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Assessment of Heavy Metal Pollution of Wetland Soils in Ijokodo, Oyo State, Nigeria

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Abstract: *Wetlands soils play significant roles in agricultural food production, but are susceptible to heavy metal contamination from recharge waters and/or agrochemicals. This study investigated distribution and level of pollution of heavy metal in soils of Ijokodo wetland, Oyo state, Southwest Nigeria. Twenty soil samples (top and sub soils) were collected randomly within the wetland in October, 2019 and analyzed for Mn, Fe, Cu, Zn, Pb, Cd, Co, Cr and Ni using standard methods. The degree of heavy metal pollution was assessed by comparing metal concentrations to sediment quality guidelines and soil quality thresholds. The results show that soil within the Ijokodo wetland is moderately polluted with cadmium and nickel at concentrations that could cause adverse impact to the wetland ecosystem. The correlation matrix and PCA both show recharge waters, agricultural inputs and parent rock composition as important sources of metals in the wetland. The presence of heavy metals in wetland soils above permissible limits is of human health concern and calls for continuous monitoring of Ijokodo wetland soils to check heavy metal enrichment above the accepted regulatory limits.*

Keywords: *Wetlands, Heavy metal, Soil contamination, Sediment quality guidelines, Oyo state*

INTRODUCTION

Wetlands are areas where the water table is close to or at the surface and whose soil is seasonally or permanently covered by shallow water. These ecosystems are among the most productive habitats in the world with, ecological, socio-cultural, and economic relevance (Tijani *et al*., 2011). With an increase in population food demands coupled with non-availability of water for irrigation during the dry seasons, wetlands provide the much needed succour for agricultural production (Tijani *et al*, 2011). Wetlands in south-west Nigeria have been shown to play important roles in ecosystem balancing and ensuring food security (Olanrewaju *et al*., 2011). Wetlands just like sediments acts as sinks for contaminants due to a variety of physico-chemical processes such as adsorption, ligand exchange, and sedimentation (Lau and Chu, 2000).

Despite their roles in increasing food production, wetlands are susceptible to pollution because they sometimes receive contaminated surface water recharge from around them, which affects the quality of soils within the wetlands.

The use of agrochemicals on wetlands is a major source of heavy metals such as cadmium, arsenic and copper (Bai et al., 2011). In Nigeria, urbanization and pollution have continued to adversely affect wetland ecosystems (Olorunfemi, 2017). Therefore, their degradation due to pollution places a heavy burden on the task of ensuring food safety and water resources management within the country.

Majority of studies on wetlands within Nigeria have focussed on the effect of water drainage and urban encroachment/ sprawl on disappearing wetlands (Oyedele and Olorunfemi, 2019; Adeoye and Dami, 2012; Tijani *et al*., 2011). There has been little to no focus on how these activities impact on soil quality within the wetlands. Therefore, the objectives of this study are: (1) to assess heavy metals (Mn, Fe, Cu, Zn, Pb, Cd, Co, Cr and Ni) pollution in soils of Ijokodo wetland; (2) to detect the distribution of these heavy metals with soil depth; and (3) to identify the possible pollution source of these heavy metals using multivariate analysis.

RESEARCH METHODOLOGY

Study Area

The Ijokodo Wetland farm is located in Ido local government area of Ibadan Oyo State, situated within Latitude 7°26'01.6"N to 7°26'14.7"N and Longitude 3°52'27.0"E to 3° 52' 39.399"E. The study area has an equatorial climate with dry and wet seasons and relatively high humidity. The study area is underlain by lithological units of the crystalline basement complex migmatite, quartzite, and quartz-schist (Tijani and Jinno, 2004).

The Ijokodo wetland farm is surrounded in part by the Apete road and in part by the Eleyele Lake. The wetland farm has a high water table and receives recharge water originating from different parts of the town (Figure I). The study area is locally termed a Fadama area and it is primary used by farmers for an all year round large scale vegetable production due to its saturation with water in all seasons.

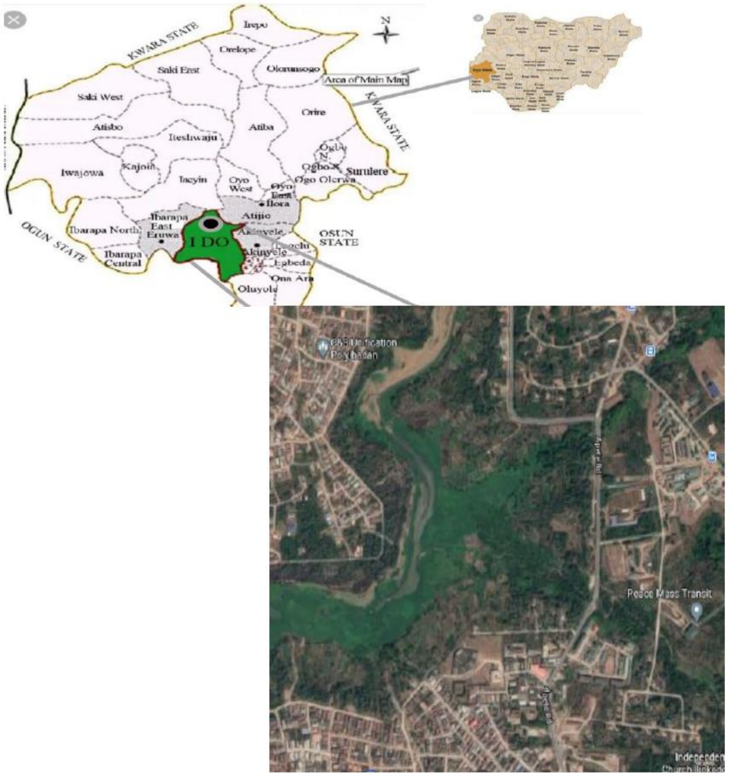

Figure I: Map of study area showing the Ijokodo wetland

Sample Collection and Analysis

Topsoil (0 – 15cm) and subsoil (15 -30cm) samples were collected from ten randomly selected sampling points within the farm. To reduce errors in heavy metal soil content, stones, twigs and dirt that can potentially impact on heavy metal content of soils were carefully removed at each sampling point prior to soil collection. Soil samples were air dried, homogenized, sieved with 2mm mesh sized sieves and stored in labelled polythene bags prior to analysis.

Soil pH was determined in soil-water extract using a D-6 Dialysate meter. Particle size distribution of samples was determined using the hydrometer method (Gavlak et al., 2005). Total organic carbon (OC) was determined by oxidation with potassium dichromate and titration with ferrous sulphate reagent (Anderson and Ingram 1989). The soil organic matter (OM) content was determined by multiplying the total organic carbon content by 1.724 (Howard, 1965).

The concentrations of heavy metals (Mn, Fe, Cu, Zn, Pb, Cd, Co, Cr and Ni) were determined in aqua-regia (HNO_3/HCl mixture, 1:3) digestate by Microwave Plasma Atomic Emission Spectroscopy (MP-AES 4200). Blanks and standard reference materials were included in the analysis to verify the efficiency of the extraction procedure.

Statistical Analysis

The results obtained from laboratory analysis were subjected to descriptive statistics using SPSS 23.0 (SPSS Inc., USA) software. A Pearson correlation analysis (PCR) was conducted to evaluate the relationships between the different heavy metals while a principal component analysis (PCA) was conducted to investigate the possible sources of heavy metals into the soil (Baltas *et al.*, 2020).

RESULTS AND DISCUSSION

Spatial Distribution of Metals in Surface Soil

The results of pH, organic carbon (OC), organic matter (OM) and textural characteristics of topsoil collected from Ijokodo Fadama farm are shown in Table I. Results are presented as mean values for triplicate analyses. The pH of topsoil within the farm was alkaline ranging from 8.02 – 8.82 with a mean value of 8.32. All topsoil samples had pH outside the desirable *soil pH range* of 6.0 - 7.5 generally accepted for optimum plant growth (Neina, 2019). *Soil* pH is an important factor that controls availability of nutrients, microbial activity and crop productivity. A high soil pH makes crops unable to take in nutrients via their roots and can potentially affect plant's growth (Neina, 2019). Organic carbon in soil from the study area ranged between 1.46% and 3.65% while the organic matter ranged between 3.52% and 6.27% with a mean value of 4.43%. Soil within the Fadama farm is relatively rich in organic matter indicating that runoffs into the farm may contain organic materials such as domestic sewage, abattoir and solid wastes indiscriminately disposed off around the study area. The topsoil can be classified as sandy loam with a high sand content (>72%) and low clay content (< 5%). The dominance of sand particles in soil samples is related to the high sand content of the soils within Ibadan, Oyo State (Adeyi and Babalola, 2017).

Table I: Mean pH, organic carbon, organic matter and particle size distribution (%) in topsoil samples from Ijokodo wetland farm.

Sampling point	pH	% OC	% OM	Particle size distribution %		
				Clay	Silt	Sand
S_1	8.19	3.46	5.96	4	21.2	74.8
S_2	8.2	3.28	5.64	4	20.3	75.7
S_3	8.23	2.37	4.08	4	20.4	75.6
S_4	8.02	1.46	2.52	4	22.6	73.4
S_5	8.82	3.65	6.27	4	24.3	71.7
S_6	8.26	2.55	4.39	4.5	21.2	74.3
S_7	8.21	1.80	3.09	6	21.2	72.8
S_8	8.31	3.47	5.96	4	21.8	74.2
S_9	8.42	1.55	2.67	4	21.2	74.8
S_{10}	8.5	2.18	3.76	4	21	75

Table II shows the range and mean concentrations of heavy metals (Mn, Fe, Cu, Zn, Pb, Cd, Co, Cr and Ni) in surface soils within the Ijokodo wetland farm. The degree of heavy metal pollution was assessed by comparing heavy metal concentrations in topsoil to sediment quality guidelines and soil quality thresholds. Mn in soil ranged from 72 mg /kg to 90.3 mg /kg with a mean value of 83.27 mg /kg. Concentrations of Fe ranged between 42.9 mg /kg to 50.7 mg /kg with a mean value of 47.08 mg /kg. Concentrations of Cu ranged from 3.2 mg /kg to 3.71 mg /kg with a mean concentration of 3.48 mg /kg. Nickel concentrations ranged from 23.4 mg /kg to 28 mg /kg with a mean of 26.69 mg /kg. Possible sources of Mn and Ni into the farm include contaminated irrigation water containing domestic solid waste, nickel-cadmium batteries and fossil fuel combustion (Howe *et al.*, 2001).

Lead concentrations in the soil samples ranged from 11.1 mg /kg to 15.45 mg /kg with a mean of 13 mg /kg. Concentrations of Cd ranged from 0.82 mg /kg to 0.91 mg /kg with a mean of 0.85 mg /kg while Co concentrations ranged from 2.52 mg /kg to 2.97 mg /kg with a mean of 2.76 mg /kg.

A comparison of results from this study with the Ontario sediment quality guidelines indicates that topsoil within the Ijokodo wetland farm contained Cd and Ni at concentrations exceeding the lowest effect level (LEL, below which no effects on soil dwelling organisms are expected). This is of concern as it points to a possible adverse impact to the wetland ecosystem from Cd and Ni pollution. However, the soils did not exceed the severe effect level for all heavy metals studied. A comparison with the EPA guidelines confirms a moderate pollution of the farm with Ni. Nickel in low soil concentrations is essential for optimum plant growth, however, in higher concentrations, it retards seed germinability and causes leaf chlorosis and necrosis, due to disruption of Fe uptake and metabolism (Iyaka, 2021). Cadmium is a non-essential non-metabolic metal that inhibits the photosynthesis in plants.

Figure II illustrates the concentration distribution of heavy metals at different depths in the study area. Generally, all the heavy metals studied had higher concentrations in the topsoil compared to the subsoils. Most leafy vegetable such as those grown in the study area are shallow rooted and can readily take up contaminants such as heavy metals through their roots. As such, pollution of the Ijokodo wetland farm with these metals is of serious health and environmental consequences due to bioaccumulation and potential poisoning of consumers.

Table II: Comparison of present study results with soil and sediment quality guideline values. *LEL* = lowest effect level, *SEL* = severe effect level (OMOE, 1993), *MOD* = moderate level, *POL* = polluted level, *HPOL* = heavily polluted level (Pekey *et al*., 2004)

	Present study (mg/Kg)		Threshold limits[a]	Guideline values				
				Ontario[b]		EPA[c]		
	Mean ± SD	Range		*LEL*	*SEL*	*MOD*	*POL*	*HPOL*
Mn	83.27 ± 5.81	72.00 – 90.30		460	110			
Fe	47.08 ± 2.50	42.90 – 50.70		2×10^4	2×10^4			
Cu	3.48 ± 0.32	3.20 – 3.71		16	110	25	50	>50
Zn	10.91 ± 1.10	9.74 – 12.87	150	120	820	90	200	>200
Pb	13.00 ± 1.63	11.10 – 15.45	200					
Cd	0.85 ± 0.05	0.82 – 0.91	1	0.6	10	-	-	>6
Co	2.76 ± 0.16	2.52 – 2.97						
Cr	17.81 ± 1.09	15.88 – 18.7	100	26	110	25	75	>75
Ni	26.69 ± 1.66	23.40 – 28.67		16	75	20	50	>50
pH	8.32 ± 0.22	8.02 – 8.82						
% OC	2.58 ± 0.84	1.46 – 3.65						
% OM	4.43 ± 1.44	3.52 – 6.27						

[a] : TBS, 2007; [b]: (OMOE, 1993); [c]: (Pekey *et al*., 2004.)

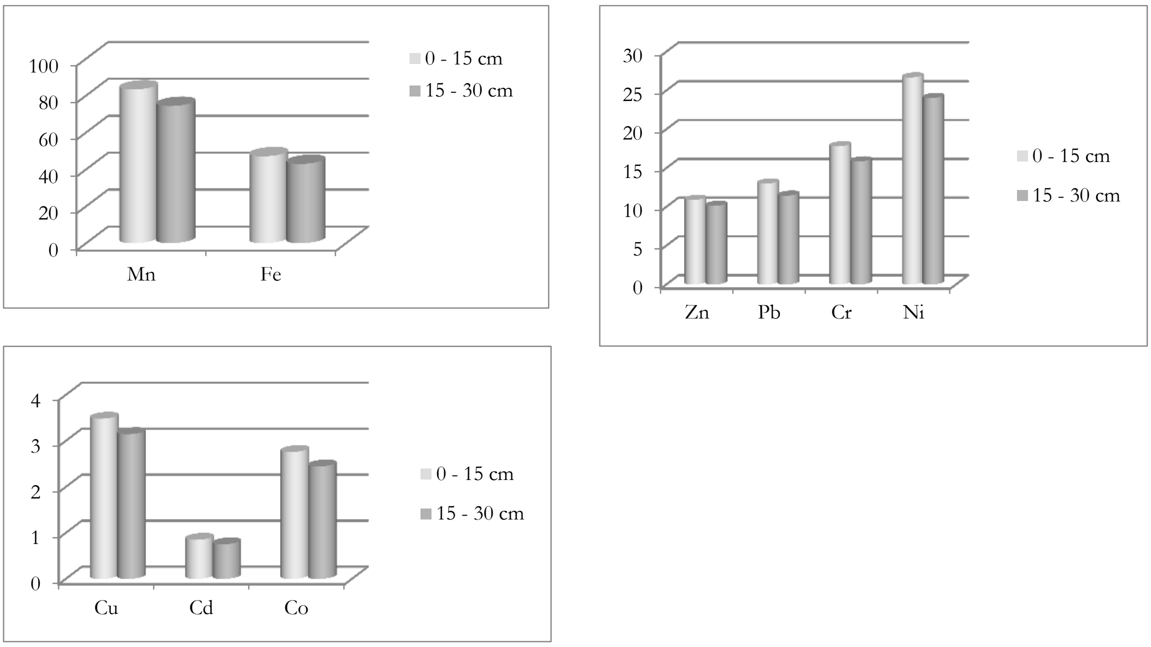

Figure II: Distribution patterns of heavy metals with depth in soil of study area

Heavy Metal Pollution Sources

The principal component analysis (PCA), an effective tool for identification of contaminant sources (Anju and Banerjee, 2012), was applied in this study to assist in the source identification of heavy metals. This technique groups heavy metals such that metals belonging to one group are highly associated with one another. Based on eigen values (eigenvalue > 1), PCA resulted in a reduction of the initial dimension of the dataset with the first three components explaining 73.32% of the variation in the data. The first component PC_1, explains 33.38% of the total variance and is strongly and positively related to Pb, Co, Fe and Cd (Table III). The second component PC_2, explains 21.22% of the total variance, showing highly positive factor loadings for Cu, Cr and Cd, while PC_3 explains 18.72% of the total variance and has strong loadings for Zn and Mn.

Table III: Rotated component matrix of PCA of heavy metal concentrations in soils of Ijokodo wetland farm. Moderate to strong loadings are in bold.

Heavy metal	PC_1	PC_2	PC_3
Pb	**0.868**		
Co	**0.858**		
Fe	**0.847**		-0.417
Cu		**0.900**	0.344
Cr	-0.338	**0.789**	
Cd	**0.525**	**0.647**	
Zn	0.437		**0.807**
Mn	0.430		**0.602**
Ni			0.497
Eigen values	3.004	1.909	1.685
% of variance	33.378	21.216	18.723
% cumulative	33.378	54.592	73.316

The scores plot illustrated in Figure III shows the pattern and relationships between metal concentrations. Pb in agricultural soils originates primarily from nearby roads with considerable traffic and/or gaseous discharges from factories (Turer *et al.*, 2001). It could also arise from surface irrigation containing domestic waste flowing into the farm. Similarly, surface waters flowing into the farm could contain wastes from paint and building materials which are important sources of Cd. Agricultural inputs such as fungicidal spray and Cu-based agrochemicals such as copper sulphate used by farmers on the farm could be responsible for soil contamination due Cu (Wuana and Okiemen, 2011).

Thus, PC_1 is most likely indicative of surface water recharge as Pb and Cd are usually consistent with contamination arising from industrial and/or transportation activities (Nouri and Haddioui, 2016), while PC_2 is indicative of agronomic activities. Zn and Mn is primarily geogenic. PC_3 is therefore indicative of lithogenic sources controlled by the composition parent rocks.

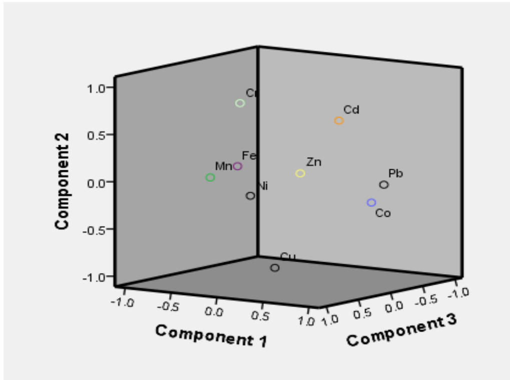

Fig III: Component plot in rotated space of studied area

The relationships between the heavy metals in topsoil were investigated using Pearson correlation analysis (Table IV). The results reveals a strong correlation with significance ($p < 0.05$) between Fe and Zn ($r = 0.699$), Fe and Pb ($r = 0.650$), Co and Pb ($r = 0.688$) indicating a possible common sources for the metals. Pb is an indicator of pollution and mostly gets into soil from petrol engine discharges and vehicular emissions (Wuana and Okiemen, 2011). The lead concentrations in Ijokodo wetland soil can be attributed to runoffs from highways and motor parks. Zinc and Fe concentrations in the soil predominantly depend on the chemical composition of the parent materials (Noulas *et al.*, 2018). However, the strong significant correlation between Fe and Pb points to additional introduction of Fe into the wetland soil from anthropogenic sources. This result shows that while some of these metals may be natural constituents of soils, their present concentrations within soils of the Ijokodo farm are a result of external contributions.

Table IV: Correlation coefficient for heavy metals in Ijokodo wetland soils.

	Mn	Fe	Cu	Zn	Pb	Cd	Co	Cr	Ni
Mn	1								
Fe	0.072	1							
Cu	0.159	-0.164	1						
Zn	-0.166	**0.699***	-0.224	1					
Pb	-0.459	**0.650***	0.044	-0.096	1				
Cd	-0.068	-0.413	-0.504	-0.169	0.408	1			
Co	-0.388	**-0.596**	0.212	-0.339	**0.688***	0.276	1		
Cr	0.210	0.196	**-0.629**	-0.242	-0.313	0.133	-0.395	1	
Ni	0.061	-0.065	0.207	-0.204	-0.099	-0.040	-0.112	0.041	1

* - Correlation is significant at the 0.05 level (2-tailed). Bold values represent strong correlations between heavy metals.

CONCLUSIONS AND RECOMMENDATION

This study assessed the distribution of heavy metals in soils within a wetland used for large scale vegetable farming, Ijokodo, Oyo State. The results show the Ijokodo wetland is moderately polluted with Cd and Ni at concentrations that could cause adverse impact to the wetland ecosystem. The correlation matrix and PCA both show that Pb, Co, Fe and Cd are closely associated and are mostly derived from surface waters recharging the wetland. Heavy metal concentrations were also higher in topsoils compared to subsoils.

The Ijokodo wetland serves an important agricultural and economic purpose for food production and livelihood support of subsistent farmers within Ibadan, Southwest Nigeria. The presence of heavy metals in soils above permissible limits is therefore harmful to human health and the environment.

Since wetland serves as a sink for heavy metals, and their pollution status can influence the quality of leafy vegetables grown on it all year round, there is a need for continuous monitoring of Ijokodo wetland soils to check heavy metal enrichment above the accepted regulatory limits.

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