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Analysis of Soil and Water Samples Collected From Sugar Estate, Sunti, Niger State

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ABSTRACT

Environmental pollution is a critical global health issue, particularly in low- and middle-income countries. This is caused chiefly by anthropogenic activities such as mining, refining, smelting, and agricultural operations, which have led to an increasing rate of environmental pollution by metals. Agricultural factories pollute the environment due to the constant release of factory waste without proper treatment before discharge. This is alarming and deserves proper attention. This is alarming and deserves proper attention. Since soil is an important aspect of our environment it serves as a sink for natural and anthropogenic processes, thereby resulting in bioaccumulation of toxic substances in plants and transferred along the food chain. Analysis of soil and wastewater from selected locations around a sugar factory was carried out using a microwave plasma atomic emission spectrometer. Eight samples consisting of water and soil were collected from three sites. The trend for results with instrument number MY19479002 is iron> cadmium > chromium > zinc >lead. The values obtained for cadmium (1.68-2.08 mg/L) are above the permissible limit while other metal concentrations were below the permissible limit of water. Also, the concentration of heavy metals in soil samples was within the range of 0.24 - 0.29, 0.03 - 0.56, 0.12 - 1.10, 0.09-below detection and 0.74 - 13.85 mg/kg for zinc, chromium, cadmium, lead and iron respectively. The observed concentration in soil samples was within the permissible limits in agricultural soils. Thus, suitable for agricultural activities.

Keywords: Sugar Factory, Agricultural Wastewater, Microwave Plasma, Concentration, Bioaccumulation.

INTRODUCTION

Environmental pollution is a pressing global issue that has significant adverse effects on public health. This pollution arises primarily from human activities that introduce contaminants into the air, water, and soil, which can lead to various health problems and diseases. It is estimated that environmental pollution causes approximately 8.9 million deaths annually in low- and middle-income countries, which represents 94 % of all deaths in these regions. These regions are characterized by high levels of contaminants in ambient air pollution, frequent exposure to toxic chemicals, pesticides, and hazardous waste, and are predominantly linked to non-communicable diseases such as asthma, birth defects, heart disease, stroke, and cancer. (Landrigan and Fuller, 2015; Suk et al., 2016; Ukaogo, Ewuzie, and Onwuka, 2020).

Anthropogenic activities such as mining, refining, smelting and agricultural operations have led to an increasing rate of environmental pollution by metals (Sut-Lohmann et al. 2020, Fajana 2020, Begum 2020). Agricultural soils are often analysed to monitor heavy metal concentrations and assess soil fertility and nutrient deficiencies (Garba et al. 2020; Olivia 2019). Industrial wastewater contains chemicals, heavy metals, oils, pesticides, silt, pharmaceuticals and other industrial by-products (Shanmuganathan 2016; Sewawa et al. 2023). However, these wastewaters can be applied for productive uses, since they contains nutrients that can be used for the cultivation of crops (Sewawa et al. 2023). Environmental contamination by trace and heavy metals through industrial wastes is one of the main health problems in industrialized countries. These metal contaminants can easily enter the food chain if contaminated water, soils and/ or plants are used for food production. Industrial effluents generally consist of organic compounds, inorganic complexes and other non-biodegradable substances (Suresh, Sudhakar, and Damodharam 2015).

Several analytical methods such as microwave plasma atomic emission spectrometry (MP-AES) have been employed for the analysis of metals in treated municipal effluents (Sewawa et al. 2023), drinking water (Rajput et al. 2020; Kumar 2017), water for pharmaceutical grade water (Samarina et al. 2018), seawater (Maxwell 2014; Smirnova et al. 2018) and industrial wastewater (Shanmuganathan 2016; Geoffrey et al. 2020). Other studies include the analysis of alkali and alkaline earth metals in water (Vasil'eva and Polyakova 2022) and the determination of arsenic and selenium in mineral water using MP-AES hyphenated with hydride generation (Mikheev et al. 2017). Mengistu et al. (2022) analysed water from gold mining areas for lead (Pb), nickel (Ni), zinc (Zn), copper (Cu) and cadmium (Cd) using MP-AES while Wiafe et al. (2022) studied the contamination in surface water and soil samples from the catchment of small scale mining in the area in Ghana using atomic absorption spectroscopy (AAS).

Mengistu et al. (2022) analysed soil for trace and major elements using an inductively coupled plasma-sector field mass spectrometer (ICP-SMS). Varga et al. (2020) analysed the composition of honey and used it as an indicator for long-term environmental changes using MP-AES. Amoakwah et al. (2020) studied soil and water around an artisanal gold mining area using ICPOES. Polyakova, Nomerotskaya, and Saprykin (2019) reported that the presence of matrix elements above 1 wt % results in a significant change in element signal.

In Nigeria, the major source of heavy metal pollution is industrial effluent discharged from various processing industries. This increases the influx of metals, which can be transported by wind and water and thus become available to plants and animals. These heavy metals attain higher concentrations and accumulate in harmful quantities in different plant parts, and finally pose serious health hazards to human beings and animals through biomagnification. This study assessed the extent of toxic trace metal contamination in industrial effluent in water and soil around Sugar Estate, Sunti in Northern industrial zone of Niger State. The metals analysed in this work include lead (Pb) zinc (Zn) copper (Cu) iron (Fe) and chromium (Cr). These heavy metals were considered widespread in the area, as informed by literature surveys. The study also focused on sugar processing factory effluent discharge because no study has been reported in this area. The present study is undertaken to assess the extent of toxic trace metal contamination in industrial effluent around the field of the Northern industrial zone of Niger State. The study was necessary as many farmers use this effluent as irrigation water due to the absence of an irrigation water system and no research has been conducted to elucidate the extent of the problems that could result from these effluents around the study area.

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MATERIALS AND METHODS

Description of the Study Area

The study area, the Sugar processing factory is located at Sunti Mokwa Local Government Area, Niger State Nigeria, with a population of about 1000 people. The Sugar Company lies on the geographical coordinates of 6°35.0′0.94″ E and 9°38′9.38″ N.

Sample Collection

A total of eight (8) samples were collected consisting of (2) soil samples and (6) water samples.

The samples were randomly collected along the main open wastewater channels on the assumption that these were the channels that were consolidating the wastes from various directions in the industrial study area. From each site, samples of the wastewater and soils were collected from the open wastewater channels. All the sampling sites were near informal settlements that included the Factory, Eppa, and Sunti Village. Control samples were taken at a site 1 kilometer away from the wastewater sites. The soil samples were collected using polyethene bags and labelled while wastewater samples were collected into a plastic bottle, and transported to the laboratory for analysis.(Baird, Rice, and Eaton, 2017).

Table 1: List of the samples collected from the factory and Sunti village

Samples	Horizon depth (m)	Sample location
Inlet wastewater	80	Wastewater site
Treated effluent	74	Wastewater site
River discharge	74	2 km away from the site
River water	70	3 km away from the site
River soil	70	3 km away from the site
Discharge soil	74	2 km away from the site

Note: Inlet wastewater (IN): this is the wastewater inlet, it is the waste collected from the factory; Treated effluent (TE): This is the wastewater that undergoes a series of treatments and is termed as the treated effluent; River discharge (RW): this is water gotten from the Eppa River where the people bathe and wash; River water (RD): this river water was gotten from the waste site discharge i.e where the discharge water enters into the river water; River soil (SA): this is the soil gotten from the ground of the river water; Discharge soil (SB): this is the soil gotten from the ground of the discharged wastewater.

Sample Preparation Water

Sample digestion was carried following modified protocol of method 3030 nitric acid – hydrochloric acid using 10 ml of wastewater and 2 g of soil samples. The process was continued has described (Baird, Rice, and Eaton, 2017). The digest was filtered into 100 ml of capacity volumetric flask and the filtrate was filled up to mark and then transferred into a plastic bottle.

Heavy metal analysis was carried out using an Agilent MP-AES (MY1947002) with SPS autosampler equipment. Equipment operation conditions include a pump speed of 70 rpm, sample uptake time of 60 sec, rinse time of 20 sec and stabilization time of 5 sec. Table 2 gives the emission wavelengths, nebulizer flow rate and correlation coefficients of analytes determined in this work.

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Table 2: Emission wavelengths, nebulizer flow rate and correlation coefficients of analytes

Analyte	Wavelength (nm)	Nebulizer flow (L/min)	correlation coefficient
Cr	425.433	0.90	0.99971
Cd	228.802	0.50	0.99982
Zn	213.857	0.45	0.99991
Pb	405.781	0.75	0.99988
Fe	371.993	0.65	0.99923

Physiochemical Analysis of Water Samples

Physiochemical analysis was conducted using a Hach (Etrex 10 model) multimeter. Conductivity, pH, TDS, salinity and resistivity were determined.

MP-AES Analysis and Operation Condition

Metal analysis was performed using an Agilent microwave plasma atomic emission spectrometer (MP-AES) with equipment number MY19479002 at the Usmanu Danfodio University in Sokoto, Nigeria. The pump speed was set at 70 rpm, sample intake was between 15 and 60 seconds, rinse time was between 8 and 20 seconds, and stabilization time was between 5 and 15 seconds. Table 2 lists the analytes' correlation coefficient and the emission lines that were taken into account.

RESULTS AND DISCUSSION

Table 3: Results of physiochemical parameters of samples

Samples	pH	Conductivity (S/m)	TDS (mg/L)	Resistivity (Ω)	Salinity
RW	6.33	53.9	24.9	18.82	0.02
RD	6.72	53.44	25.1	18.72	0.02
IN	4.87	297	141.9	3380	0.14
TE	8.17	700	341	14320	0.34
WHO	6.5-8.5	10-1000	500	-	-

Results of physiochemical parameters of samples are given in Table 3. The pH observed in the water samples ranged from 4.87 - 8.17 which fall within the recommended values of WHO (6.6-8.5) while sample C is below the recommended value. Similar pH range of 6.54 – 7.34 was found by Barambu et al (2020) while higher range of 9.3 – 10.2 was found by Ma et al. (2020). pH is important for biotic communities as most of the plant and animal species can survive in a narrow range of pH from slightly acidic to slightly alkaline. The findings show the value obtained for electrical conductivity ranged from 53.9-700 S/m. This is similar to range of 56 – 71.21 S/m found by Barambu et al. (2020). Ma et al. (2020) reported values of 1060.17 – 1335.21 S/m higher than ranged found in this work. The values obtained are within the accepted value (1000 (S/m) for all samples. Resistivity values observed from the wastewater sample ranged from 18.82-14320 Ω. The highest Resistivity measured was in sample D, this might be due to high nutrient in the inlet wastewater sample. The total dissolved solid (TDS) observed in the wastewater samples ranged from 24.9 mg/L to 341 mg/L. These values are within the acceptable limit of WHO which is 500 mg/L. TDS is a very useful parameter used in describing the chemical constituent of the water and can be considered edaphically related that contribute to productivity within the water body. The results obtained for salinity are within the acceptable limit while resistivity is also within the range in all samples except sample D which has higher value than the mean.

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Table 4: Concentrations of heavy metals in wastewater

Samples	Zn (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Fe (mg/kg)
RW	0.04 ± 0.01	NA	1.68 ± 0.03	0.04 ± 0.00	0.48 ± 0.01
TE	NA	NA	2.08±0.00	0.04 ± 0.00	0.44 ± 0.00
RD	0.00 ± 0.00	0.02 ± 0.01	1.74 ± 0.01	0.04 ± 0.00	0.44 ± 0.00
IN	0.22 ± 0.00	0.04 ± 0.00	1.42 ± 0.01	NA	1.14 ± 0.02
WHO	5	0.05	0.030.00	0.05	-

Results are represented in mean±SEM; NA*= not analysed or below detection limit

Results show the presence of Zn in Sample RW and IN but absent in TE and RD, Cr was absent in RW and TE but present in RD and IN. The results above show the presence of Cd, Pd and Fe in all samples having similar mean values.

The results of concentrations of heavy metals in wastewater samples are presented in Table 4. The level of heavy metals in the wastewater is in the following trend; Fe> Cd > Cr > Zn >Pb, the values obtained. For Cd (1.68-2.08 mg/L) are above the permissible limit of 0.003 mg/L and other higher than values obtained by 0.001 – 0.0024 mg/L found by Barambu et al. (2020) and Rattan et al. (2005) in industrial effluents samples. For Zn, higher values of 1.390 – 2.00 mg/L were found by Barambu et al. (2020) and 12 mg/L by Ma et al. (2020). Rattan et al. (2005) found lower values of 0.006 – 0.151 mg/L for Zn industrial effluent. Values reported in this study for Pb, Cr and Fe are similar to concentrations range of 0.001 – 0.067, 0.001 – 0.013, and 0.639 – 3.793 mg/L reported by Barambu et al (2020) and Rattan et al (2005). Other heavy metals in all samples were below the permissible limit of water set by WHO.This indicates that the activities in the study area does not have significant effect on the wastewater quality. However, regular monitoring is recommended to prevent the accumulation and migration of heavy metals during the rainy season.

Table 5: Concentrations heavy metals in soil

Samples	Zn (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Fe (mg/kg)
SA	0.24 ± 0.00	0.56 ± 0.00	1.10 ± 0.02	NA	0.74 ± 0.00
SB	0.29 ± 0.00	0.03 ± 0.00	0.12 ± 0.01	0.09 ± 0.00	13.85 ± 0.21
WHO	300	5.00	3.00	50	200

Results above show the presence of heavy metals in all soil samples except for SA which Pb is absent. And Sample SB attains higher Fe concentration compared to sample SA.

The results of concentrations of heavy metals in soil samples are presented in Table 5. The levels of heavy metals in soil samples were within the range of 0.24 - 0.29 mg/kg, 0.03 - 0.56 mg/kg, 0.12 - 1.10 mg/kg, 0.09 mg/kg-NA and 0.74 - 13.85 mg/kg for Zn, Cr, Cd, Pb and Fe, respectively. The observed levels in soil samples were below toxic threshold in agricultural soils recommended by FAO/WHO (2011). The findings suggest that the soil samples were not polluted by the heavy metals of interest. These findings are similar to the work of Adedokun et al. (2016) who reported that all heavy metals in both soil and water samples are within the acceptable limits. Also, results reported by Khan et al. (2008) indicate that the values of Zn, Cd, Cr, and Pb in the range of 136-176 mg/kg, 0.41-

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1.71 mg/kg, 58.3-62.5 mg/kg, and 47.7-52.6 mg/kg, respectively, were observed. It should be noted that these values differ from the findings of this study, except for Cr, where similar results were obtained in certain areas.

Zinc is an essential element, yet it gives undesirable astringent taste to water at levels above the standard limit (5.0 mg/L). The low level of Zn in the analysed wastewater and soil samples was probably due to the zero industrial and vehicular activities in the study area. Previous reports however, have shown that water quality within most of rural river catchment areas in Nigeria has degraded due to intensive land use, hence increasing Cr, Hg and Pb levels and surpassing the critical guidelines of WHO (Ayenimo et al. 2016). In the current study area, humans can become exposed to such pollutants when surface runoff finds its way into residential areas or utilising the contaminated soils for agricultural activities. Due to the low concentration of heavy metal in soils, this may lead to decrease in Phyto-accumulation of metals in the crops grown. Clogging of open waste water channels with solid wastes, mud and overgrown vegetation can enhance surface runoff of the wastewater to surrounding areas (Rajaganapathy et al. 2018). One of the factors which may increase the chance of exposure to metal pollutants in the study area is the presence of a dense population in the informal settlements near the sample area. However, treatment of wastewater for reuse is a common practice in many countries since it can alleviate natural water shortage and minimize contaminants finding their way into natural aquatic ecosystems.

CONCLUSION

This study determined the level of heavy metals (Cr, Zn, Cd, Pb, and Fe). The results revealed that the level of the investigated metals in soil and water in the sampled points were below toxicity threshold recommended by FAO/WHO and WHO of soil and water standards respectively. Thus, the results show that the soil samples of the study area were not polluted by the investigated heavy metals. The research recommend that the industrial effluent is safe use for irrigation. However, further screening for heavy metals not determined in this study should be carried out .

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