



Original Article

Effects of Effluent on Cultivated Soil Properties in Kedjoun Ketinguh, Northwest Region of Cameroon

Mofor Nelson Alakeh¹*, Tangoh Frinde Adeline¹, Mbene Kenneth², Fai Joel Alongifor³ & Njoyim Estella Buleng Tamungang^{3,4}

¹ The University of Bamenda, Bambili, P. O. Box 39 Bambili, Cameroon.

² University of Yaounde 1, P. O. Box 47, Yaounde, Cameroon.

³ University of Dschang, P. O. Box 39 Bambili, Cameroon.

⁴ Calvin University, Grand Rapids, Michigan, USA.

* Correspondence ORCID: <https://orcid.org/0000-0003-3164-3458>; Email: nelsonmofo@yahoo.com

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ABSTRACT

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This study assessed the physicochemical and heavy metal properties of cultivated soils contaminated by effluent and uncontaminated soils in Mphiewen-Kedjoun Ketinguh, Northwest region of Cameroon, in the rainy and dry seasons respectively. In addition, the physicochemical and heavy metals properties of effluent from Mphiewen, responsible for contamination of Mphiewen soil were assessed. We hypothesized that heavy metals from the effluent affected the cultivated soil and plants grown on it. All analyses were carried out on the soil and effluent samples using standard analytical methods. The results revealed that, the soil samples had pH values ranging from 5.9 to 6.0. The effluent sample had pH value of 5.9 and 6.9 in rainy and dry seasons respectively. The organic matter levels in the soils were high and ranged from 5.0-8.92% in both seasons. Total nitrogen content in all the soils were low ($N < 1\%$) and ranged from 0.1 to 0.3%. C/N ratios were high (ranging from 15 to 17), indicating that the organic matter was inadequately mineralized. Heavy metals analysis showed that the cultivated soil was contaminated by cadmium with total concentration of 3.7 mg/kg in the dry season, and chromium with total concentrations of 100.05 and 105.49 mg/kg in rainy and dry seasons respectively. Pearson correlation between some physicochemical properties of the contaminated soil and effluent physicochemical properties were all unity ($r = 1.000$; $p < 0.01$). This indicated that the effluent from the dumpsite was the main source of contaminant in the cultivated soil receiving the effluent. The problem of Cd and Cr toxicity in the contaminated soil can be solved by using various methods based on physical, chemical, and biological processes such as chemical precipitation, membrane separation, ion exchange, electrodialysis, phytoremediation, and surface adsorption.

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INTRODUCTION

A major consequence of current industrialization and the desire for a better quality of life has led to an increasing rate of soil contamination due to municipal waste, which poses a serious danger to the overall health of the soil-water-plant-human systems (Chukwuebuka et al., 2023). Studies have shown that open dumpsites remain the most popular source of environmental pollution (Divya et al., 2020). Environmental pollution is a worldwide problem, and its potential threat to public health is significant (Perminova et al., 2019). The impact of pollution near congested cities has reached a disturbing magnitude and these problems include, amongst others, soil pollution by effluent or leachate from dumpsites (Begum et al., 2009). Effluent is formed as a byproduct from biodegradation of the different chemical compounds that develop in municipal waste. Effluent consists of various substances such as nutrients, soluble organic and mineral compounds, heavy metals, suspended particles, and many chemical compounds that cause danger to the natural ecosystem (Yahya et al., 2023). Effluent from improper waste disposal has been widely observed as one menace to the sustainability of the ecosystem. Such leachates or effluent are often found in surface water bodies, underground water, soil, and other biophysical components of the environment, resulting in adverse effects on humans, aquatic organisms, plants, and animals (Amos et al., 2014). Toxic metal accumulation in organic matter in soil leads

to degradation of soil health and contamination of the food chain (Khan et al., 2018).

Soil is a vital component, medium of unconsolidated nutrients and materials, and forms the life layer of plants. It is a basic life support component of the biosphere. The yield and quality of products obtained from any given agricultural activity depends largely on soil quality (Gebregewergis, 2022). However, the agricultural sector in the world today tends to face a lot of challenges associated with the quality of soil due to various forms of pollution, amongst which, effluent from waste dumpsites (Njoyim et al., 2016a). Therefore, the concept of waste technology to prevent environmental pollution through several means is critical for environmental sustainability. This is because pollution is considered one of the well-known world disasters (Omeiza and Dary, 2018).

Unlike developed countries, most African countries rely on open dumpsites without a standardized sanitary landfill (Omeiza et al., 2022). According to the International Solid Waste Association (ISWA), municipal waste generation in developed countries is fast beginning to be stable. However, United Nations Environmental Program expresses fear over upsurge in waste generation in developing nations, while economic activities continuous to crawl across the world. Thus, Cameroon being a developing country faces waste management as one of the most serious environmental problems. Cameroon has minimal waste collection coverage which forces majority

of the waste to be dumped on open lands. The land filling of biodegradable waste has proven to contribute to cultivated soil degradation, mainly through the production of highly polluting leachate or effluent (Rahman et al., 2023).

The persistent increase in anthropogenic activities in the environment gives rise to higher levels of pollution which can step-up the level of soil degradation. Soil contamination is the major source of danger to human and animal health as well as plants (Munzel et al., 2022). Most of the soil degradation problem in Cameroon is due to poor effluent disposal and management. Heavy metals contained in effluent have become one of the major chemical pollutants in agricultural soils and this is one of the global challenges facing food production and the sustainability of the ecosystem (Mofor et al., 2017). The problems associated with farmlands contamination by heavy metals have raised a serious concern for emerging countries such as Cameroon (Njoyim et al., 2016b). Heavy metals which accumulate in soil result from rapidly expanding industrial areas, disposal of high metal wastes, sewage sludge, and atmospheric deposition (Okereafor et al., 2020; Khan et al., 2008). Heavy metals enter plants through roots and leaves. Some of these metals such as Zn, Cu, Mn, Ni and Co are micronutrients necessary for plant growth at recommended concentrations, while others like Cd, Pb, As, and Hg lack the known biological functions and are considered toxic (Nabulo et al., 2010).

The rapid increase in population in Kedjoum katinguh-Northwest Cameroon in recent years has resulted to increase in anthropogenic activities such as garage works, metallurgical, and oil exchange services, and as a result, large quantities of wastes are dumped on and around the farmlands and water systems used for irrigation. These have led to the introduction of huge amounts of heavy metals into the soil. The uptake of some of these heavy metals by plants and leaching of some into water bodies poses serious threats to human health (Yunginger et al., 2018). Therefore, analysis of the physicochemical properties of the agricultural soils and effluent

from dumpsite passing through the soils of Mphiewen-Kedjoum katinguh is of great importance.

Based on the above problem, this article seeks to determine the physicochemical properties of soils and effluent on and around farm dumpsites in Mphiewen; determine the concentrations of selected heavy metals (Cd, Pb, Hg and Cr) in the samples and finally, this article seeks to determine the extent of heavy metal pollution of the farmed dumpsites and provide possible mitigation measures.

MATERIALS AND METHODS

Site Descriptions

The study area is a farmlands of Mphiewen found in the grass field zone of Cameroon, specifically in Tubah subdivision, Mezam division of the Northwest Region. Tubah Subdivision is located on latitude N6°2'18.41" and longitude E10°17'26.84" and at an elevation of 1350 m above sea level. It covers a surface area of 450 km² with a population of about 65,250 persons and population density of 145 persons / km².

The study site has two distinct climates, rainy and dry seasons which runs from mid-March to mid-October and from mid-October to mid-March respectively and sampling was done in September 2022 and February 2023. Three sampling sites (an uncontaminated soil, a cultivated soil contaminated by effluent and a dumpsite where effluent is flowing) were chosen in Mphiewen for sample collection. For the soil samples, two surface soil samples were collected at a depth of (0-30) cm in a diagonal array to represent a true picture of each site. A total of four soil samples and two effluent samples were collected from the sampling sites. One liter (1 L) each of effluent sample was collected from the dumpsite in September and February. All the samples were labelled accordingly and transported to the laboratory for analysis. The sampling point of uncontaminated soil of Mphiewen (USM) is located on latitude N5°5'7.63" and longitude E10°2'0.59" and at an elevation (altitude) of 1108.6 m above sea level. The sampling point of

cultivated (contaminated by effluent) soil of Mphiewen (CSM) is located on latitude N5°5'8.73" and longitude E10°3'0.50" and at an elevation of 1088.5 m above sea level. Mphiewen dumpsite is located just beside the cultivated farmland of Mphiewen. The study site is located on latitude N5°5'7.73" and longitude E10°3'2.50" and at an elevation of 1088.0 m above sea level.

Laboratory Analysis

Freshly collected soil samples from the field were air dried in the laboratory, ground in a porcelain mortar using a pestle and sieved through a 2 mm sieve. The two soil samples per site and per season were bulked to produce a unique composite sample. The fine earth (< 2 mm) was then analyzed for the various physicochemical and heavy metal properties using international standard methods (Jones, 2003). Soil pH was measured over a 1:2.5 soil: solution ratio in 1 N KCl (pH-KCl) and distilled water (pH-H₂O) with the help of a pH meter. Electrical conductivity (EC) was measured over a 1:5 soil-water solution ratio with a conductometer (MTW MODEL). Organic carbon (OC) was determined by the oxidation of OC by potassium dichromate (K₂Cr₂O₇) in the presence of concentrated sulfuric acid followed by titration with hydrated iron (II) sulfate (FeSO₄·7H₂O) (Walkley and Black, 1934), and organic matter (OM) was calculated from the levels of organic carbon in the soil by multiplying by 1.72 as reported by Hazelton and Murphy (2007). Exchangeable bases were determined following the Schollenberger method using a 1 M ammonium acetate solution buffered at pH 7, and after which, the amount of Na⁺ and K⁺ ions in the extract were determined by flame photometry, with Ca²⁺ and Mg²⁺ ions determined by complexometric titration. Cation exchange capacity (CEC) was determined as a direct continuation of the Schollenberger method using a 1 N KCl solution for the displacement of ammonium ions, and the desorbed ammonium ions were determined by the Kjeldahl's distillation method using 0.02 N HCl and 0.02 N NaOH solutions. Total nitrogen (%N) was determined by Kjeldahl's distillation method.

Available P was determined by Bray 2 method. Particle size (texture) was determined by the hydrometer method. The levels of available heavy metals in the samples were determined using Atomic Absorption Spectrometry (AAS) analysis. The heavy metal extraction solution is aqua regia (a mixture of conc. HNO₃ and HCl in the volume ratio of 1:3).

Statistical Analysis

Student's test (t-test) was used to compare correlation matrix between soil physicochemical properties, Pearson correlation coefficient matrix between soil physicochemical properties and heavy metal properties, and Pearson correlation between the properties of the cultivated soil contaminated with effluent and effluent physicochemical properties. Statistical analysis was done using the Statistical Package for Social Sciences (SPSS) version 20 and Origin 2018 software.

RESULTS AND DISCUSSION

Soil Physicochemical Properties

Results of physicochemical properties of effluent from the dumpsite at Mphiewen (EFM) passing through the cultivated soil, physicochemical properties of the uncontaminated soil (USM) and contaminated soil (CSM) of Mphiewen, are presented in *Table 1* and *Table 2* respectively.

Results of physicochemical properties showed that the soil textural class of the cultivated soil contaminated with effluent was clay silt, which is a fine textural soil with a high water and nutrient holding capacity. The uncontaminated soil was of soil type sandy clay (FAO, 2006). This soil type shows low water and nutrient holding capacity due to inadequate organic matter. Soil pH (H₂O) for the uncontaminated farmland was 4.9 and 5.9 in the dry and rainy seasons respectively, with a mean value of 5.2 ± 0.7 . The uncontaminated soil was thus classified as strongly acidic and not good for farming (Bruce and Rayment, 1982; Hazelton and Murphy, 2007).

Table 1: Physicochemical properties of the effluent sample

		pH- H ₂ O	EC (mS/cm)	Turbi (NTU)	Cl-(mg/L)	SO ₄ ²⁻ (mg/L)	HCO ₃ ⁻ (mg/L)	NO ₃ ⁻ (mg/L)	PO ₄ ³⁻	NH ₄ ⁺ (mg/L)	K ⁺ (mg/L)	Na ⁺ (mg/L)	Ca ²⁺ (mg/L)	Mg ²⁺ (mg/L)
EFM	SEPT	5.9	0.12	249	32.6	3.16	1.47	45.02	120	119	3.25	0.05	44	30.4
	FEB	6.9	0.22	303	42.6	4.16	2.47	47.02	121.3	122.9	4.25	0.99	44	31.59
	Mean	6.4± 0.7	0.17±0.0 7	276±38. 2	37.6±7.07	3.66±0.7	1.97±0.7	46.02±1.4	120.65±0.9	120.95±2.7	3.75±0.7	0.52±0.6	44±0.0	30.995±0.8

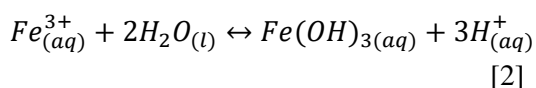
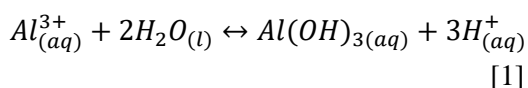
EC = Electrical Conductivity; Turbi = Turbidity

Table 2: Soil physicochemical properties

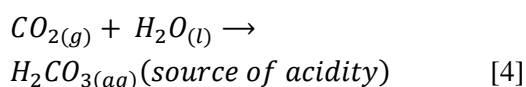
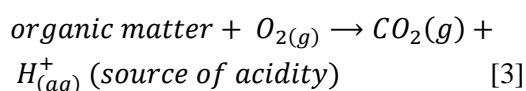
Properties		pH- H ₂ O	pH-KCl	N(g/kg)	%N	%OC	%OM	C/N	CEC (cmolc/kg)	P (mg/kg)	K+(cmolc/kg)	Na+(cmolc/ kg)	Ca2+(cmol c/kg)	Mg2+(cmol c/kg)	SBE(cmolc /kg)	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)
USM	Sept	4.9	3.8	1.59	0.1	2.03	5	15.96	25.2	4.3	0.04	0.36	9.9	1.48	13.4	25.46	30.5	43	25.46	30.5	43
	Feb	5.9	4.8	1.79	0.179	3.03	5.22	17	28.2	11.7	2.4	0.49	11.4	2.5	16.4	25.5	30.5	44	25.5	30.5	44
	Mean	5.2 ±0.7	4.3 ±0.7	1.7 ±0.1	0.1±0.06	2.5 ±0.7	5.1 ±0.2	16.4±0.7	26.7 ± 2.1	8 ± 5.2	1.2 ± 1.7	0.4 ± .09	10.6 ± 1.06	1.9 ± 0.7	14.9 ± 2.1	25.5 ± 0.03	30.5 ± 0.0	43.0 ± 0.7	25.48±0.7	30.5±0.1	43.5±0.2
CSM	Sept	5	4.1	2	0.2	4.2	7.2	15.9	30.4	9.7	1.4	0.3	10	4.5	15.8	17	50.5	20.6	17	50.5	20.6
	Feb	6	5.1	2.96	0.3	5.18	8.92	17	32.4	5.29	1.04	0.36	10.9	5.5	17.79	17	60.5	22.5	17	60.5	22.5
	Mean	5.5 ±0.7	4.6 ±0.7	2.48±0.67	0.25±0.07	4.69±0.69	8.06±1.2	16.45±0.77	31.4 ± 1.4	7.5 ±3.1	1.22±0.25	0.33 ± 0.04	10.45 ± 0.6	5 ± 0.7	16.8 ± 1.4	17 ± 0.0	55.5± 7.07	21.55 ± 1.3	17.0±0.0	55.5±0.6	21.55±0.4

OC = Organic carbon, N = Total nitrogen, OM = Organic Matter, C/N = Mineralization factor, CEC = Cation Exchange capacity, P= phosphorus, SBE= Sum of Bases

The cultivated soil contaminated by effluent had pH values of 5.0 and 6.0 in the dry and rainy season respectively, with a mean value of 5.5 ± 0.7 . This soil type is classified as moderately acidic. The pH (H_2O) of effluent was 5.9 and 6.9 in dry and rainy seasons respectively, with mean value of 6.4 ± 0.7 . When soil is acidic, the availability of the nutrients (P, N and soluble bases) is reduced (Mofor et al., 2017). This is because at low pH values, oxides and hydroxides of iron and aluminium become soluble in soil solution and tend to adsorb these nutrients (Njoyim et al., 2016b), making them unavailable for plants uptake. The optimum pH range favorable for plant growth is between 6.0 and 8.0, because most plant nutrients are readily available in this pH range (Mofor et al., 2017). The high acidity of the uncontaminated soil could be due to the presence of soluble metal ions of Al and Fe (acidic cations), which reacted with water in soil solution, thus, releasing H^+ according to the following equations (Mofor et al., 2022):



The acidic nature of the cultivated soils contaminated with effluent could probably be due to decaying organic matter (equations (3) and equation (4)) that produced H^+ , an ion responsible for the increase in soil acidity (Mofor et al., 2022). This could be evident by the high organic matter content in the cultivated soil, with a mean value of 8.06%. This soil type is thus nonporous and shows high nutrients holding capacity.



Lime pellet legume seed and use of Molybdenum (Glendinning, 1986) will reduce acidity and induce the immobilization of the components responsible for the adsorption of soil essential

nutrients, thereby releasing inorganic plant nutrients such as N, S and P to soil solution. The organic matter levels in the soils were high as per the ratings established by Vitinotes (2006). Soil organic matter (%OM) in the soil ranged from 5.0-8.92% in both seasons, with mean values of 5.1 and 8.06% for the uncontaminated soil and cultivated soil contaminated with effluent respectively. According to the rating established by Beernaert and Bitondo, (1992), the %OM in the soils was classified as very high (>5). These soils thus had good structural condition, high structural stability, and soils probably water repellent (Hazelton and Murphy, 2007). The maximum amount of %OM was observed in the cultivated soil contaminated with effluent during the dry season. The high organic matter content of this soil could have resulted from effluent from the dumpsite around the farmland and organic waste being directly dumped on the surface of the farmland. Total nitrogen content in all soils was low ($N < 1\%$) (Bruce and Rayment, 1982), and ranged from 0.1 to 0.3% in both seasons, with mean values of 0.1 and 0.25 for the uncontaminated soil and cultivated soil contaminated with effluent respectively. Nitrogen is considered a limiting nutrient because much of it is held in the organic matter in the soil (Hazelton and Murphy, 2007). C/N ratios were high, ranging from 15 to 17, indicating that the organic matter was inadequately mineralized, and decomposition may proceed at the maximum rate possible under environmental conditions (Beernaert and Bitondo, 1992). The poor mineralization of the OM% could be explained by the prevalence of low pH values and low water content in the soils. Low soil N content and high C/N values could be attributed to immobilization and denitrification processes by soil bacteria (Mofor et al., 2022). Available phosphorus in the soils ranged from 4.3 and 11.7 mg/kg in both seasons, with mean values of 8 and 7.5 for the uncontaminated soil and cultivated soil contaminated with effluent respectively. Available P values were low (Hazelton and Murphy, 2007) in all soil samples, in both seasons. Low P concentration in the soils may be associated with the acidic nature of the soil. At low pH values, oxides and hydroxides of Al, Fe,

and Mn are highly soluble in soil solution and react with phosphate ions (H_2PO_4^-) to form insoluble metal-phosphates, which are unavailable for plants (Mofor et al., 2022). Exchangeable bases (Ca^{2+} , Mg^{2+} , K^+ , and Na^+) in all soil samples showed the following trend: $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+ > \text{Na}^+$. Quantitatively, the concentrations of these cations varied as follows: Ca^{2+} (between 9.9 and 11.4 cmolc/kg), Mg^{2+} (between 1.48 and 5.5 cmolc/kg), K^+ (between 0.04 and 1.4 cmolc/kg), and Na^+ (between 0.3 and 0.49 cmolc/kg), in both seasons. These concentrations were quite low (especially for K^+ , Na^+ , and Mg^{2+}) and high for Ca^{2+} based on the ratings established by (Metson, 1961). These low concentrations of K^+ , Na^+ , and Mg^{2+} may be due to the porous nature of the soils that are prone to base leaching (Hazelton and Murphy, 2007). The low concentrations could also be explained by the prevalence of pH values of less than 5.5, where these cations are deficient (Mofor et al., 2022). Cation exchange capacity (CEC) of the soils ranged from 25.2-32.4 cmolc/kg in both seasons,

with mean values of 26.7 and 31.4 cmolc/kg for the uncontaminated soil and cultivated soil contaminated with effluent respectively. The CEC values of the soils were high as per the ratings established by Hazelton and Murphy, (2007). These high CEC values indicated the capacity of the soil to retain, resist change in pH, retain nutrients and supply positively charged nutrient ions called cations. These include Ca^{2+} , Mg^{2+} , K^+ , NH_4^+ , and many of the micronutrients (Spargo et al., 2013). CEC values were higher in the soil contaminated with effluent probably due to its high organic content and nonporous nature.

Heavy Metal Properties

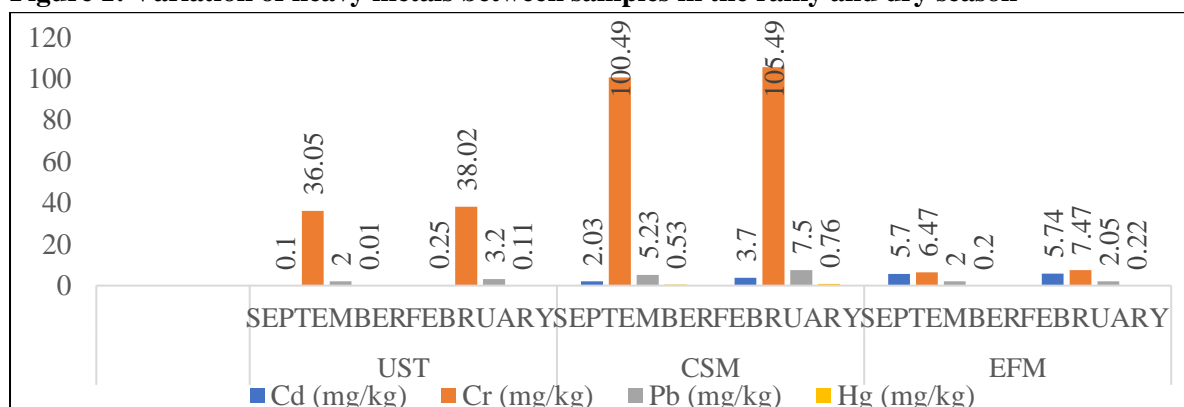
Results of total heavy metals concentrations in the soil samples and effluent sample from Mphiewen are presented in Table 3 and on Figure 1 respectively. These results are discussed with respect to Maximum Allowable Concentration (MAC) reported by Kabata-Pendias (2011) and De Vries et al. (2003).

Table 3: Total heavy metal concentrations for both soil and effluent samples

Sample/heavy metal type	USM	Mean value	CSM	Mean value	MAC in soil	EFM	Mean values	MAC in waste water
Cd (mg/kg)	Sept	0.1	0.175±0.1	2.03	2.865±1.2	0.9-3	5.7	5.72±0.02
	Feb	0.25	3.7			5.74		
Cr (mg/kg)	Sept	36.05	37.035±1.4	100.05	102.77±3.8	100	6.47	6.97±0.7
	Feb	38.02	105.49			7.47		0.537
Pb (mg/kg)	Sept	2	2.6±0.9	5.23	6.365±1.6	30-50	2	2.025±0.04
	Feb	3.2	7.5			2.05		5
Hg (mg/kg)	Sept	0.01	0.06±0.07	0.53	0.66±0.2	0.03-2	0.2	0.21±0.01
	Feb	0.11	0.79			0.22		0.01

UST = uncontaminated soil Mphiewen, CSM = Contaminated soil Mphiewen, EFM = Effluent Mphiewen, MAC = Maximum Allowable Concentration

Figure 1: Variation of heavy metals between samples in the rainy and dry season



Cadmium (Cd)

The mean total concentration of Cadmium in the soil samples, in both seasons, were 0.175 and 2.865 mg/kg for USM and CSM respectively. The effluent sample had mean total concentration of Cd as 5.72 mg/kg. The total concentration of cadmium in the cultivated soil contaminated by effluent was 2.03 and 3.7 mg/kg in the rainy and dry seasons respectively. Cd value in the dry season thus, was above the maximum permissible limit (Kabata-Pendias, 2011; De Vries et al., 2003) (< 3 mg/kg). Apparently, this value of Cd in the dry season higher than background contents reflected the anthropogenic impact such as the use of fertilizers, pesticides, and effluent from Mphiewen on the Cd status of the topsoils. However, this elevated levels of Cd in the soil could also be of lithogenic (geogenic) origin (Curlik and Forgac, 1996). The result further showed that, the uncontaminated soil was deficient of Cd, thus, an indication that there are no nutritional implications related to Cd in the uncontaminated soil. In uncontaminated soils, Cd concentration is highly governed by soil texture. In acidic soils, SOM and sesquioxides largely control the labile pole of Cd. Cd binds to SOM in acidic soils and its residual fraction seem to be relatively stable. This implies that the exchangeable Cd in the contaminated soil resulted from sewage from the dumpsite. Cd has no known essential function in the human system but causes toxicity above certain tolerance levels. Occupational exposure to cadmium can result to flu-like symptoms such as chills fever, and muscle pains. Kitagishi and Yamane (1981) reported that the best and most reliable results in reducing Cd availability is achieved by layering of unpolluted soil over polluted soil to a depth of 30 cm. In recent years, phytoremediation technique with the use of *Zea mays*, *Salix viminalis*, *Helianthus annuus*, and *Viola baoshanensis*, has been applied to remediate Cd from contaminated soils (Dickinson and Pulford, 2005).

Chromium (Cr)

The mean total concentration of chromium in the soil samples were 37.06 and 102.77 mg/kg for

USM and CSM respectively, in both seasons. The total concentration of Cr in the cultivated soil contaminated with effluent was 100.05 and 105.49 mg/kg in the dry and rainy seasons respectively. These concentrations were above the maximum allowable limit reported by Kabata-Pendias, (2011) and De Vries et al., (2003) (<100 mg/kg). The main source of Cr in the contaminated soil is from dyestuffs and leather tanning when wastes are discharged directly onto the cultivated soil either as liquids or solids. Also, sewage from residential sources in the dumpsite of Mphiewen discharge substantial amount of Cr to the cultivated soil. The mean total concentration of Cr in the effluent was 6.79 mg/kg. The effluent thus, had Cr value higher than that required for irrigation water (< 0.537 mg/kg), as stated by Kabata-Pendias, (2011) and De Vries et al., (2003). In a small amount, Cr stimulates the growth of agricultural crops; excess of it, however, promotes various diseases. Cr in its normal allowable dose in the human system helps in the proper functioning of the brain. However, a wide distribution of Cr in the environment is unfavourable for humans and animals. Therefore, Cr toxicity depends on its oxidation status and concentration. Cr occurs in two states in soils. The oxyanion chromate, CrO_4^{2-} , is highly mobile and more toxic in soils and groundwater. On the contrary, the reduced ion, Cr (III), forms either a weakly soluble hydroxide or stable complexes with soil minerals (Vodyanitskii, 2016). In uncontaminated (pristine) soils at neutral pH, Cr is slightly mobile and thus, not readily available to plants which may have nutritional implications (Chung and Sa, 2001). Smectite clays, coal, burnt charcoal and other sorbents, the use of electrokinetic techniques, reduction of Cr by ferrous Sulfate and/or sulfate reducing bacteria, bacterial biofilms, and phytoremediation have been identified as processes to remediate Cd in contaminated soil (Kabata-Pendias, (2011).

Table 4: Pearson correlation coefficient matrix between soil physicochemical properties

	pH	pHKCL	OM	C/N	Tot N	AP	Mg	CEC	SBE	Sand
Ph	1									
pHKCL	0.333	1								
OM	0	0.899	1							
C/N	-0.5	-0.866	-0.559	1						
TotN	-1,000**	0.961	0.985	-0.240	1					
AP	0	1,000**	0.899	-0.482	-0.5	1				
Mg	-0.277	0.866	0.559	1,000**	-0.866	0.866	1			
CEC	-0.756	-0.5	-0.829	0	-0.5	-0.5	1.000	1		
SBE	1,000**	0.5	0.069	-0.866	-1,000**	0.5	0.866		1	
Sand	-0.839	0.454	0.545	0.866	0.866	0.545	0	0.277	0.891	1

*, Correlation is significant at the 0.05 level (2-tailed). **, Correlation is significant at the 0.01 level (2-tailed).

Table 5: Pearson correlation coefficient matrix between soil physicochemical and heavy metal parameter

	pH	pHKCl	OM	C/N	P	N	Ca	Na	CEC	SBE	Clay	Silt	Sand
Cd	0.961	-0.971	0.277	-0.24	0.277	1,000**	-0.277	0.517	-0.908	-0.24	0.277	0.693	-0.655
Cr	0.866	-0.5	-0.5	-0.866	-0.5	0.866	1,000**	-0.856	-0.327	-0.866	-0.5	1,000**	-0,999*
Pb	0	0.5	-1,000**	-0.866	-1,000**	0.866	1,000**	-0.517	0.655	-0.866	-1,000**	0.5	-0.545
Hg	-0.327	0.756	-0.945	-1,000**	-0.945	0.655	0.945	-1,000*	0.866	-0.655	1,000**	0.189	-0.24

*, Correlation is significant at the 0.05 level (2-tailed). **, Correlation is significant at the 0.01 level (2-tailed).

Table 6: Pearson correlation coefficient matrix between some effluent (EFM) and contaminated soil (CSM) (physicochemical properties)

properties	pH- H ₂ O(EFM)	EC(EFM)	Turbi(EFM)	Cl ⁻ (EFM)	K ⁺ (EFM)	Na ⁺ (EFM)	Ca ²⁺ (EFM)	Mg ²⁺ (EFM)
pH- H ₂ O(CSM)	1*							
pH-KCl(CSM)	1*	1*						
P (CSM)	1*	1*	1*					
K ⁺ (CSM)	1*	1*	1*	1*				
Na ⁺ (CSM)	1*	1*	1*	1*	1*			
Ca ²⁺ (CSM)	1*	1*	1*	1*	1*	1*		
Mg ²⁺ (CSM)	1*	1*	1*	1*	1*	1*	1*	
SBE(CSM)	1*	1*	1*	1*	1*	1*	1*	1*

*, Correlation is significant at the 0.01 level (2-tailed).

Lead (Pb)

The mean total concentration of Pb in the soil samples were 2.600 and 6.365 mg/kg for USM and CSM respectively, in both seasons. Mean total concentration of Pb in the effluent was 2.025 mg/kg. In all the soil samples, the total concentration of Pb ranged from 2-7.5 mg/kg. These concentrations were below the maximum allowable limit of <100 mg/kg reported by Manikandan, (2005) and Kabata-Pendias, (2011). Pb accumulation near the soil surface mainly is due to its sorption by SOM. Studies conducted by Sipos et al. (2005) suggested that SOM plays a decisive role in the Pb adsorption, but its fixation by clay minerals is much stronger. The increase in Pb concentration in the contaminated soil was probably the result of anthropogenic activities such as Pb shots from hunting (Darling and Thomas, 2003). Similarly, the total concentration of Pb in the effluent was within the standard for irrigation water (<5 mg/kg) (Kabata-Pendias, 2011). There has been a lot of attention paid to Pb levels in soil because it is well-known to cause adverse health effects and is relatively widespread as a result of its historical use in many commercial products, from gasoline to paint. Pb adversity results from its accumulation with age in bones, aorta, kidney, liver and spleen. Pb can enter the human body through uptake of food (65%), water, (20%) and air (15%) (Ruqia et al., 2015). The present study revealed that, over time, Pb concentration in the cultivated soil contaminated by effluent could exceed the safe limit because the amount of Pb in the effluent was growing over time, due to continuous dumping of commercial waste on Mphiewen dumpsite.

Mercury (Hg)

The mean total concentration of mercury in the soil samples were 0.06 and 0.66 mg/kg for USM and CSM respectively. The total concentrations of Hg in the soils ranged from 0.01-0.79 mg/kg in both seasons. The total concentrations of Hg in all soil samples were within the allowable limit reported by Kabata-Pendias, (2011) (<5 mg/kg). The Hg content in these soils could be inherited from parent materials, degassing and thermal

activity of the earth, waste incineration, and sewage from the dumpsite. The sorption of Hg is however positively correlated to OC and CEC of the soil. The mean total concentration of Mercury in the effluent was 0.21 mg/kg, and the total concentrations of Hg in the effluent were 0.20 and 0.22 mg/kg in the dry and rainy seasons respectively. These values were lower than the concentration of Hg allowable for sewage sludge reported to range from 0.6-3.0 mg/kg, and average 1.6 mg/kg (Mukherjee et al., 2007). Despite Hg being the most abundant and toxic heavy metal pollutant in the environment, it has no known essential biological function and its emission from industrial sources is of great environmental concern (Pribil et al., 2020).

Results of Statistical Analysis

Results of Pearson correlation matrix between soil physicochemical properties, and Pearson correlation coefficient matrix between soil physicochemical and heavy metal parameter are presented in *Table 4* and *Table 5* respectively. Additionally, Pearson correlation matrix between some soils and effluent physicochemical properties is presented in *Table 6*. Soil pH showed significant positive correlation with exchangeable bases ($r = 1.000$; $p < 0.01$). Therefore, as pH increases the base saturation increases, thus the amount of exchangeable Ca, Mg, and K in the soil increases. Soil organic matter showed significant positive correlation with the soil nitrogen ($r = 0.985$; $p < 0.05$). This can be attributed to the fact that since organic matter in soils is composed of various organic compounds, including proteins, amino acids, and other N-containing molecules, as organic matter decomposes, N within the compounds is released and becomes available for plant uptake. Correlation study further showed that SOM significantly correlated positively with clay ($r = 1.000$; $p < 0.01$). Cation exchange capacity correlated positively with magnesium ($r = 1.000$; $p < 0.01$), this may be due to the fact that magnesium being a divalent cation found in the soil can adsorb and hold the negatively charged surfaces of soil particles, such as clay minerals and organic matter. The sum of bases correlated positively with magnesium ($r = 0.866$; $p < 0.05$)

indicating that Mg^{2+} contributed significantly to the CEC of the soil. Hg and Na^+ correlated negatively ($r = -0.997$; $p < 0.05$), this is possible because Hg and Na^+ ions have contrasting geochemical behaviours in the soil environment. Hg is a heavy metal that tends to adsorb strongly to organic matter and clay particles, while Na^+ is a monovalent cation that is more soluble and mobile in the soil solution. The correlation carried out between some physicochemical properties of the soil contaminated with effluent and effluent physicochemical properties were all perfect ($r = 1.000$; $p < 0.01$). This indicated that, the effluent from the dumpsite were the main contributors of the higher levels of the physicochemical properties in the cultivated soil contaminated by effluent.

CONCLUSION

This research work was aimed at determining the physicochemical properties of soils and the concentrations of selected heavy metals (Cd, Pb, Hg and Cr) from effluents collected around farms and dumpsites in Mphiewen and provide possible mitigation measures.

Results of this study showed that, soil pH ranged from 5.9 to 6.0, and effluent pH was 6.9 respectively. Soil organic matter levels in the soils were high and ranged from 5.00 to 8.92%. Total nitrogen content in all soils was low ($N < 1\%$) and ranged from 0.1 to 0.3%. C/N ratios were high (ranging from 15 to 17), indicating that the soil organic matter was inadequately mineralized. Particle size analysis showed that the soils were of soil type clay loam for cultivated soil contaminated with effluent and sandy clay for uncontaminated soil. Heavy metal analysis showed that the research area is linked to varying degrees of heavy metal contamination. The cultivated soil was contaminated by the heavy metals cadmium with total concentration of 3.7 mg/kg in the dry season, and chromium with total concentrations of 100.05 and 105.49 mg/kg in rainy and dry seasons respectively. Natural origins and anthropogenic activities such as fertilizer application and domestic waste disposal were identified as the major sources of Cr and Cd

in the cultivated soil and effluent from the dumpsite. Cd, Cr, Hg and Pb concentrations in the effluent from the dump site were higher than the maximum limit for irrigation water. The effluent was therefore of great environmental concern to man who depends solely on the soil for survival. The above results showed that there are potential health hazards associated with the consumption of crops from such soils contaminated by Cr and Cd. Although Cr and Cd remain in soil for a very long time, there are some steps that can be taken to reduce the level of risk they pose. Varieties of treatments have been applied with different effects depending upon the specific geochemical conditions of Cr and Cd-contaminated sites. Some of the remediation treatments are based on physical, chemical and biological processes such as chemical precipitation with the use of hydroxides, sulfide and chelating agents; membrane separation by the use of bulk liquid membrane with tri-n-butyl phosphate as the carrier; ion exchange with the use of ion exchange resins; electrodialysis; immobilization of Cr using materials of high sorption capacity such as smectite clays, coal, burnt charcoal and other sorbents. Pearson correlation between some physicochemical properties of the soil contaminated with effluent and effluent physicochemical properties were all perfect ($r = 1.000$; $p < 0.05$). This indicated that the effluent from the dumpsite were the main sources of contaminants in the cultivated soil contaminated by effluent. To maintain a safe environment, Tubah subdivision must also enforce the use of effluent treatment facilities and increasing awareness of soil pollution by waste among the population.

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Declaration of Competing Interests

The authors of this research article declare that there are no known conflicts of interest that could have appeared to influence the work reported in this paper. All the standards and ethics of scientific writing have been respected.

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