Journal of Materials and Environmental Science
ISSN : 2028-2508
e-ISSN : 2737-890X
CODEN : JMESCN

J. Mater. Environ. Sci., 2023, Volume 14, Issue 12, Page 1517-1528

http://www.jmaterenvironsci.com

Impact Assessment of some Toxic Phenols and Heavy Metals in Farmlands' Soils of Obio-Akpor LGA, Rivers State, Nigeria

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Received *09 Nov2023,*
Revised *10 Dev 2023,*
Accepted *12 Dev 2023*

Keywords:
- *Contamination/pollution index;*
- *Obio-Akpor;*
- *Risk quotient;*
- *Anthropogenic;*
- *Toxic phenols;*
- *Heavy metals*

Citation*: Chokor A. A. (2023) Impact assessment of some toxic phenols and heavy metals in farmlands' soils of Obio-Akpor LGA, Rivers State, Nigeria, J. Mater. Environ. Sci., 14(12), 1517-1528*

Abstract: This paper presents the results of potential ecological and human health risks of some toxic phenols and heavy metals in farmlands' soils of some communities in Obio-Akpor LGA of Rivers State, Nigeria. Composite soils samples were taken from five communities in the LGA at depth 0 – 20cm and investigated for some toxic phenols and heavy metals using standard methods. The concentrations of phenols in mg/Kg ranged from 0.002 – 0.018 for 4-C-3-MP; 0.282 – 3.172 for 2-CP; 0.537 – 0.971 for 2,4-DCP; 0.104 – 1.107 for 2-MP; 0.435 – 1.643 for 4-MP; 0.259 – 0.899 for 2-NP; 0.240 -0.258 for P; and 0.017 – 0.052 for 2,4,6-TCP. The total concentrations of the eight determined phenol ($\sum_8$Phenols) ranged from 1.897 – 5.956mg/Kg in the farmlands' soils. There were wide variations in the concentrations of metals in the different farmlands' soils. However, the average values for Cr, Cu, Zn, and Ni were: 9.79±2.08; 9.54±10.36; 38.92±24.14; and 2.46±1.22mg/Kg respectively. Lead (Pb) and Cd had average values of 9.76±11.38 and 2.64±0.70mg/Kg respectively. The total metals contents in mg/Kg for the six determined metals ($\sum_6$Metals) in different communities were: Choba (36.92 ± 2.43), Rumuogholu (148.46 ± 10.84), Rumuokoro (76.37 ± 21.36), Ozuoba (68.08 ± 4.44), and Rumuosi (36.44 ± 10.32). The overall average for the six determined metals in all the communities was 73.11±93.03mg/Kg. The average risk quotient (RQ) for the individual phenols in all the communities farmlands' soils were within the range of 0.1 – 1.0; indicating medium level of risk. The total risk quotient however indicated high risk. The order of pollution based on total risk quotient was:

Rumuokoro > Rumuogholu > Choba > Rumuosi > Ozuoba

Generally, the farmlands' soils in different communities did not show evidences of pollutions with respect to the individual metals except for Cd that exhibited moderate to severe levels of pollution. Characterization based on multiple pollutions with respect to the six (6) metals however; classify the soils as slightly polluted. The order of pollution of the communities farmlands' soils based on the metals follows the same trend as that of phenols except that the position of Choba and Ozuoba were swabbed.

1. Introduction

One of the most valuable resources to mankind is the soil. This is because of the enormous services it offers. The soil supports plants growth and biogeochemical cycling of nutrients. It provides habitats for both micro and macro-organisms. It interacts with the atmosphere and hydrosphere and impacts the quality of air and water that contacts it (Chokor, 2019). The soil is a transformation compartment providing room for homeostatic inter-relationship between the biota and abiotic components (Kabata-Pendias and Saduiski, 2004; Chokor, 2019). The soil also serves as a sink or an interacting medium for nutrients as well as contaminants (such as toxic phenols and heavy metals) that impacts lives forms – humans, plants, wildlife, and other organisms (Chokor, 2019). Therefore, the pollution of soils by toxic phenols and heavy metals represents a major threat to the ecosystem (Alaqarbeh *et al.*, 2022).

Many researchers have implicated phenols to be highly toxic, exhibiting carcinogenic, teretogenic and mutagenic properties with resultant adverse effects on human health (Michalowicz and Dauda, 2007; CPCB, 2016; Zhou *et al*., 2017; Chokor and Odokwo, 2021). A more recent concern is the endocrine disrupting chemical (EDCs) nature of several environmental phenols. Phenols mimic estrogen by positioning their hydroxyl residues to bind with the estrogen receptors (ER) instead of 17β hydroxyl group of the hormones thus, disrupting the sexual hormones functions. This can result in several conditions such as feminization of the male species, development of breast and endometrial cancer, decreased libido, lower sperm count, cryptorchidism, prostates enlargement, and subsequent sterility of animals and humans. The overall effect is majorly associated with decline in wildlife and loss of biodiversity (Safe *et al.*, 2004; Delta Seta *et al.*, 2008; Pastsaul and Adewale, 2009; Chen *et al.*, 2013; Chokor and Odokwo, 2021). As a result of their toxicity, some phenols are included in the lists of priority pollutants in many countries and are required to be determined (ECC, 2001; USEPA, 2014).

Phenols have wide ranging applications in household products and industrial synthesis such as: disinfectants in household cleansers, creams, lotions, ointments and mouthwash; colouring agent (azo dyes) in dye industries; wood preservatives (particularly cresols and chlorophenols); production of herbicides and insecticides (eg.chlorophenoxycarboxylic herbicides and organophosphorous insecticides); production of phenolic resins (use in moulded articles, insulators in electrical equipment such as circuit board, household laminates, gluing and bonding building materials etc.); and in production of medicinal and industrial organic chemicals. Thus, the contaminations of soils can result from any of these wide ranges of applications. The transformation of alkylphenol polyethoxylates, present in detergents as non-ionic surfactants also produces alkylphenols (Michalowicz and Dauda, 2007; CPCB, 2016; Chokor and Odokwo, 2021). The transformations of phenolic biocides like pentachlorophenol (PCP) and some pesticides such as 2-buthyl-4,6-dinitrophenol (dinoseb) , 2.4 dichlorophenoxyacetic acid (2.4-D), 4-chloro-2- methylphenoxyacetic acid (MCPA), and 2,4,5-trichloro-phenoxyacetic acid (2,4,5-T) also generate phenols in soils. Phenols though occur naturally in soil environment as a result of the decomposition products of plants, vegetation and animal waste, their excessive presence in the environment usually results from domestic, agricultural and industrial activities (Bouknana *et al.*, 2014).

Heavy metals constitute another form pollutant that is of most concern to man in recent time (El Hammari *et al.*, 2022). Accumulated metals in soils particularly farmlands may result in loss of ecosystem and agricultural productivity, diminished food chain quality, economic loss and animals and human illness (Chokor, 2017a, b; Karim *et al.*, 2016). The major sources of anthropogenic metals pollution in soil include; mining, smelting, fossil fuel combustion, wastes disposal, and agricultural practices (He *et al.*, 2015; Chokor, 2016; Benkaddour *et al.*, 2019). Automobile workshops activities is also becoming a growing source of heavy metals pollution in most Nigerian cities due to the rising inflow of used automobiles into Nigerian market with its attendant increase in automobile repairs and workshops activities (Chokor and Ekanem, 2016; Chokor, 2017b). Unlike organic contaminants, most heavy metals are not degraded by microbial or chemical processes in the soil environment. Therefore, their total concentrations and eco-toxicological effects remain for a long time even after their introduction to the soil environment (Zhou and Haynes, 2010). The inhibitory effects of metals on rate of microbial degradation of phenols in soil environment have also been established by many authors (Amor *et al.*, 2001; Duraisamy *et al.*, 2020; Batkhuyag *et al.*, 2022). Excessive metals concentrations in soil may stunt plant growth, lower biomass and yield (Scoccianti et al., 2006; Sutapa and Bhattacharyya, 2008). Sutapa and Bhattacharyya (2008) have shown that there is a significant negative correlation of yield to concentrations of Cd, Cu, Pb, Zn. and Cr in root and shoot. Metals in soils are incorporated into food chains and results in forage and food contaminations with its ultimate impacts on man's health (Bazzi *et al.*, 2022)

The symptoms that are generally related to heavy metals' toxicity include: gastrointestinal disorders, diarrhea, stomatitis, tremor, hemoglobinuria, ataxia, paralysis, vomiting, convulsion and depression (Chokor, 2020; 2021). In particular, toxicity resulting from lead accumulation may cause decrease in hemoglobin production. Lead being a systemic toxicant, affects several body organs and systems such as: liver, kidneys, central nervous system, hematopoietic system, endocrine system and reproductive system (Ibrahim *et al*., 2006; Sharma *et al*., 2014; Singh *et al*., 2018; Chokor, 2018). Kidney dysfunction, hepatic damage, and hypertension can results from long time accumulation of cadmium in body tissues and organs (Klassen, 2001; Manahan, 2003). Zinc though essential to normal functioning of the body systems, in high doses, causes system dysfunctions with resultant impairment in growth and development (Chokor, 2020; 2021). Likewise, copper though an essential element can result in anemia, liver and kidney problems, and stomach and intestinal irritations when presence in large doses (Spee, *et al*., 2005). Contamination by chromium is of great concern because of its toxic, mutagenic, carcinogenic, and teratogenic effects (Zhitkovich, 2011; Remy *et al*, 2017). This work seeks to assess the levels of toxic phenols and heavy metals in farmland soils in Obio-Akpor LGA of Rivers State Nigeria. Their potential ecological and human health risks were also evaluated.

2. Methodology

2.1 Study area and site locations

The study was conducted on soils samples taken from farmlands soils of Obia-Akpor LGA in Rivers State Nigeria (**Fig. 1**). Five communities viz: Com-A (Choba), Com-B (Rumuogholu), Com-C (Rumuokoro), Com-D (Ozuoba), and Com-E (Rumuosi) were chosen for this research.

2.2 Sample collection

Composite soil samples were collected from the surface soils (0 – 20cm) in the five communities' farms using standard (hand) auger. At each community, soils from five (5) different farmlands were taken and aggregated to form a composite sample. Samples for metals' analysis were wrapped in polyethene bags, while those for the analysis of phenols were placed in wide-mouth amber bottles with Teflon-lined screw caps for onward transportation to laboratory for analysis.

2.3 Preparation and analysis of metals in soils samples

Samples were placed in a well-ventilated place and allowed to air-dry for a period of two weeks. Representative samples were obtained using quartering method. The dried representative soils samples were crushed in porcelain mortals and sieved through 2mm (10mesh) stainless sieve and then digested with (5:1) mixture of nitric and perchloric acid (Tessier *et al.*, 1979). After digestion, total heavy metals in soils were determined with atomic absorption spectrophotometer (model 210 VGP

Fig 1: (A) Map of Nigeria, showing Rivers State; and (B) Map of ObioAkpor LGA, indicating the sampled communities

2.4 Preparation and analysis of phenols in soils samples

Air dried soils samples were grinded smoothly, sieved through 1mm sieve and stored in amber glass bottles. 10 g of sample was extracted three times with mixture of 0.1M NaOH in methanol (75 ml) using ultrasonic bath for 30 min. The mixture was allowed to settle, and extracted layer was filtered through Whatman 41 filter paper (Khairy, 2013; Kumar et al., 2014). The filtrate was poured into a separating funnel, adjusted to pH <2 by slow addition of sulphuric acid (1:1v/v) and extracted three (3) times with 50 ml of dichloromethane for 2 min each. The combined extracts were dried over Na_2SO_4 and concentrated to 2mL by a rotary evaporator. The extract solvent was then exchange to 2-propanol, and re-concentrated to 2mL by rotary evaporation/gentle N_2 blowing. 1µL of the concentrated extract was injected into the GC/FID for phenol separation and analysis (Chokor and Odokwo, 2021). Fused silica capillary column (DB-5, 20m X 0.15mm X 0.15µm) was used for the separation. The carrier gas was helium at a flow rate of 1.5mL/min. Samples were injected in split less mode and the volume of sample injected was 1µm. The injector and detector temperature were 250°C and 300°C respectively.

The oven temperature was programmed as follows: initial column temperature was 90°C, increased to 240°C at a rate of 15°C/min. and held for 5min. The method completion time was less than 15minutes. The phenols were identified by comparing their retention time with those of corresponding standards and quantification was done by evaluating the area under the peaks (Chokor and Odokwo, 2021).

2.5. Quality control and assurance

Analytical grade reagents (BDH and Sigma) were used for metals analysis. Buck scientific standard solution was used to calibrate the atomic absorption spectrophotometer. Blank determinations were subjected to similar extraction method using same amount of reagents. Matrix spikes were analysed to determine the performance (precision and bias) of the analytical methods used and to determine whether matrix interferences exist. The analyses were carried out in triplicates and the results expressed in mean ± standard deviation from the mean. Pesticide grade solvents were used for the analysis of phenols. Mix standard solutions of phenols containing 4-chloro-3-methyl phenol (4-C-3-MP); 2-chlorophenol (2-CP); 2,4-Dichlorophenol (2,4-DCP); 2-methyl phenol (2-MP); 4-methyl phenol (4-MP); 2-Nitrophenol (2-NP); phenol (P); and 2,4,6-Trichlorophenol (2,4,6-TCP) in propan-2-ol were used to performed method validation and quality control with correlation coefficients for calibration curves all higher than 0.9573. Recovery test was performed by spiking blank samples with the mix standards. The recoveries ranges were within 93 -110% signifying the method used is suitable.

3. Results and Discussion

The concentrations of each phenol and the total for the eight (8) determined toxic phenols in sampled soils at the various communities' farmlands' soil are as shown in Table 1. Table 2 shows the statistical description of the phenol's concentrations in the sampled communities. The total concentrations for the eight determined phenols ranged from 1.897mg/Kg in Com-D to 5.956mg/Kg in Com-C with a mean and median value of 3.955 and 4.324mg/Kg. Individual phenols concentrations were of the range of 0.002 – 1.643mg/Kg. 2-CP, 4-MP, 2,4-DCP, and 2-NP were the most abundant phenols in the soils with mean values of: 1.044, 0.894, 0.781, and 0.575mg/Kg and contributing to 26.40, 22.60, 19.70, 14.50% of the total phenols respectively. The other four (4) phenols viz: 2-MP, P, 2,4,6-TCP, and 4-C-3-MP listed in decreasing order of percent abundance, constituted the remaining 17%. The observed range of concentrations of 4-methyl phenol (0.435–1.643mg/Kg) in the soils was comparatively higher than that of 2-methy phenol (0.104–1.107mg/Kg).The potential ecological risks of the phenolic compounds were calculated using the equation:

$$RQ = MEC / PNEC$$

Where; RQ is the risk quotient, MEC is the measure environmental concentrations in the soil, and PNEC is the predicted no effect concentrations. Risk quotient (RQ) less than 0.1 represent low risk; values between 0.1 – 1.0 connote medium risk level; whereas those above one (1) indicate high risk (USEPA,1986). Acute toxicity data (ECB, 2006) was used to obtained PNECsoil value for Phenol (P), PNECsoil for 4-C-3-MP; 2,4-DCP; and 2,4,6-TCP were obtained from equilibrium partitioning method using PNECaq performed by reference (ECHA, 2008; Jin et al., 2011,2012). The Canadian quality guidelines value (3.8mg/Kg) for phenols were used as PNEC values for the other phenols.

Table 1: Concentrations (mg/Kg) of toxic phenols in farmlands' soils of Obio-Akpor LGA, Rivers State

Types	Concentrations (mg/Kg)				
	Com-A	Com -B	Com-C	Com-D	Com-E
4-C-3-MP	0.013	0.009	0.003	0.018	0.002
2-CP	0.600	0.872	3.172	0.282	0.295
2,4-DCP	0.971	0.913	0.935	0.537	0.547
2-MP	0.723	0.394	0.166	0.104	1.107
4-MP	1.643	0.960	0.870	0.560	0.435
2-NP	0.880	0.899	0.524	0.312	0.259
P	0.024	0.223	0.258	0.067	0.043
2,4,6-TCP	0.033	0.052	0.029	0.017	0.021
Total	4.887	4.324	5.956	1.897	2.709

*4-C-3-MP = 4-chloro-3-methyl phenol; 2-CP = 2-chlorophenol ; 2,4-DCP = 2,4-Dichlorophenol ; 2-MP = 2-methyl phenol ; 4-MP = 4-methyl phenol; 2-NP = 2-Nitrophenol ; P = phenol ; and 2,4,6-TCP = 2,4,6-Trichlorophenol.

Table 2: Statistical descriptions of toxic phenols concentrations in farmlands' soils of Obio-Akpor LGA, Rivers State

Types	Range(mg/Kg)	Median(mg/Kg)	Mean(mg/Kg)	SD(mg/Kg)	%Contribution
4-C-3-MP	0.002 – 0.018	0.009	0.009	0.006	0.20
2-CP	0.282 – 3.172	0.600	1.044	1.214	26.4
2,4-DCP	0.537 – 0.971	0.913	0.781	0.219	19.7
2-MP	0.104 – 1.107	0.394	0.499	0.418	12.6
4-MP	0.435 – 1.643	0.870	0.894	0.471	22.6
2-NP	0.259 – 0.899	0.524	0.575	0.304	14.5
P	0.024 – 0.258	0.067	0.123	0.109	3.10
2,4,6-TCP	0.017 – 0.052	0.029	0.030	0.014	0.80
Total	1.897 – 5.956	4.324	3.955	1.643	100

*4-C-3-MP = 4-chloro-3-methyl phenol; 2-CP = 2-chlorophenol ; 2,4-DCP = 2,4-Dichlorophenol ; 2-MP = 2-methyl phenol ; 4-MP = 4-methyl phenol; 2-NP = 2-Nitrophenol ; P = phenol ; and 2,4,6-TCP = 2,4,6-Trichlorophenol

Table 3 gives risk quotient for the phenols in the different communities. The phenol that constitute the highest risk was 2,4-DCP whose RQ values in all stations were above one (1) indicating high risk with respect to this compound. The high risk factor of 2,4-DCP may not be unconnected to the use of 2,4-Dichlorophenoxyacetic acid (2,4-D) herbicide in these farms. The phenolic compound with RQ next to 2,4-DCP was phenol (P) whose values were above one in two communities (Rumuogholu & Rumuokoro); and between 0.1 – 1.0 in the other communities. This connotes medium to high risk with respect to phenol. The phenol that constituted the least risk was 4-C-3-MP which was in all communities less than 0.1. 4-metyl phenol (4-MP) was between 0.1 – 1.0 in all communities; same was true for 2-MP except in com-C (Rumuokoro). These indicate a medium level of risk with respect to these compounds. The average RQs for the phenols in all communities were within the range of 0.1 – 1.0 (medium level of risk) except for 4-C-3-MP; 2,4,6-TCP; and 2,4-DCP. The mean RQ for 4-C-3-MP and 2,4,6-TCP were 0.001 and 0.012 respectively indicating low level of risk; while that for 2,4-DCP was 2.692 connoting high risk. The total Risk Quotient (RQ) values for the eight phenols in the sampled communities (**Table 3**) showed that there were high risks, as values of RQ were all higher than one (1). Based on total risk quotient, the order pollution with respect to the eight (8) phenols was: Rumuokoro > Rumuogholu > Choba > Rumuosi > Ozuoba.

Table 4 shows the concentrations of individual metals as well as the sum total for the six determined metals. Zn had the highest concentration in the soils, while the least was Ni. The sum of the six determined metals (∑6Metals) was highest in Rumuogholu (148.46±10.84mg/Kg) while the least was at Rumuosi (36.44±10.32mg/Kg). The average sum total for all the area was 73.11±93.03mg/Kg. Cr in the soils ranged from 6.73 – 11.88mg/Kg with a mean of 9.79±2.08mg/Kg. These values are well below the chromium critical limits in soil for several countries (**Table 5**)

Table 3: The Risk Quotient values of eight phenols in the different communities

Types	PNEC (mg/Kg)	RQ					
		Com-A	Com-B	Com-C	Com-D	Com-E	Ave.
4-C-3-MP	6.40	0.002	0.001	0.0004	0.003	0.0002	0.001
2-CP	3.80	0.158*	0.230*	0.8348*	0.074	0.0777	0.275*
2,4-DCP	0.29	3.349**	3.150**	3.2247**	1.850**	1.8857**	2.692**
2-MP	3.80	0.190*	0.103*	0.0436	0.027	0.2914*	0.131*
4-MP	3.80	0.432*	0.253*	0.2289*	0.147*	0.1145*	0.235*
2-NP	3.80	0.231*	0.237*	0.1378*	0.082	0.0683	0.151*
P	0.14	0.173*	1.595**	1.8405**	0.481*	0.3090*	0.880*
2,4,6-TCP	2.46	0.013	0.021	0.0120	0.007	0.0084	0.012
Total		4.549**	5.590**	6.3227**	2.672**	2.7552**	4.378**

**high risk; *medium risk; low risk; Ave. = average

Table 4: concentrations (mg/Kg) of heavy metals in farmlands' soils of the different Communities

Com.	Concentrations (mg/Kg)						
	Cr	Cu	Zn	Ni	Pb	Cd	∑6Metals
A	9.05	0.93	23.45	1.22	1.20	1.07	36.92
	±0.15	±0.13	±0.23	±0.13	±0.05	±0.23	±2.43
B	11.51	15.02	86.75	4.21	28.46	2.51	148.46
	±1.54	±0.36	0.35	±0.27	±0.74	±0.11	±10.84
C	6.73	24.85	24.13	4.47	12.32	3.87	76.37
	±0.71	±3.3	±0.91	±0.39	±0.55	±0.06	±21.36
D	9.78	6.38	41.71	2.51	5.37	2.33	68.08
	±0.08	±0.08	±0.50	±0.37	±0.34	±0.18	±4.44
E	11.88	0.54	18.56	1.89	1.45	2.12	36.44
	±0.98	±0.11	±1.19	±0.31	±0.69	±0.04	±10.32
Average	9.79	9.54	38.92	2.46	9.76	2.64	73.11
	±2.08	±10.36	±28.14	±1.22	±11.38	±0.70	±93.03

*A = Choba; B = Rumuogholu; C = Rumuokoro; D = Uzuoba; E = Rumuosi

Table 5: Critical limits of metals in soil for several countries

Countries	Critical limits (mg/Kg)					
	Cr	Cu	Zn	Ni	Pb	Cd
Canada	20	30	50	20	25	0.5
Denmark	50	30	100	10	40	0.3
Finland	80	32	90	40	38	0.3
Czech Republic	130	70	150	60	70	0.4
Netherland	100	36	140	35	85	0.8
Switzerland	75	50	200	50	50	0.8
Ireland	100	50	150	30	50	1.0
Eastern Europe	90	55	100	85	32	0.2

Sources: De Vries and Bakker, 1998 *(Eastern Europe includes Russia, Ukraine, Moldova and Belarus)

The concentration of Cu in farmland soils was highest for Rumuokoro (24.85mg/Kg) and least at Rumuosi (0.54mg/Kg). The values for the other areas were: Choba (0.93mg/Kg), Rumuogholu (15.02mg/Kg), and Ozuoba (6.38mg/Kg). These values were all lower than the critical limits of Cu for several countries. However, the large variation in concentrations of Cu in the various soils is an indication of anthropogenic influences. The range of Zn concentrations in the different communities was from 18.56 – 86.75mg/Kg. The mean value was 38.92mg/Kg. The highest value recorded which was at Com-B (Rumuogholu) (86.75mg/Kg) was typically higher than the 50mg/Kg critical limit recommended in Canada, but lower than those proposed by other countries (**Table 5**). Again, the large variations in concentrations levels for the different areas having essentially the same geology can only be ascribed to anthropogenic enrichment. Nickel (Ni) in the farmland soils was highest at Rumuokoro (4.47mg/Kg); the lowest value (1.27mg/Kg) was at Choba. The values in other areas were: Rumuogholu (4.21mg/Kg), Ozuoba (2.51 mg/Kg), and Rumuosi (1.89 mg/Kg). The values for all the areas were much lower than the critical soil limits for several countries. This indicates that contaminations by Ni in the soils are of less significance. The levels of Pb concentrations ranged from 1.20mg/Kg in Choba to 28.46mg/Kg in Rumuogholu. Rumuokoro had values of 12.32mg/Kg; while Ozuoba and Rumuosi had values of 5.37 and 1.45mg/Kg respectively. De Vries and Bakker (1998) reported the critical total Pb content (mg/Kg) for several countries to be 25 in Canada, 40 in Denmark, 38 in Finland, 70 in Czech Republic, 85 in Netherland, 50 in both Switzerland and Ireland, and 32 in eastern Europe. The values obtained in this study (except for Rumuogholu (28.46mg/Kg) that was higher than the Canadian critical limit) were significantly lower than the critical limits for several countries. The large variations in concentrations of the various communities however point to anthropogenic contaminations of Pb. The total element concentrations of Cd were: Choba (1.07mg/Kg), Rumuogholu (2.51 mg/Kg), Rumuokoro (3.88 mg/Kg), Ozuoba (2.33 mg/Kg), and Rumuosi (2.12 mg/Kg). The average value for the areas was 2.64±0.70mg/Kg. The obtained data in the studied soils indicated total Cd to be higher than the set critical limits of: 0.3 mg/Kg in both Finland and Denmark; 0.5 mg/Kg in Canada; 0.4 mg/Kg in Czech Republic; 0.8 mg/Kg in both Switzerland and Netherland; 0.1 mg/Kg in Ireland and 0.2 mg/Kg in Eastern Europe. The presence of cadmium as an impurity in phosphate fertilizers applied to these farms might have contributed to increased concentrations in these soils.

To appraise the human risks for the metals, a method base on the calculations of contamination / pollution (C/P) index was used. The C/P index is the ratio of the metal content effectively measured in the soil by chemical analysis to the critical limit from a reference table (De Vries and Bakker, 1998). The Canadian critical limits for heavy metals were used for this calculation (**Table 5**). Most Regulatory limits are derived with the principle "As Low As Reasonably Achievable" (ALARA). Critical limit however, are based on the viewpoint of protection of human health (De Vries et al., 2007). **Table 6** shows the C/P indices distributions for the different metals in the different communities, as well as the average C/P values for the metals at the different communities. Much difference exists between the concentrations of metals in soils (**Table 4**) and the potential threat pose by them expressed through their C/P index value (**Table 6**). Lacatusu (2000) affirmed that C/P index is directly correlated to their level of contamination and pollution; higher value >1 connote higher risk, while lower values < 1 represent minimal risk to the environment (**Table 7**). It could be seen that C/P values for the metals in different communities ranged from 0.34 – 0.59 for Cr; 0.02 – 0.83 for Cu; 0.37 – 1.74 for Zn; 0.06 – 0.22 for Ni; 0.05 – 1.14 for Pb; and 2.14 – 7.74 for Cd.

Table 6: Heavy metal pollution profile, calculated from individual metal C/P index

Samples	Cr	Cu	Zn	Ni	Pb	Cd	Ave
Com-A	0.45	0.03	0.47	0.06	0.05	2.14	0.53
Com-B	0.58	0.50	1.74	0.21	1.14	5.02	1.53
Com-C	0.34	0.83	0.48	0.22	0.49	7.74	1.68
Com-D	0.49	0.21	0.83	0.13	0.21	4.66	1.09
Com-E	0.59	0.02	0.37	0.09	0.06	4.24	0.89
Average	0.49	0.32	0.78	0.14	0.39	4.76	1.15

Table 7: Significance of intervals of contamination/pollution (C/P) index

C/P	Significance
<0.1	Very slight contamination
0.10 – 0.25	Slight contamination
0.26 – 0.50	Moderate contamination
0.51 – 0.75	Severe contamination
0.76 – 1.0	Very severe contamination
1.1 – 2.0	Slight pollution
2.1 – 4.0	Moderate pollution
4.1 – 8.0	Severe pollution
8.1 – 16.0	Very severe pollution
>16	Excessive pollution

Source: Lacatusu, 1998

The average C/P values for the metals in communities A and E were 0.53 and 0.89 respectively indicating contaminations levels (of severe and very severe contaminations) for these communities, whereas Com. B, C, and D had values that were slightly higher than one (>1) connoting slight pollution. Generally, the soils showed evidence of contamination levels (i.e., no pollution) with respect to the individual metals (Cr, Cu, Zn, Ni, & Pb) except for Cd that showed moderate to severe level of pollution. The degree of metals contamination or pollution in the studied areas was: Cd > Zn > Cr > Pb > Cu > Ni; while the degree of metal contamination /pollution for the communities was in the order: Runuokoro>Rumuogholu>Ozuoba>Rumuosi>Choba. This was almost similar to the order of pollution due to phenols except that there was a reversal for soils in Choba (Com-C) for Ozuoba (Com-D). Characterization based on the significance of intervals of contamination / pollution (C/P) index in **Table 7**, reveals that due to multiple pollution, all the communities were slightly polluted with respect to the six metals.

Conclusion

The natures of contaminants and concentrations levels are basic inputs for evaluation of potential ecological and human risks. Although the individual toxic phenols and metals (except 2,4-DCP and cadmium) concentrations in these farmlands' soils did not indicate much threat, the total concentrations of the eight determined phenols implicated high risk based on the calculated total risk quotient; also, characterization based on the significance of interval of contamination/pollution (C/P) index indicated that due to multiple pollutions, all the communities were slightly polluted with respect to six determined metals. Due to the possibility of further accumulations of these toxic metals and phenols in the farmlands' soils, and possible bioaccumulations along the food chains, it is recommended that market survey of the concentrations of these contaminants in farm products harvested from these communities be assessed. This is necessary to provide mitigation measures and protect public health in general.

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