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Health Risk Assessment of Sugarcane Grown in an Area under the Influence of Hospital Wastewater

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Abstract:

Plants like sugarcane grown in soils contaminated with metals inevitably take up some of the metals thereby posing a food safety issue. Sugarcane plant and soil were sampled from fifteen points in a sugarcane farm under direct influence of wastewater from KomfoAnokye Teaching Hospital (KATH), Kumasi, Ghana. The surface water passing through the sugarcane farm was sampled at five points within the farm. Samples collected and analysed using standard methods for lead (Pb), copper (Cu), cadmium (Cd), and manganese (Mn). Heavy metal concentrations in all water samples 4.1 ± 0.11 , 9.8 ± 0.24 , 0.4 ± 0.12 , $5.3 \pm 0.03 \mu\text{g L}^{-1}$ for Pb, Cu, Cd, and Mn respectively. Significant difference ($p = 0.0001$) was obtained in metal concentrations analysed in the soil samples with metal concentrations ranged from 5.68 to 11.23 mg Kg^{-1} for Pb, 25.43 to 25.69 mg Kg^{-1} for Cu, 0.53 to 0.59 mg Kg^{-1} for Cd and from 27.22 to 27.42 mg Kg^{-1} for Mn. In this study, Pb, Cd, Cu, and Mn concentrations in sugarcane stem (edible portions) were 2.57 , 5.84 , 0.027 , and 8.03 mg Kg^{-1} , respectively. These were all below their corresponding European Commission (EC) maximum tolerable limits for fresh foods. The metals analysed had a wide range of transfer factor (TF) values of 0.18 to 0.38 , 0.1 to 0.35 , 0.04 - 0.14 , and 0.11 - 0.34 for Pb, Cu, Cd, and Mn respectively. The detected fraction in the edible parts (stem) of the sugar cane samples represented 50 – 90% of root concentrations. The trend in Pb, Cu, Cd, and Mn distribution in the soils stood the same with increasing distance from the stream (source of contamination). No significant difference existed between the levels at 0 – 20m , 20 – 40m , and 40 – 60m ($p=0.21$). Metal pollution may have spread evenly within the area studied and long cultivation of sugarcane on the land could lead to high levels in the plant. The results suggest that sugarcane cultivated on soil impacted by the wastewater from KATH contain metals but not in levels above the recommended levels. However, since metal levels in plants do accumulate over time, routine monitoring is recommended.

Keywords: Sugarcane, hospital wastewater, lead, cadmium, human health risk assessment

1. Introduction

Agriculture, mining, and waste management are all examples of anthropogenic activities that pollute the environment with heavy metals (Bortey-Sam et al., 2015). The toxicity of metals has been thoroughly shown in studies. Lead (Pb), for example, has been linked to kidney failure, liver malfunction, and mental health issues in people (Iwegbue, 2010). Mn has been linked to the development of Parkinson's disease (Matusch et al., 2010). Sugarcane (*Saccharum* spp.) has a robust root system with a maximum root depth of more than 6 m, allowing it to draw water and nutrients from great depths while also taking advantage of water up-flow from water tables (Zhang et al., 2014). Sugarcane produced on metal-contaminated soils will invariably absorb some of the metals, providing a food safety concern (Segura-Muñoz et al., 2006). Sugarcane plantlets were able to endure up to 100 mol/L copper in nutritional solution for 33 days, accumulating 45 mg/kg Cu on a shoot dry weight basis and showing no significant drop in fresh weight (Serenio et al., 2007). Xia et al. (2009) also looked at the development and heavy metal accumulation of sugarcane that grew in artificially polluted soil with varying levels of Cd, and discovered that sugarcane has a high ability to tolerate and absorb Cd due to its huge biomass. The hospital wastewater from Komfo Anokye Teaching Hospital (second largest teaching hospital in Kumasi, Ghana) drains directly into a tributary of the Subin River in Kumasi (Azanu et al., 2018). Sugarcane has been planted in the

wetlands along this river. According to a preliminary inquiry, this sugarcane was marketed to the general public for consumption (Oppong et al., 2018). The number of metals present in this sugarcane must be known to calculate food intake and assess human exposure to dangerous metal concentrations (Iwegbue, 2010). The goal of this study is to determine the levels of lead, cadmium, copper, and manganese in sugar cane plants collected within 1 km from the contaminated stream and determine the transfer factor of metals into the various sugarcane parts.

2. Material and Methods

2.1. Study Area and Sampling

Kumasi, the second-largest city in Ghana, is situated on the edge of a drainage divide. The Offin River receives water from 28% of the urban area, which drains to the west. In the south of the Oda River which drains 72 percent of the developed area. Major streams begin in Kumasi's administrative boundaries. The Sisa and Wiwi Rivers, which are located north of Kumasi, provide the only significant outside input. It has a total area of 254km², of which about 80% is developed. According to Obuobie et al., (2006) open space or undeveloped lands, such as river valleys or other sparsely populated areas, was designated as 75km² (30%) of the land area. Sampling took place in Kumasi, Ghana's second-largest city, which is around 150 kilometers north of Accra. In 2021, the population of Kumasi was estimated to be at 3, 348 million with a growth rate of 4.2% (GSS, 2021). Wetland along a tributary of Subin river in Kumasi where sugarcane has been grown served as the sampling site. Sugarcane stems and soils were collected at distances of 0-20 m, 20-40m, and 40 – 60m from the stream (Fig. 1). Surface water at the farm was taken. Using the Global Positioning System, the sampling areas were marked out. Sampling was done in the wet season (June-July), and in the dry season (January -February). A triplicate of 30 sugarcane stems, 30 triplicate sugarcane roots, 30 triplicate sugarcane leaves, 30 triplicate soil samples, and 10 triplicate water samples was taken for this research. Sample containers were used to keep the samples with clear labels and delivered to KNUST's Chemistry Department for analysis.

Figure 1: Study Area in Kumasi, Showing Points of Sampling

2.2. Sample Preparation

The analytical reagent grade concentrated nitric acid (95%) was utilized (BDH Chemical Ltd, Poole, England). To make a 1000 mg/l stock solution, nitrate salt such as Cd,Cu,Pb, and Mn were obtained from Merck Chemicals in Germany. Nitrate salt was used to make serial dilutions for various elements.

After soaking in a detergent solution overnight, the glassware used for digestion and digest storage was washed under running tap water. They were then immersed in 10% nitric acid overnight before being washed in distilled water. Sugarcane root, stem, and leaf samples were collected from sugarcane farm stands that were averagely matured. The soil and dirt were removed from the sugarcane stems by washing in distilled water. These samples were cut into smaller pieces using a stainless knife and dried for two days at 40°C in an oven.

Mortar and pestle are used to pulverize the soil were pulverize, afterward sieved in a laboratory with a 2 mm nylon, the sample was air-dried for three days at room temperature. The conductivity, organic carbon content, pH, and particle size of a sample of the soil were all assessed at the KNUST Soil Science Laboratory.

At each sampling site, a water sample with a volume of 1000mL was collected and acidified with 5 mL 65 percent HNO₃ (Suprapur E Merck) before being kept in an ice chest. Until the materials were digested, they were kept frozen.

Another 1000 mL water sample was obtained at each measurement station, and the pH, dissolved oxygen (DO), conductivity, and turbidity were not acidified and used to assess physico-chemical parameters.

A 5 mL of 65 percent nitric acid was mixed with 1 mL sample in a 50-mL digestion tube (Suprapur E. Merck). The mixture was warmed for 30 minutes at 200°C. The digest was cooled before being diluted with distilled water to a final amount of 50 mL and put into a 100 mL collecting bottle.

Following a conventional technique, the soil samples were digested with aqua regia (1:3) HNO₃: HCl (Vowotor et al., 2014). In a 50 mL digestion tube with 10 mL aqua regia, a 0.5 g soil sample was accurately placed. The contents were heated to 150°C for 30 minutes, then cooled and diluted to a final volume of 50 mL with deionized water.

Standard procedures were used to digest the water samples (American Public Health Association, 2005). An aliquot of 10 mL of 65 percent nitric acid (Suprapur E. Merck) was added to 100 mL in the fume hood and on a hot plate at 200 °C. The solution was kept boiling until it reached a volume of about 25 mL. It was allowed to cool, before using the digest. It was then filtered into a 50 mL volumetric flask and diluted to 50 mL with distilled water.

2.3. Metal Analysis

A Spectra AA 220 AAS atomic absorption spectrometer with several hollow cathode lamps was used for the analysis of metals in the digested sugarcane juice samples. Various concentration of standard as Cd, Cu, Pb and Mn solutions were used to calibrate the equipment.

2.4. Statistical Analysis of Data

Each experiment was repeated thrice, with the results presented in Microsoft Excel as mean and standard deviation) using Microsoft Office Excel 2019 (Version 21, Microsoft, USA). GraphPad Prism was used to perform one-way ANOVA and Persons correlation statistics on the data (Version 6.01, San Diego, USA). The statistics was done with 95% confidence level, indicating that significant is accepted if the significance level is less than 0.05.

2.5. Quality Control

Using triplicates of serial dilution standard solution, calibration curves for various elements were produced. Multiple element spike recovery was achieved by adding 50mg of each element to one of the samples and using the same digestion method and testing. The amount recovered was then calculated. By repeating the process eight times and calculating the standard deviation, the precision of the instrument was determined.

2.6. Transfer Factor

The transfer factor, which is the ratio of the respective metal content in plant tissue ([M]_v) to the total concentration of that metal in soil ([M]_s), was calculated as follows: $TF = [M]_v / [M]_s$ (Cui et al., 2005).

3. Results and Discussion

3.1. Result of Quality Control Analysis

The method used to ensure the validity of metal analysis in this study were explained in this section. Recoveries, regression co-efficiencies, and limits detection of elements were shown in Table 1. The linearity of all metals, indicated as regression coefficient values, varied from 97 to 99 percent. The recoveries in this investigation ranged from 95 to 98 percent, which were within the permissible range of 95 to 100.4 percent (Thompson, 2005).

Elements	Detention Limits(ppb)	Precision (%CV)	Recovery (%)	Regression Co-Efficiencies (R ²)
Pb	2	3	97	99
Cu	3	5	98	99
Cd	1	5	95	98
Mn	3	4	96	97

Table 1: Recoveries, Regression Co-Efficiencies, and Limits Detention of Elements

3.2. Heavy Metals Occurrence in Samples Analysed

3.2.1. Metal Concentration in Water Samples

The average concentration ($\pm$ standard deviation) of Pb, Cu, Cd, and Mn in water samples collected within sugarcane-growing area were 4.1 ± 0.11 , 9.8 ± 0.24 , 0.4 ± 0.12 , 5.3 ± 0.03 $\mu\text{g L}^{-1}$ (Fig. 2). There was significant difference ($p=0.001$) in the concentrations of heavy metals analysed in the water samples. Heavy metal concentrations in all water samples were in the following order: Cu>Mn>Pb> Cd. Ghana Environmental Protection Agency (G EPA) has stipulated surface water guideline values for Pb, Cu, Cd and Mn to be 100, 5000, 50 and 4000 $\mu\text{g L}^{-1}$ respectively (Ghana Environmental Protection Agency, 2002). Comparing metal concentration in surface water studied with G EPA guidelines, all metals concentration were within the permissible limit.

The average Pb concentration ($4.1 \mu\text{g L}^{-1}$) found in water samples from this study was comparable to Pb result ($5.0 \mu\text{g L}^{-1}$) found in wastewater from Saint Patrick Hospital in Offinso, Ghana, however Mn level ($5.5 \mu\text{g L}^{-1}$) in water sample analyzed this study were lower than $24.0 \mu\text{g L}^{-1}$ found in wastewater from Saint Patrick Hospital in Offinso. It is difficult to

single out the possible reason for low Mn concentration found in water sample in this study compared to Mn found in wastewater from Saint Patrick Hospital in Offinso, Ghana.

Figure 2: Distribution of Heavy Metals in Water Samples Analysed

3.2.2. Metal Concentrations in the Soil Samples

Significant difference ($p = 0.0001$) was obtained in metal concentrations analysed in the soil samples in this study. The metal concentrations ranged from 5.68 to 11.23 mg Kg⁻¹ for Pb, 25.43 to 25.69 mg Kg⁻¹ for Cu, 0.53 to 0.59 mg Kg⁻¹ for Cd and from 27.22 to 27.42 mg Kg⁻¹ for Mn (Fig. 3). Background acceptable values for Pb, Cu, Cd, and Mn in soils are 150, 100, 5, and 250 mg Kg⁻¹ (Food and Agriculture Organization (FAO) and International Soil Reference and Information Centre (ISRIC), 2004). The concentrations recorded in this study were below the acceptable levels in soil by FAO and ISRIC. Cultivation of crops in areas like dumpsite, wetlands are common in developing countries and Ghana is not an exceptional. The major reasons for these practices are quest for fertile land and water for irrigation respectively. Odai et al. (2008), reported levels of Pb (54.6 mg Kg⁻¹), Cd (2.87 mg Kg⁻¹) and Cu (1631.67 mg Kg⁻¹) in waste dumpsite soils used for vegetable cultivation in Kumasi, Ghana. The concentration found by Odai et al are in two to hundred times higher than those found in this study. The obvious reason could be because waste dumpsites are major point source of heavy metals (Abuanyi, 2010; Kumar et al., 2011; Lente et al., 2014). Most farmers farming in contaminated areas do not take into consideration the health effect chemical pollutant like heavy metals in the soil.

Figure 3: Distribution of Heavy Metals in Soil Samples Analysed

3.2.3. Metals Concentration in Sugarcane Parts Analysed

Lead, Cd, Cu, and Mn concentration in sugarcane root samples ranged from 2.83-3.14, 8.13-8.39, 0.722-9.30 mg Kg⁻¹; while in leaf samples is from 1.09-1.42, 2.11-2.61, 0.021-0.026, 2.84-3.68 mg Kg⁻¹ and 2.12-2.76, 5.718-5.89, 0.024-0.030, 7.92-8.19 mg Kg⁻¹ (Fig. 4) in sugarcane stem samples. The quantity of metals discovered in various sugarcane parts differed significantly ($p=0.001$). However, the Turkey multiple comparison test showed that there is no difference ($p=0.2$) in levels of metals found in sugarcane root and stem in this study. This could best be explained by higher uptake of metal by plant root and less translocation into stem and root tissue.

Arranging heavy metal from the highest to lowest in terms of concentration in all sugarcane samples is Cu>Mn>Pb> Cd, while increment of concentration in terms of part of sugarcane is root>stem>leaf. Segura- Muoz et al. (2006), in Brazil, looked at metals in sugarcane grown near a municipal dump and a medical waste treatment system, a similar pattern was revealed for the part of sugarcane accumulated with heavy metals. The factors that could cause the differences in metal accumulation in various parts of the sugarcane plant analysed are absorption and internal distribution of metals in the plant according to the differences in the retention capacity of the absorbing element in roots, stage of

development of the plant, the time of exposure to the metal and the chemical species of the element in each sampling point (Bradl, 2005; Tangahu et al., 2011).

In this study, Pb, Cd, Cu, and Mn concentrations in sugarcane stem (edible portions) were 2.57, 5.84, 0.027, and 8.03 mg Kg⁻¹, respectively. These were all below their corresponding European Commission (EC) maximum tolerable limits of Pb, Cu, Cd, and Mn in fresh foods being 10.0, 20.0, 1.0, and 10.0 mg Kg⁻¹ respectively (EC, 2006). Sugarcane sold on the street of Kumasi had a higher concentration of Cd (0.041) than that found in this study (Azanu et al., 2015). Cadmium (Cd) is a naturally occurring hazardous metal with no known health advantages. Lead has no health benefits and is exceedingly hazardous when consumed more than tolerable levels. A correlation analysis for elements in the edible portion of sugarcane analysed showed significant positive correlation between Cu and Pb ($r = 0.89$, $p = 0.001$), Mn and Pb ($r = 0.56$, $p = 0.03$) and Cd and Cu ($r = 0.62$, $p = 0.01$). This is an indication that they were likely contributed simultaneously from their source of contamination. Some of the elements were not significant and poorly correlated positively indicating that they might have different geochemical factors influencing their concentration in the sediment samples.

Figure 4: Distribution of Heavy Metals in Sugarcane Samples Analysed

3.3. Transfer Factor

The metals analysed had a wide range of transfer factor (TF) values of 0.18 to 0.38, 0.1 to 0.35, 0.04-0.14, and 0.11-0.34 for Pb, Cu, Cd, and Mn respectively (Fig. 5). In general, the sugarcane leaf had the lowest TF values followed by the stem, and the root had the highest TF values. The transfer factors obtained in this study revealed that the retention prevalence of Pb, Cu, Cd, and Mn occurs mostly in sugarcane root, which is to similar study on metal transfer factors (TFs) from soil to sugar cane collected in MLS area (Segura-Muñoz et al., 2006). The internal distribution of metals in the plant depends on the differences in the retention capacity of the absorbing element in roots (Salt and Rauser, 1995). However, it is important to note that the detected fraction in the edible parts (stem) of the sugar cane samples represented 50–90% of root concentrations, which is in agreement with those reported by Segura-Muñoz et al., (2006).

Figure 5: Mean Transfer Factors of Metals Analysed

3.4. Variation along the Stream

The trend in Pb, Cu, Cd, and Mn distribution in the soils (Fig. 6) stood the same with increasing distance from the stream (point source of contamination). No significant difference existed between the levels at 0–20m, 20–40m, and 40–60m ($p=0.21$). There was a slight reduction in Pb, Cu, Cd, and Mn levels as one moved away from the stream for various sugarcane parts. There was no significant difference existed between the levels at 0–20m, 20–40m and 40–60m for stem ($p=0.14$), root ($p=0.32$) and leaf ($p=0.13$) parts of sugarcane studied (Fig. 6). This could suggest that the metals pollution

has spread evenly within the area studied. This is in contrast with studies that reveal that metal pollution decreases as you move from the point source (Adengala et al., 2016).

Figure 6: Variation of Concentration of Metal in Various Plants Tissues with Distance from the Stream

4. Conclusion

All the analyzed samples contained detectable concentrations of Pb, Cu, Cd, and Mn. The average concentrations of heavy metals in wastewater, soil, and sugarcane samples were in the order of $Cu > Mn > Pb > Cd$, while the increment of concentration of metals in sugarcane parts was in the order $root > stem > leaf$. Sugarcane leaves had the lowest TF values, followed by stem and root, which had the highest. The trend in Pb, Cu, Cd, and Mn distribution in the soils stood the same with increasing distance from the stream (point source of contamination). No significant difference existed between the levels at 0- 20m, 20-40m, and 40-60m ($p=0.21$). Metal pollution may have spread evenly within the area studied and long cultivation of sugarcane on the land could lead to high levels in the plant.

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6. Consent to Publish

We further confirm that the order of authors listed in the manuscript has been approved by all of us. We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, concerning intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

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8. Competing Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

9. Availability of Data and Materials

The data used to support the findings of this study would be made available from the corresponding author upon request.

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