites	Cd	Pb	Cr
1	1.77±0.066	0.496±0.008	0.0016±0.00018
2	1.4367±0.024	0.4701±0.011	0.0023±0.00015
3	1.456±0.049	0.45±0.12	0.0019±0.00012
4	1.3743±0.009	0.467±0.023	0.0023±0.00032
5	1.324±0.002	0.487±0.016	0.0019±0.00009
Lsd (5%)	0.1216	0.174	0.0006
p	≤0.001	>0.05	>0.05
FAO/WHO standard (2007)	≤0.20	≤0.30	≤2.30

Similarly, high levels of cadmium were reported in studies conducted in Harare, Varanasi and Addis Ababa (Mapanda et al., 2007; Sharma et al., 2007; Weldegebriel et al., 2012). Vegetables at site 2, 4 and 5 contained similar amount of cadmium but were all lower than in site 1 and 3. Ingestion of cadmium and lead contaminated vegetables can cause neurological and kidney problems (World Health Organization, 2020). Except for cadmium which showed a strong relationship ($r^2 = 0.75$), weak relationships were observed between concentrations of lead ($r^2=0.04$) and chromium ($r^2 =0.11$), and the distance (Appendix 5). Chromium levels across all sites were < 0.0023 and were more in site 2 and 4 than in site 1. Chromium did not compromise the safety of the vegetables as its concentrations were not over and above its allowable limit as was observed in a similar study by where chromium in cultivated vegetables was below limits.

3.5 Heavy metals in water, soil and vegetable

Cadmium, chromium and lead concentrations difference among the soils, water and vegetables are presented in Table 4. Concentrations of the three chemicals in that corresponding order ranged from 0.07 to 1.47, 0.002 to 0.005 and 0.11 to 0.54 mg/L (Table 4). Concentrations of the chromium and cadmium in soil and vegetables were similar ($p > 0.05$) but the former contained higher ($p > 0.001$) lead concentration than the latter. Lead and cadmium concentrations were lower in the water than in the soil and vegetables. The water contained the highest chromium which was significantly higher than that contained in both soil and vegetables. Concentrations of heavy metals are in the order soil > vegetable > irrigation water. This can be due to the bioaccumulation of metals present in irrigation water used over an extended period of time (about 40 years) in the soil. Findings through a similar research buttresses this with their findings that showed more than 85% of applied trace elements accumulated in the soil, most especially in the surface few centimetres (Evans et al., 1979).

Table 4: Heavy metals in soil, vegetables and water

Treatments	Cd	Cr	Pb
Soil	1.474±0.017	0.0019±0.00011	0.541±0.017
Vegetable	1.472±0.044	0.0020±0.00010	0.474±0.021
Water	0.068±0.009	0.0047±0.00037	0.110±0.014
Lsd (5 %)	0.0348	0.0008	0.047
P	≤ 0.001	≤ 0.001	≤ 0.001

Cadmium and lead are relatively immobile in the soil and as a surface derived contaminant, gets accumulated in the surface of the soil (Zanders et al., 1996; de Abreu et al., 1998). Usually, soil contaminated by human activities have the highest concentrations of heavy metals in the surface horizons (Horvath and Gruiz, 1996; Chopin et al., 2003; Boularbah et al., 2006). Leafy vegetables cultivated on contaminated soils are considered one of the major sources of heavy metals in human diet (Zhou et al., 2016). Fast growing plants like lettuce tend to undergo luxury consumption where they absorb high levels of nutrients which are in excess of their immediate requirements for growth within the soil (Lambers and Poorter, 1992). Also, the major source of heavy metal accumulation is the soil-plant interface (Bini et al., 2012; Khan et al., 2015). This can explain the cadmium and lead pollution of vegetables on the farm. It is extremely difficult to remove heavy metals from living organisms because heavy metals pass through a series of processes that include bioaccumulation, transformation, and biomagnification after entering the food chain (Widowati, 2012).

3.6 Total and faecal coliforms in irrigation water and on vegetables

Total and faecal coliform in the irrigation water are in Table 5 with their concentrations ranging from 3.3E+07 to 4.9E+10 CFU/ 100 ml and 3.7E+06 to 4.1E+10 CFU/ 100 ml. Point source of effluent contained the highest total and faecal coliforms with concentrations generally decreasing away from the effluent entry points. Relationship between distance and faecal coliform in water was weak but distance accounted for about 62 % of the variations observed in total coliform present in water (Appendix 6). A strong ($r = 0.59$) relationship existed between distance and total coliforms on vegetables but a weak relationship existed between distance and faecal coliform on vegetables (Appendix 7).

Table 5: Populations of faecal and total coliforms in water

Points	Total coliform	Faecal coliform
Point 1	4.9E+10	4.1E+10
Point 2	2.7E+10	1.8E+09
Point 3	3.3E+07	3.7E+06
Point 4	6.5E+08	2.6E+08
Point 5	1.1E+08	1.8E+07
Point 6	2.6E+08	1.2E+08
Point 7	7.6E+08	1.8E+08

Populations of total and faecal coliforms decreased away from the entry point of effluent due to the dilution effect along the river. As expected, populations of total coliform exceeded faecal coliform because total coliform includes all bacteria found in human or animal waste and, water and soil which have been affected by surface water while faecal coliform comprises only bacteria specifically found in the gut and faeces of warm-blooded animals (New York State Department of Health, 2020). The populations of total and faecal coliforms in the water corresponds to the coliforms found on vegetables (Table 6). High populations of coliforms were found on vegetables in farms close to the entry point of effluent and vice versa.

Table 6: Total and fecal coliforms on vegetables.

Sites	Total coliform	Faecal coliform
Site 1	2.4E+10	1.7E+09
Site 2	6.1E+09	9.8E+07
Site 3	3.5E+08	4.2E+06
Site 4	6.7E+09	3.5E+08
Site 5	4.4E+07	4.2E+06

According to World Health Organization, Escherichia coli (E coli) are the only true indicator of faecal contamination hence their presence at all points indicates faecal pollution is present and possibly, pathogens are present as well (World Health Organization, 2011). Ingestion of faecal contaminated food could lead to fever, nausea, headache, abdominal pain, vomiting and diarrhoea (World Health Organization, 2020). The populations of faecal coliform in the water exceeded the recommended standard in irrigation water at all points at 1.0E+3 CFU/ 100 ml (World Health Organization, 2000) rendering it unsuitable for vegetable crop irrigation. The vegetables produced with the irrigation water were contaminated with faecal coliforms hence unsafe for human consumption especially as it is consumed raw and washing them may not properly eliminate the contaminant (Hirsch, 2019).

4. Conclusion

The following conclusions can be drawn from the study:

- Even though the TDS and pH of the irrigation water were within Ghana's Environmental Protection Agency's standard, dissolved oxygen levels were low, biological oxygen demand and temperature were high. This indicates low water quality of irrigation water.
- Heavy metals (Cd, Pb and Cr) are present in the water, soil and vegetables with cadmium and lead found in vegetables at concentrations above the permissible levels. This makes them unsafe for human consumption as they can have adverse health implications on consumers.
- Microbial populations of faecal coliforms were found in the irrigation water as well as on vegetables produced beyond required levels indicating the vegetables produced are contaminated and of low quality hence can affect human life when consumed.

It is strongly recommended that:

- Farmers be extensively educated and encouraged to relocate to other suitable farming land.
- Also, the study should be extended to other equally toxic metals in future research.

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Declarations

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Conflicts of interest/Competing interests
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REFERENCES

Abagale, F.K., Sarpong, D.A., Ojediran, J.O., Osei- Agyemang, R., Shaibu, A.G. and Birteeb, P. T., 2013. Heavy metal concentration in wastewater from car washing bays used for agriculture in the Tamale Metropolis, Ghana. International journal of current research, 6 (5), Pp. 1571-1576.

Akan, J.C., Abdulrahman, F.I., Ogugbuaja, V.O., Ayodele, J., 2009. Heavy Metals and Anion Levels in Some Samples of Vegetables Grown Within the Vicinity of Challawa Industrial Area, Kano State, Nigeria. Am J Appl Sci., 6 (3), Pp. 534- 542.

American Public Health Association (APHA), the American Water Works association (AWWA), and the Water Environment Federation (WEF), 2017. 9010 INTRODUCTION, Standard methods for examination of water and wastewater. DOI: 10.2105/SMWW.2882.179

American Public Health Association (APHA). 2017. 3030 Preliminary treatment of samples, Standard methods for the examination of water and wastewater. DOI: 10.2105/SMWW.2882.041

Amoah, P., Drechsel, P., Henseler, M., Abaidoo, R., 2007. Irrigated urban vegetable production in Ghana: Microbiological contamination in farms and markets and associated consumer risk groups. Journal of water and health, 5, Pp. 455- 466.

Anon. 2011. Industrial wastewater guide book.

Baruthio, F., 1992. Toxic effects of Chromium and its compounds. Biol Trace Elem Res., 32, Pp. 145-53.

Bini, C., Wahsha, M., Fontana, S. and Maleci, L., 2012. Effects of heavy metals on morphological characteristics of Taraxacum officinale Web growing on mine soils in NE Italy. J. Geochem Explor, 123, Pp. 101-108.

Boularbah, A., Schwartz, C., Bitton, G., Aboudrar, W., Ouhammou, A., Morel, J.L., 2006. Heavy metal contamination from mining sites in South Morocco: 2. Assessment of metal accumulation and toxicity in plants. Chemosphere, 63, Pp. 811- 817.

Bradl, H., 2005. Heavy metals in the environment: origin, interaction and remediation. London, Elsevier/ Academic Press.

British Columbia Ministry of Environment, Lands and Parks, Land Data B.C., and Geographic Data B.C., 1998. Version 1.0. Guidelines for Interpreting Water Quality Data. Prepared for the Land Use Task Force, Resources Inventory Committee.

Bruins, M.R., Kapil, S. and Oehme, F.W., 2000. Microbial resistance to metals in the environment. Ecotoxicology and environmental safety, 45 (3), Pp. 198- 207.

Byamugisha, D., and Ntambi, E., 2016. Effects of seasonal variations in physical parameters on quality of gravity flow water in Kyanamira Sub-County, Kabale District, Uganda. Journal of Water Resource and Protection. [Online] 8, Pp. 1297- 1309. Available from: http://dx.doi.org/10.4236/warp.2016.813099 [Accessed 22nd January 2020]

Chopin, E.I.B., Black, S., Hodson, M.E., Coleman, M.L. and Alloway, B.J., 2003. A preliminary investigation into mining and smelting impacts on trace element concentrations in the soil and vegetation around Tharsis, SW Spain. Mineral Mag., 67 (2), Pp. 279- 288.

Cornish, G.A., Aidoo, J. and Ayamba, I., 2001. Informal irrigation in the peri-urban zone of Kumasi: an analysis of farmer's activity and productivity. Department for International Development (DFID). Report number: OD 144.

Davies, P.S., 2005. The biological basis of wastewater treatment. West of Scotland: Strathkelvin instruments Ltd.

Divya, S., Archana, T., Gupta, R., 2012. Phytoremediation of lead from wastewater using aquatic plants. Journal of Agricultural Technology, 8 (1), Pp. 1-11. Available from: http://www.ijat-aatsea.com

Donner, E., Eriksson, E., 2010. Metals in greywater: Sources, presence and removal efficiencies. Desalination, 248 (1-3), Pp. 271-278. DOI: 10.1016/j.desal.2008.05.065

Dyjak, A., 2018. Surface water: What you need to know. [Online] Available from: https://www.hydroviv.com/blogs/water-smarts/surface-water-what-you-need-to-know

Ejaz, U.I., Xiao-e, Y. and Zhen-li, Q.M., 2007. Assessing potential dietary toxicity of heavy metals in selected vegetables and food crops. Journal of Zhejiang University Science, 8 (1), Pp. 1-13.

Eriyamremu, G.E., Asagba, S.O., Akpoborie, A. and Ojeaburu, S.I., 2005. Evaluation of lead and cadmium levels in some commonly consumed vegetables in the Niger- Delta oil area of Nigeria. Bulletin of Environmental Contamination and Toxicity, 75, Pp. 278-283.

European Union. 2002. Heavy metals in wastes. European Commission on Environment. [Online] Available from: http: //ec. Europa.eu/ environment/ waste/ studies/ pdf/ heavy metals reports. pdf.

Evans, K.J., Mitchell I.G., Salau B., 1979. Heavy metal accumulation in soils irrigated by sewage and effect in the plant-animal system. Progressive Water Technology, 11 (4/5), Pp. 339-252.

Hirsch, J., 2019. Washing your greens won't protect against E. coli. [Online] Available from: https://www.consumerreports.org/e-coli/washing-greens-protect-e-coli/ [Accessed March 8th 2020].

Hossner, L.R., 1996. Dissolution for Total Elemental analysis. Methods of soil analysis:Part 3 Chemical Methods. SSSA Book Series. Edition 5.3. Wisconsin, Soil Science Society of America, Pp. 49-64.

Horvath, B., Gruiz, K., 1996. Impact of metalliferous ore mining activity on the environment in Gyongyosoroszi, Hungary. Sci. Total Environ., 184 (3), Pp. 215- 227.

Jegatheesan, V., Visvanathan, C., Aim, R.B., 2008. Advances in biological wastewater treatment. [Online] Available from: http://www.faculty.ait.ac.th/visu/.../10/BookChapyer-Final.pdf. [Accessed May 20,2021]

Keraita, B., Drechsel, P., 2004. Agricultural use of untreated urban wastewater in Ghana. In Scott, C. A., Faruqui, N. I. and Raschid-Sally, L. (eds.) Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities. Wallingford, UK, IWMI.

Khan, S., Cao, Q., Zheng, Y. M., Huang, Y.Z. and Zhu, Y.G., 2008. Health risks of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China. Environ. Pollut., 152 (3), Pp. 686-692.

Khan, S., Waqas, M., Ding, F., Shamshad, I., Arpd, H.P.H. and Li, G., 2015. The influence of various biochars on the bioaccessibility and bioaccumulation of PAHS and potentially toxic elements to turnips (Brassica rapa L). J Hazard Mater, 300, Pp. 1-11. DOI: 10.1016/j.jhazmat.2015.06.050

Kim, E.J., Herrera, J.E., Huggins, D., Braam, J. and Koshowski, S., 2011. Effect of pH on the concentrations of lead and trace contaminants in drinking water: a combined batch, pipe loop and sentinel home study. Water Res., 45 (9), Pp. 2763-2774.

Kris, M., 2007. Wastewater pollution in China. [Online] Available from: http://www.dbc.uci/wsustain/suscoats/krismin.html [Accessed May 20, 2021]

Kundzewicz, Z.W. and Krysanova, V., 2010. Climate change and stream quality in the multi-factor context. Clim. Chang., 103, Pp. 353- 362.

Lambers, H., Poorter, H., 1992. Inherent variation in growth rate between higher plants: a search for physiological causes and ecological consequences. Advances in Ecological Research, 22, Pp. 187- 261.

Lente, I., Ofosu-Anim J., Brimah, A.K. and Atiemo, S., 2014. Heavy metal pollution of vegetable crops irrigated with wastewater in Accra, Ghana. West African Journal of Applied Ecology, 22 (1), Pp. 41- 58.

Mapanda, F., Mangwayana, E.N., Nyamangara, J. and Giller, K.E., 2007. Uptake of heavy metals by vegetables irrigated using wastewater and the subsequent risks in Harare, Zimbabwe. Physics and Chemistry of the Earth, Parts A/B/C, 32, Pp. 1399-1405. DOI: 10.1016/j.pce.2007.07.046

Marschner, H., 1995. Annals of Botany. Mineral nutrition of higher plants. Second edition. London, Academic Press.

Marshall. 2004. Enhancing food chain integrity: quality assurance mechanism for air pollution impacts on fruits and vegetables systems. Crop Post Harvest Program. Report number: R7530.

McDonald, R.I., Green, P., Balk, D., Fekete, B., Revenga, C., Todd, M., Montgomery, M., 2011. Urban growth, climate change, and freshwater availability. Proc. Natl. Acad. Sci. USA, 100, Pp. 6312-6317.

Mico, C., Recatala, L., Peris, M., Sanchez, J., 2006. Assessing heavy metal sources in agricultural soils of a European Mediterranean area by multivariate analysis. Chemosphere, 65, Pp. 863-872.

Milly, P.C.D., Dunne, K.A., Vecchia, A.V., 2005. A global pattern of trends in streamflow and water availability in a changing climate. Nature, 438, Pp. 347- 350.

Muchuweti, M., Birkett, J.W., Chinyanga, E., Zvauya, R., Scrimshaw, M.D., Lester, J.N., 2006. Heavy metal content of vegetables irrigated with mixture of waste water and sewage sludge in Zimbabwe: implications for human health. Agriculture, Ecosystem and Environment, 112, Pp. 41-48.

New York State Department of Health. 2020. Coliform bacteria in drinking water supplies. [Online] Available from: https://www.health.ny.gov/environmental/water/drinking/coliform_bacteria.htm [Accessed 3rd June 2020]

Nigam, R., Srivastava, S., Prakash, S. and Srivastava, M.M., 2001. Cadmium mobilization and plant availability- the impact of organic acids commonly exuded from roots. Plant soil, 230, Pp. 107-113.

Nolan, K., 2003. Copper toxicity syndrome. Journal of Orthomolecular Psychiatry, 12, Pp. 270-282.

Obuobie, E., Keraita, B., Danso, G., Amoah, P., Cofie, O.O., Raschid- Sally, L., Drechsel, P., 2006. Irrigated urban vegetable production in Ghana: Characteristics, benefits and risks. IWMI- RUAF-IDRC CPWF, Accra, Ghana, 150 pp. Available from: http:// www.cityfarmer.org/ Ghana Irrigate Vegis. html. [Accessed 15th August 2019]

Ogwegbu, M.O.C. and Muhanga, W., 2005. Investigation of lead concentration in the blood of people in the copper belt province of Zambia. Journal of Environment, 1, Pp. 66-75.

Oliveira, H., 2012. Chromium as an environmental pollutant: insights on induced plant toxicity. Journal of botany. [Online] Available from: https://doi.org/ 10.1155/ 2012/ 375843

Pescod, M., 1992. Wastewater treatment and use in agriculture. FAO irrigation and drainage. Report number, Pp. 47.

Pusey, B.J., Arthington, A.H., 2003. Importance of riparian zone to the conservation and management of freshwater fish: A review. Marine and freshwater research, 54 (1).

Radwan, M.A., Salama, A.K., 2006. Market basket survey for some heavy metals in Egyptian fruits and vegetables. Food Chem. Toxicol., 44 (8), Pp. 1273- 1278.

Roychoudhury, A., 2019. What are the reasons for increase in pH after the anaerobic reactors? [Online] Available from: http://www.researchgate.net. [Accessed 4th July 2020].

Saidi, M., 2010. Experimental studies on the effect of heavy metals presence in industrial wastewater on biological treatment. International Journal of Environmental Sciences, 1 (4), Pp. 666- 676.

Sharma, R., Agrawal, M., Marshall, F., 2007. Heavy Metal Contamination of Soil and Vegetables in Suburban Areas of Varnasi, India. Ecotoxicol Environ Saf., 66 (2), Pp. 256-266.

Sirota, J., Baiser, B., Gotelli, N.J., Ellison, A.M., 2013. Organic- matter loading determines regime shifts and alternative states in aquatic ecosystem. Proc. Natl. Acad. Sci. USA, 110, Pp. 7742- 7747.

Taub, F.B., 2004. Fish 430 lectures (Biological impacts of pollutants on aquatic organisms). [lecture] College of Ocean and Fishery Sciences. University of Washington. Seattle, WA.

Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K., Sutton, D.J., 2012. Heavy metal toxicity and the environment, In: Luch, A. (ed.) Molecular, clinical and environmental toxicology. Basel, Switzerland, Springer, Pp. 133-164.

Townshend, A., 1995. Encyclopedia of Analytical Science. San Diego, Academic Press Inc.

Toze, S., 2006. Reuse of effluent water- benefits and risks. Agric water manag., 80, Pp. 147- 159.

United States Environmental Protection Agency. 2012. Water: Monitoring and Assessment. Available: http://www.archive.epa.gov. [Accessed August 1, 2020].

Weldegebriel, Y., Chandravanshi, B.S., Wondimu, T., 2012. Concentration levels of metals in vegetables grown in soils irrigated with river water in Addis Ababa, Ethiopia. Ecotox. Envir. Saf., 77, Pp. 57-63.

Wen, Y., Schoups, G., Giesen, N., 2017. Organic pollution of rivers: Combined threats of urbanization, livestock farming and global climate change. Sci. Rep., 7.

Widowati, H., 2012. The influence of cadmium heavy metal on vitamins in aquatic vegetables. Makara J Sci., 16 (1), Pp. 33-38.

Wodaie, A., Abebaw, A., 2017. Determination of heavy metals concentrations in soils used for cultivation of Allium sativum L. (garlic in East Goiiam Zone, Amhara Region, Ethiopia. Cogent Chemistry. Available from: https;//www.tandfonline.com/loi/oach20 [Accessed 14th February 2020].

World Health Organization. 2000. WHO Guidelines for the safe use of wastewater, excreta and greywater. Wastewater in Agriculture. [Accessed August 1, 2020].

World Health Organization. 2011. Enterohaemorrhagic Escherichia coli (EHEC). Fact sheet 125. [Online] Available from: http://www.who.int/mediacentre/fact-sheets/fs1 25/en/ [Accessed August 1, 2020].

World Health Organization. 2020. Food safety. [Online] Available from: https://www.who. int/news-room/fact-sheets/detail/food-safety-105k [Accessed August 1, 2020].

Yeketetu, B.A., 2017. Toxic heavy metal and salinity assessment in water, soil and vegetable around Meki irrigation farms. International Journal of Scientific and Technology Research, 6 (9), Pp. 5- 9.

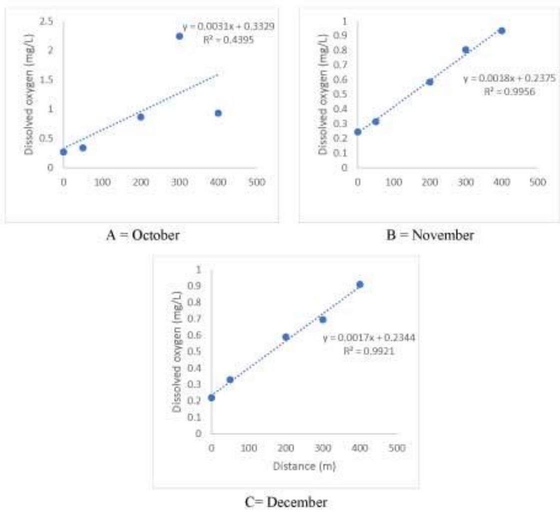
Young, R.A., 2005. Toxicity profiles: toxicity summary for cadmium, risk assessment information system. University of Tennessee. Available from: www.rais.ornl.gov/tox/profiles/cadmium.shtml.

Zanders, J.M., Tillman, R.W., Hedley, M.J., Lee, J., 1996. Cadmium movement down repacked soil columns as affected by soil type and chloride concentrations. In: Australian and New Zealand National Soils Conference 1996. University of Melbourne. Pp. 279- 280.

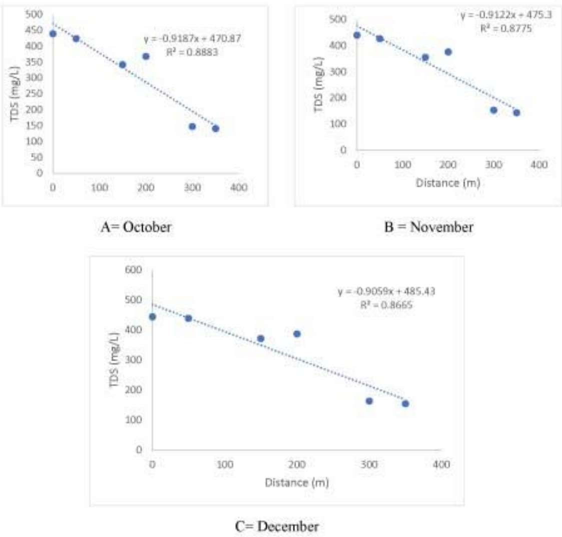
Zhang, Y., Zhang, H., Zhang, Z., Liu, C., Sun, C., Zhang, W., Marhaba, T., 2018. pH effect on heavy metal release from a polluted sediment. Journal of chemistry, 7.

Zhou, H., Yang, W., Zhou, X., Liu, L., Gu, J., Wang, W., Zou, J., Tian, T., Peng, P., Liao, B., 2016. Accumulation of heavy metals in vegetable species planted in contaminated soils and the health risk assessment. Int J Environ Res Public Health, 13 (3), Pp. 289. DOI: 10.3390/ijerph13030289

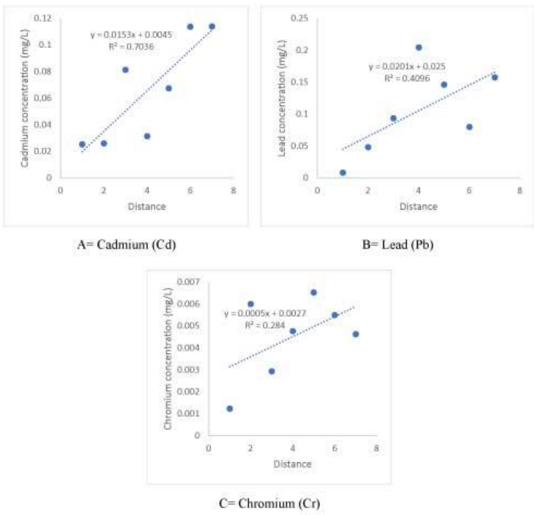
APPENDICES



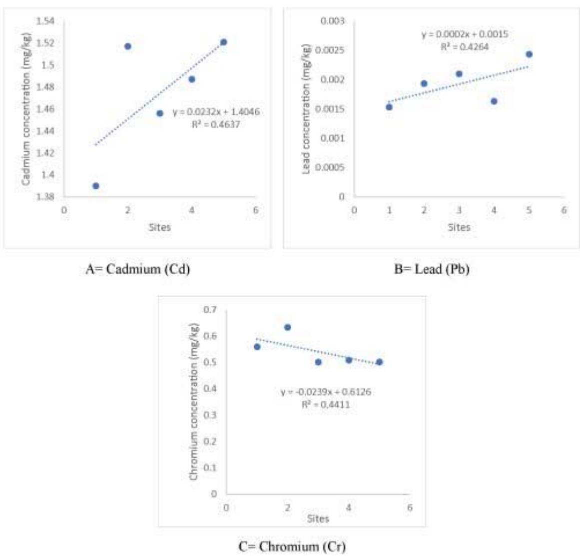
Appendix 1: Correlation between dissolved oxygen concentrations and distance



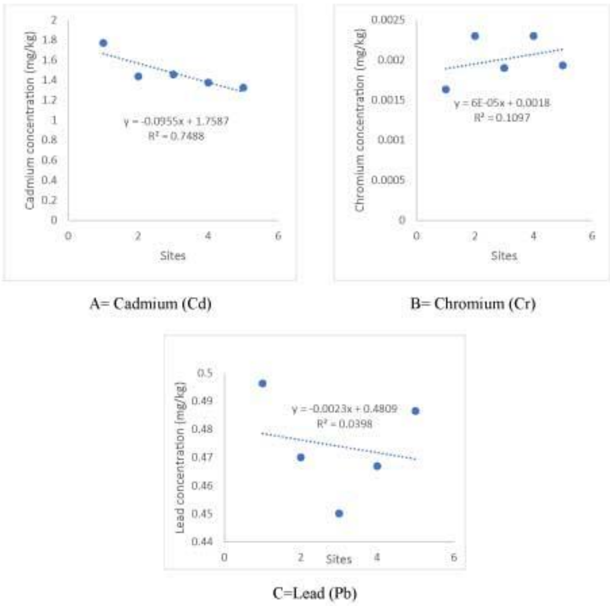
Appendix 2: Correlation between TDS concentrations in water and distance



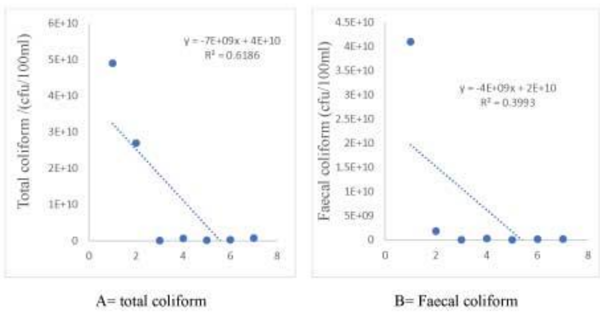
Appendix 3: Correlation between heavy metal concentrations in water and distance



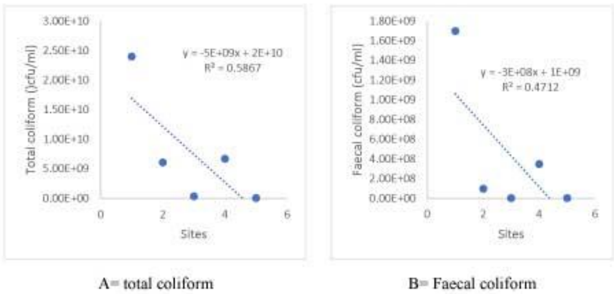
Appendix 4: Correlation between heavy metal concentrations in soil and distance



Appendix 5: Correlation between heavy metal concentrations in vegetables and distance.



Appendix 6: Correlation between microbes in water and distance.



Appendix 7: Correlation between microbes on vegetables and distance.

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