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Heavy metal levels and their ecological risks in surface soils at Sunyani magazine in the bono region of Ghana

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ABSTRACT

The study investigated the level of seven heavy metals, arsenic (As), chromium (Cr), copper (Cu), manganese (Mn), lead (Pb), titanium (Ti), and zinc (Zn), in surface soils at three different sampling points, namely, General overhauling (GO), Oil exchange (OE), and Spraying (SP) shop in the Sunyani magazine in the Bono region of Ghana. The ecological risks for the various metal were also measured. Generally, the metal levels were alarming as compared to the reference sample and they followed the decreasing order: Pb, Mn, Zn, Ti, Cu, Cr, As at GO shop; Mn, Pb, Cr, Ti, Zn, Cu, As, at OE shop; and Mn, Pb, Zn, Ti, Cr, Cu, As at SP shop. The contamination factor evidenced Pb as the most polluted metal and Mn as the least polluted metal in the surface soil of all sampling points in the Sunyani Magazine. The PLI results also suggested GO as the most polluted location followed by SP and then OE. I-geo values clearly confirm the heavy contamination of the surface soils with Pb, Zn, Cu, and As in all sampling locations, except at OE, where there was no contamination with arsenic. Practically, the surface soils at all sampling points were unpolluted (I-geo $<$ 0) with Cr, Mn, and Ti. The potential ecological risk index (PERI) also showed a considerable risk for surface soil at OE shop and a very high risk for GO and SP shops. Pearson product moment correlation matrix suggested a significant positive correlation ($p < 0.05$) among As, Cu, Pb and Zn, in the surface soils. Statistical analyses employed in various hazard indices such as contamination factor, pollution load, geo-accumulation, and potential ecological risks all indicate elevated levels of Pb, Zn, Cu, As, and hence contamination of the surface soil due to anthropogenic influence but background levels of Cr, Mn, and Ti, which can be attributed to geological factors.

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Introduction

The levels of naturally occurring metals in soils depend on the prevailing geogenic and anthropogenic which may vary significantly [31]. Notwithstanding, occasionally their concentrations can rise beyond background environmental soil quality guidelines without anthropogenic influences [32]. Therefore, it is imperative to understand the quantum and causes of natural variability for ecological and human health risk assessment. Although trace amounts of metals such as the first-row transition metals, i.e., iron, chromium, nickel, copper, manganese, and zinc exist as essential nutrients to humans and other biota due to their known biological functions, at elevated levels they are toxic and pose threat to human health, biological species, and the environment as a whole. The existence of metal(loid)s such as arsenic, cadmium, mercury, and lead in the various spheres of the environment are non-essential and of no benefits to biota.

For so many decades, the phrase "heavy metals" have been used by environmentalists and scientists in ecotoxicological studies. Heavy metals have been widely employed in many industrial applications such as manufacturing of batteries, alloys, electroplated metal parts, agro-chemical applications, and road constructions [28]. Heavy metals which have densities about 5 times greater than density of water [19], are non-biodegradable and are therefore monotonously contaminating the air, deposited into soil, water, as well as sediments [20]. The presence of heavy metals in the environment has aroused great concern due to their potential long-term detrimental effects on human, animal, and plant life particularly in developing countries where mitigation processes are fledgling [5]. For instance, the degeneration of spermatogenesis and semen quality in human male, particularly sperm motility and hormonal discharges has been attributed to Cd contamination [30], hypertension and other cardiovascular related illnesses in both humans and animals have been reported to be due to Pb exposure even at low levels [9], and the adverse alteration of neurological, nervous, digestive, immune, and reproductive systems in humans and wildlife has been linked to Hg pollution [14].

Human exposure to heavy metal toxicants in surface soils usually occurs through suspended dust inhalation, oral ingestion, and dermal contact [12]. Surface soils instead of other soil horizons usually record higher levels of heavy metals as a result of human activities such as burning of fossil fuels, disposal of electrical and electronic equipment, paints, pesticides, incineration of domestic wastes, spills of motor oils, automobile exhaust, atmospheric depositions from industrial activities, and increased organic matter [6,27]. Elevated levels of the toxic metals defy goal 1 and 3 of the Africa Union's Agenda 2063 [13]. That is, they represent a momentous threat to quality of life and well-being for all citizens, as well as impede living resources and ecological systems because of their increased discharge, poisonous nature, and other adverse effects on the environment.

'Magazine' is a popular term used to refer to areas where auto mechanic shops are located in Ghana. Activities carried out in such areas are but not limited to charging batteries, welding and soldering, automobile body works, as well as spraying. These activities are carried out by the use of highly poisonous and hazardous materials such as those found in solvents, paints and primers [34]. Wastes generated at the magazine and its environs include spent lubricants, worn out parts, metal scraps, and stripped oily sludge packaging materials (Adebayo et al. 2015).

Several researches have reported elevated levels of heavy metals in soils at areas where human activities are predominant. However, little is said about the ecological risks and other implications of these heavy metals to biota. Therefore, not only are the total metal levels of anthropogenic and natural source metals in surface soil of the magazine relevant, but also the ecological risk of anthropogenic versus natural forms of these metals to humans. This is because, the afore mentioned activities of the magazine operators can lead to accumulation of the toxic metals which can pose a great hazard to both residents and workers should they come into contact with them. Consequently, this investigation aimed at assessing the level of heavy metal toxicants in the Sunyani magazine at three selected areas where their activities is predominant, estimate the extent of contamination at the surface soil using pollution indices, as well as the ecological risks posed by the heavy metals. Although the soil samples were analyzed for 33 elements including Cd and Hg, this paper focuses on seven selected toxic metals, arsenic, chromium, copper, manganese, lead, titanium, and zinc. cadmium and mercury were not included because their concentration values were basically below detection limits.

Methods

Study area

Sunyani is a fast-developing city and the capital of the Bono region of Ghana. It lies between latitude 7.34º and longitude -2.33º. The Sunyani auto mechanic workshop commonly referred to as Sunyani magazine is located directly opposite the Sunyani Technical University (STU) along the Sunyani – Abesim stretch. The magazine is about 9 kilometers from the main Sunyani township. Fig. 1 shows the sampling points at the Sunyani magazine for this current studies.

Soil sampling and preparation

Samples were collected during the dry season in March, 2020 at a depth of 0-15 cm from three different sampling locations at the study area, namely; General Overhauling (GO), Spraying Shop (SP), and Oil Exchange (OE). It is reported that, the surface soil layer which may have direct correlation with oral ingestion or re-suspension is practically shallower than 15 cm [22], it was however anticipated that the degree of mixing in the magazine soils is very high. For each sampling

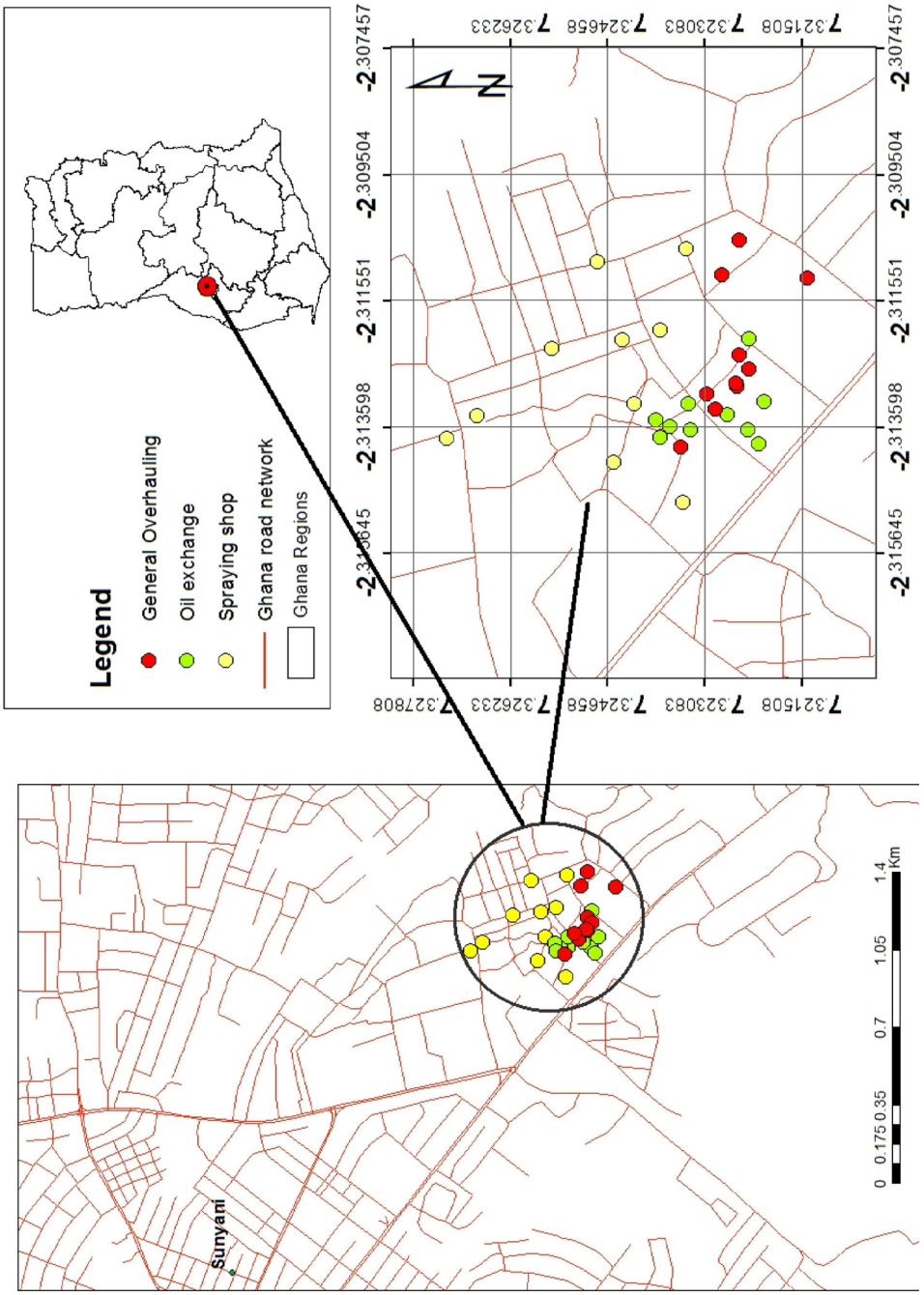


Fig. 1. Soil sampling locations.

location, ten different shops were considered and at each shop, two soil samples at a distance of about 10 m to 15 m apart were collected using a stratified random sampling approach. In total, 60 soil samples were collected (including replicates) with the aid of a cleaned soil auger and placed into a well-labelled zip lock bag. Reference samples were taken from the University of Energy and Natural Resources (UENR) botanical gardens due to its less susceptibility to human activities. All the collected soil samples were transported to the laboratory, air-dried and homogenized. Prior to laboratory analysis, large pebbles were removed from the dried samples, and clumps of dried materials were carefully disaggregated using a clean mortar and pestle. The samples were then sieved through a 2 mm mesh sieve. The collected sieved samples were placed in ziploc bags.

Soil characterization

Soil pH and EC for samples were determined using pH/Conductivity meter 901 (BANTE INSTRUMENTS) at a soil: solution ratio of 1:5 (w/v) in a Digi-tube. The supernatant was shaken for 1 hour using a mechanical shaker (DRAGONLAB SK-0330-PRO). pH and EC values were recorded after the mixture was allowed to stand for 30 minutes. Total metal concentrations in soils were measured following protocol outlined in USEPA 3050B aqua regia alternative (USEPA, 1996). In short, 10.0 g of soil sample was digested in a beaker with 25 ml conc HNO_3 and 100 ml conc HCl. The mixture was then analyzed for heavy metal level by use of ICP-MS (Nexion 2000).

Data treatment and statistical analyses

Data obtained for this study were tabulated using Microsoft Excel whereas statistical analyses (minimum, maximum, mean and standard deviation) were performed by the use of Minitab® 17. Potential ecological risk indices were calculated manually by the use of a scientific calculator. To ascertain the inter-relationship between metal levels and pH, Spearman's rank correlation analysis was employed.

Soil pollution indices

The degree of heavy metal contamination can be evaluated by either comparing site-specific data to background reference data, or through the use of pollution indices [7,29]. In this present work, level of contamination was measured using contamination factor (CF), pollution load index (PLI), and geoaccumulation index (I-geo).

Contamination factor (CF) is the ratio of the metal concentration in the soil sample to that of the baseline or background concentration [15]. It was employed to assess the extent of metal contamination. The CF values were tabulated using Eq. (1).

$$CF = \frac{M_c}{M_r} \tag{1}$$

where M_c and M_r are mean concentrations of metal toxicants in soil samples and background reference sample respectively [25]. Reference samples were taken from the University of Energy and Natural Resources (UENR) botanical gardens due to its less susceptibility to human activities.

Pollution load index (PLI) estimates the overall pollution status of the sample at a particular sampling location. PLI values were tabulated using Eq. (2).

$$PLI = n\sqrt{CF1.CF2.CF3 \ldots\ldots\ldots\ldots CFnth} \tag{2}$$

where, **n** is the number of metals (six in this present study).

Geoaccumulation index (I-geo) which is a quantitative measure of the magnitude of contamination by each metal, was first defined by Muller [24]. In this study, I-geo was used to quantify the degree of anthropogenicity and calculated for each metal using Eq. (3).

$$Igeo = log_2\left[\frac{M_c}{1.5\ x\ Bn}\right] \tag{3}$$

where *Mc* denotes the mean concentration of the metals and *Bn*, the geochemical baseline values of the metals. The constant value 1.5 accounts for lithogenic effects in the content of a given substance in the environment as well as very small anthropogenic inputs [8].

Potential ecological risk

The potential ecological risk coefficient (E_rf) or risk indices (RI) was measured to ascertain the ecological risk each heavy metal in the lithosphere poses. Eq. (4) was used for the calculation [15].

$$E_rf = \ T_rf\ x\ CF = \frac{T_rf\ x\ M_c}{M_r} \tag{4}$$

where T_rf is the toxic response factor of each studied heavy metal, indicating the level of toxicity and sensitivity of biota to it; CF, Mc, and Mr are explained in Eq. (1). The toxic response factor (T_rf) for the studied metals are as follows: As = 10, Cr = 2, Cu = Mn = Pb = 5, and Zn = 1. Ti was not included because its T_rf is not known. The degree of ecological risk is categorized as: low risk (E_rf < 40), moderate risk (E_rf = 40-80), considerable risk (E_rf = 80-160), high risk (E_rf = 160-320), very high risk ($E_rf \geq 320$).

Potential ecological risk index (PERI) which is the sum of the individual risk indices (RI), was employed to assess the extent of heavy metal pollution in soils with respect to the contamination factor (CF) of heavy metals and the environment's response to the pollutant (T_rf). Eq. (5) was used for the calculation.

$$\text{PERI} = \sum_{i}^{n} (E_rf) \tag{5}$$

where n represents the number of studied heavy metals (six in this study) in the sample. The categorization according to Hakanson [15] were modified as follows: low risk (PERI < 150), moderate risk (PERI = 150-300), considerable risk (PERI = 300-600), high risk (PERI = 600-1000), very high risk (PERI > 1000).

Results and discussion

For the purposes of comparison, the data obtained from this study have been compared to values from the Canadian soil quality guidelines [11], Clarke values [23], as well as values from the control site. The data are presented in Tables 1 to 4.

pH and EC

According to Smith [35], soil pH has adverse effects on both the solubility and the retention of heavy metals in the lithosphere. Greater retention and lower solubility of a metal occur at elevated soil pH. For instance, Cr (VI) adsorption decreases with increasing pH whiles Cr (III) adsorption increases with increasing pH. The soil pH at the Sunyani magazine ranged from 6.52 to 7.77 with a mean of 7.32 at GO; 6.63 to 7.35 with a mean of 6.87 at OE; and 7.28 – 8.43 with a mean of 7.68 at SP. Quantitatively, approximately 45% of the soil samples recorded pH < 7 indicating acidic soils. The average electrical conductivities of the soil ranged from (262.9, 146.4, 199.8) µS/cm at GO, OE and SP respectively which probably indicates high levels of inorganic ions including metals in the soils. Soil pH and EC values are summarized in Table 1.

Heavy metal levels

The levels of the seven studied heavy metals in the surface soil of magazine at the three different sampling points, descriptive statistics, Canadian soil quality guidelines are summarized in Table 1. Lead content ranged from 1.77 – 28.24 mg kg^{-1}, 0.54 – 28.88 mg kg^{-1}, and 11.70 – 501.10 mg kg^{-1} at OE, SP, and GO respectively. Mean values of Pb at each sampling point was significantly higher than the value recorded for the control sample but lower than CCME reference value. This suggests anthropogenic inputs negatively affecting the surface soil such as the indiscriminate and improper disposal of lead batteries [34] which eventually enter into the soil. Mean value of Pb (109.30 mg kg^{-1}) recorded at GO is exceedingly greater than the Clarke reference value (17 mg kg^{-1}), and is the highest among the three sampling points. This probably may be due to the auto-electrical and auto-mechanical operations such as welding and soldering carried out at that particular location. Similar study carried out by Nna Orji and his team [26] in Gwagwalada, Nigeria, revealed high levels of Pb at oil exchange points. Relatively high levels of Pb at OE is an indication of Pb containing oil spillage affecting the soil. Most auto paints, particularly of older vehicles contain appreciable amounts of lead. Artisans at spraying shops rub off already existing paint with abrasive paper before new paints are sprayed on vehicles. This activity introduces Pb into the soil, thus polluting it. This may explain the high mean Pb level at spraying shops than seen in the control sample.

Cu mean levels recorded were 2.46 mg kg^{-1}, 4.03 mg kg^{-1}, and 6.33 mg kg^{-1} at OE, SP, and GO respectively. These levels exceeded the value recorded at the control sample (0.83 mg kg^{-1}) but are far lower than Clarke reference value (25 mg kg^{-1}) as well as the Canadian soil guidelines value (63 mg kg^{-1}). These values are also lower than the mean value obtained by Akoto and his team (9.67 mg kg^{-1}) who investigated the levels of heavy metals at railway servicing workshops in the Kumasi Metropolis of Ghana [4]. The relatively high levels of Cu observed at GO may be as a result of connecting wires and other copper containing rusted metals which are left exposed to the surface soil. At GO shops, activities such as engine repair, car straightening, and welding are carried out. Copper can be found in vehicular engines [2] and some vehicle alloys contain copper [10].

Zinc content ranged from 0.55 – 18.09 mg kg^{-1}, 1.00 – 9.62 mg kg^{-1}, 8.48 – 15.69 mg kg^{-1} at SP, OE, and GO respectively with the highest mean concentration recorded at GO (11.90 mg kg^{-1}). The values were generally higher than the control sample but lower than the two international standards used in this study, CCME (200 mg kg^{-1}) and Clarke values (71 mg kg^{-1}). Zinc though an essential nutrient, at elevated levels is toxic to biota. Zinc levels in the lithosphere are basically associated with zinc sulfide ores, Fe-Mn oxides as well as mafic minerals such as hornblends and biotite, and precious metal deposits [17]. The primary source of zinc into the surface soil at magazine could be from mechanical abrasion of vehicles, Zn addictive lubrication and motor oils, vehicle emissions, as well as scraps from auto parts [37].

Table 1
Descriptive statistics of heavy metal levels (mg kg^{-1}) at each sampling location and their physicochemical parameters.

Metals	Study Area												P-Value	Reference Standard [11]	Clarke values [23]	Control Sample Mean
	General Overhauling (GO) Shop				Oil Exchange (OE) Shop				Spraying (SP) Shop							
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD				
As	0.04	0.17	0.11**a**	0.05	0.01	0.05	0.02**a**	0.02	-0.03	0.98	0.21**a**	0.39	0.38	12	1.5	0.02
Cr	3.99	8.21	6.33**a**	1.49	6.04	13.85	9.35**a**	2.65	2.10	5.95	4.63**b**	1.43	0.003	64	60	6.82
Cu	1.73	26.62	6.87**a**	9.70	0.78	7.26	2.46**a**	2.39	0.48	12.30	4.03**a**	4.46	0.49	63	25	0.83
Mn	12.35	23.69	18.07**a**	4.85	5.80	24.29	13.28**a**	6.60	13.52	27.47	18.81**a**	5.25	0.21	-	600	34.03
Pb	11.70	501.10	109.30**a**	193.90	1.77	28.24	9.43**a**	11.06	0.54	28.88	13.71**a**	11.81	0.25	140	17	1.15
Ti	6.51	14.39	10.03**a**	2.94	3.98	13.34	7.35**a**	3.54	2.98	9.44	6.30**a**	2.22	0.11	-	3120	8.02
Zn	8.48	15.69	11.90**a**	2.90	1.00	9.62	4.65**a,b**	3.24	0.55	18.09	9.64**a**	7.10	0.05	200	71	1.64
pH	6.52	7.77	7.32**a,b**	0.45	6.63	7.35	6.87**b**	0.26	7.28	8.43	7.68**a**	0.48	0.013			8.13
EC (µS/cm)	98.3	723.0	262.9**a**	236.3	77.8	217.1	146.4**a**	61.0	60.1	350.0	199.8**a**	97.3	0.432			142.1

Note: Mean values with similar letter(s) within a column are not significantly different at $\alpha = 5\%$ (0.05) by Fisher's LSD multiple comparison tests.

Table 2
Mean Contamination Factor (CF) of metals in Sunyani Magazine and PLI values for the different sampling locations.

Sample Location	Contamination factor of metals							**PLI**
	As	Cr	Cu	Mn	Pb	Ti	Zn	
General Overhauling (GO) Shop	5.28	0.93	8.28	0.53	95.04	1.25	7.26	**4.07**
Oil Exchange (OE) Shop	1.02	1.37	2.96	0.39	8.20	0.92	2.84	**1.66**
Spraying (SP) Shop	10.45	0.68	4.86	0.55	11.92	0.79	5.88	**2.68**

Interpretation to CF and PLI values as indicated by Asare et al., [8]. Low contamination (CF < 1), moderate contamination (CF = 1-3), considerable contamination (CF = 3-6), Very high contamination (CF > 6). PLI < 1 denote perfection; PLI = 1 indicates only baseline levels of pollutants are present and PLI > 1 shows deterioration of site quality.

Table 3
Geo-accumulation index (Igeo) of heavy metals in the Sunyani Magazine.

Sample Location	I-geo values of metals						
	As	Cr	Cu	Mn	Pb	Ti	Zn
General Overhauling (GO) Shop	1.87	-0.69	2.46	-1.49	5.99	-0.26	2.27
Oil Exchange (OE) Shop	-0.58	-0.13	0.98	-1.94	2.45	-0.71	0.92
Spraying (SP) Shop	2.81	-1.23	1.69	-1.44	2.99	-0.93	1.97

The distribution of Cr at the various sampling locations differed significantly ($p = 0.003$). Cr is a metal with low mobility, particularly at moderate oxidizing and reducing conditions at around near to neutral pH values. Cr at +6 oxidation state is hazardous to biological systems [18]. Cr concentration for the control sample (6.82 mg kg^{-1}) is higher than obtained mean Cr value at GO (6.33 mg kg^{-1}) and SP (4.63) but lower than OE (9.35 mg kg^{-1}). All these values are about 7 to 10 times lower than the international reference standards. This indicates natural or baseline levels of chromium in the magazine surface soil and no anthropogenic influence. The contamination of soils with Cr elsewhere, have been linked to industrial activities such as anodizing, dyes and pigments, metal plating, tanning, glues, wood preservations, and textiles (Alloway, 1995).

Arsenic, manganese and titanium had concentrations lower than international reference standards as observed in Table 1. Arsenic for instance, though very toxic are usually very low even in their geogenic background. The Canadian SQGs value of 12 ppm for As is about 60 times higher than the highest mean value recorded for As (at SP shop, 0.21 ppm). Manganese levels at the various sampling points also shows twice lesser values as compared to the control sample. There is no reference value for titanium in the Canadian SQGs but comparing the mean values recorded at various sampling locations to the Clarke value indicates extremely low levels of Ti. This reveals that artisan activities at the Sunyani Magazine does not anthropogenically introduce As, Mn and Ti into the surface soil but may exist naturally in the soil.

Quantification of surface soil pollution

In order to quantify the extent of contamination of soils at Sunyani Magazine, contamination factor (CF), pollution load index (PLI), and geoaccumulation index (I-geo) were employed (Tables 2 and 3). CF revealed moderate to very high contamination of arsenic at all sampling location. Yidana [37] reported a CF value of 4.19 for As in a work carried out at auto mechanic shops in Accra. This value is lesser than observed at GO and SP shops but higher than OE shop. CF values of Cu indicates very high contamination at GO, considerable contamination at SP, and moderate contamination at OE shop. Report form Akoto et al., [4] showed a mean value of 7.21 for Cu in surface soil at Kumasi which is lower than GO but greater than OE and SP shops in this present study. Values of Pb in all sampling locations shows very high contamination of lead in the surface soil of Sunyani Magazine with GO recording 95.04. These values are much higher than 3.08 reported by the study at auto mechanic shops at Okitipupa, Ondo state, Nigeria [3]. This clearly confirms artisan activities such as haphazard and improper disposal of Pb containing batteries and other Pb materials at the magazine is elevating Pb levels in the surface soils. Zn also showed moderate contamination at OE, considerable contamination at SP and very high contamination at GO shop. Mn on the other hand, revealed low contamination in all sampling location with Ti showing low contamination at both SP and OE shops but moderate contamination at GO. PLI values confirms pollution at all sampling points with surface soils at GO as most polluted.

Geo-accumulation index (I-geo)

The data for geo-accumulation index as shown in Table 3 indicates moderate pollution, moderate to strong pollution, and extreme pollution of arsenic, zinc and lead respectively, at the surface soils located at GO shops in the magazine. Surface soils at OE shops were practically unpolluted with all the metal except Pb and Cu. At SP shops, the soils were moderately to strongly polluted with arsenic and lead, moderately polluted with Cu, and practically unpolluted with Cr, Mn, and Ti.

Table 4
Risk indices and Potential ecological risk index at different sampling location in the Sunyani magazine.

Sample Location	Risk indices of individual metals							PERI
	As	Cr	Cu	Mn	Pb	Ti	Zn	
General Overhauling (GO) Shop	52.80 **(M.R)**	1.86 **(L.R)**	41.40 **(M.R)**	2.65 **(L.R)**	475.20 **(V.H.R)**	-	7.26 **(L.R)**	3487.02 **(V.H.R)**
Oil Exchange (OE) Shop	10.20 **(L.R)**	2.74 **(L.R)**	14.80 **(L.R)**	1.95 **(L.R)**	41.0 **(M.R)**	-	2.84 **(L.R)**	441.18 **(C.R)**
Spraying (SP) Shop	104.50 **(C.R)**	1.36 **(L.R)**	24.30 **(L.R)**	2.75 **(L.R)**	59.60 **(M.R)**	-	5.88 **(L.R)**	1190.34 **(V.H.R)**

L.R = low risk, M.R = moderate risk, C.R = considerable risk, V.H.R = very high risk.

Table 5
Pearson product moment correlation matrix for the parameters measured.

	As	Cr	Cu	Mn	Pb	Ti	Zn	pH	Ec
As	1								
Cr	-0.491	1							
Cu	0.17	-0.076	1						
Mn	0.45	-0.45	0.51	1					
Pb	**0.628***	-0.262	**0.711****	0.394	1				
Ti	-0.051	0.538	0.112	0.096	-0.022	1			
Zn	**0.569***	-0.311	0.469	0.487	**0.611***	0.295	1		
pH	0.27	**-0.604***	-0.164	0.142	0.021	-0.138	0.179	1	
Ec	0.241	-0.229	-0.106	0.009	0.074	-0.187	-0.245	0.267	1

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

Classification [8]: practically unpolluted (Igeo $\leq$ 0), unpolluted to moderately polluted (Igeo = 0-1), moderately polluted (Igeo = 1-2), moderately to strongly polluted (Igeo = 2-3), strongly polluted (Igeo = 3-4), strongly to extremely polluted (Igeo = 4-5), extremely polluted (Igeo $\geq$ 5).

Ecological risk assessment

The data for the ecological risk assessment is summarized in Table 4. Interpretations to values are explained above under section 3.5. Cr, Cu, Mn, and Zn showed low ecological risks at all sampling points revealing lithogenic contributions of heavy metals to surface soils [36]. Lead on the other hand was found to exhibit moderate ecological risk at OE and SP shops but very high risk at GO shops. It has been reported in many studies [1,16,21,33] that children are more exposed and susceptible to lead poisoning ingesting about 30% of 100 mg of soil per day. This means that children must be restricted in and out of the Sunyani magazine. The toxic arsenic metal also showed moderate risk and considerable risk at GO and SP shops respectively but low risk at OE shop. PERI results clearly indicate considerable risk at OE shops and very high risks at both GO and SP shops, with GO recording the highest and this can be attributed to anthropogenic inputs. This implies that workers in the Sunyani magazine can easily bioaccess toxic metals if they do not work under safe conditions.

Correlation analysis

Correlation analyses have been widely used in the study of the environment. It is an effective tool applied to understand the relationships between multiple variables. In this study, the inter-elemental association was assessed by Pearson product moment correlation matrix (2-tailed) to evaluate possible common sources of the heavy metals. Table 5 shows high and significant positive correlation among some of the metals. The observed highest correlation ($p < 0.01$) was found between Cu and Pb ($r = 0.711$). Also, high and significant correlations ($p < 0.05$) were observed for As and Pb ($r = 0.628$); Pb and Zn ($r = 0.611$); As and Zn ($r = 0.569$); Cr and pH (-0.604). The strong positive correlation among Cu, Pb, As, and Zn suggest the likelihood of the metals being released from similar origin.

Conclusion

This study has demonstrated that surface soils among the various sampling points in the Sunyani magazine is densely polluted with heavy metals. Impacts of these metal toxicants has further been investigated by aid of the Canadian soil quality guidelines, Clarke reference values, pollution indices, and risk indices. The data obtained from the present study clearly indicates that anthropogenic inputs at the Sunyani magazine are elevating heavy metal levels, particularly lead, zinc, copper, and arsenic, causing detrimental effect to the surface soil. Lead contributed the most to the overall risk, specifically at GO shops: lead is a very common environmental hazard that can negatively affect the cardiovascular, reproductive, and digestive systems in humans and animals. The extend of the pollution by the heavy metals has been confirmed with the hazard indices employed in this research. Consequently, the heavy metals can be bioavailable and bioaccessible to humans in and around the magazine through ingestion, vapor inhalation and/or skin contact. Workers especially could be receptors to

these metal pollutants. It is therefore expedient regulatory bodies ensure administration and implementation of regulations to keep these workers and inhabitants around safe and healthy.

Declaration of Competing Interest

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