International Research Journal of Pure & Applied Chemistry

18(4): 1-17, 2019; Article no.IRJPAC.47040
ISSN: 2231-3443, NLM ID: 101647669

Impacts of Anthropological Activities on Soils of Some Parts of Rivers State, Nigeria

W. P. Wanjala[1*], L. Odokuma[2], I. Etela[3] and R. Ramkat[4]

[1]Department of Biological Sciences, Moi University, Eldoret, Kenya.
[2]Department of Microbiology, University of Port Harcourt, Nigeria.
[3]Department of Animal Science, University of Port Harcourt, Nigeria.
[4] Center of Excellence in Phytochemicals, Textiles and Renewable Energy, Moi University, Eldoret, Kenya.

Authors' contributions

This work was carried out in collaboration among all authors. Authors WPW and LO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors IE and RR managed the analyses of the study. Author WPW managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2019/v18i430096
Editor(s):
(1) Surendra Reddy Punganuru, Department of Biomedical Sciences, School of Pharmacy, Texas Tech University Health Sciences Center, Amarillo, USA.
Reviewers:
(1) Norbert Nkafu Fomenky, University of Buea, Cameroon.
(2) Shipra Jha, Amity University, AUUP, India.
(3) Mohammad H. Golabi, University of Guam, Guam.
Complete Peer review History: http://www.sdiarticle3.com/review-history/47040

Original Research Article

Received 29 January 2019
Accepted 16 April 2019
Published 26 April 2019

ABSTRACT

The study is a post project implementation Environmental Monitoring (EM) of impacts of anthropological activities on levels of soil physicochemical parameters. The study evaluates levels of physicochemical parameters in soils of 9 locations in Port Harcourt and its environs in Rivers State, Nigeria, grouped into 3 categories; urbanized, industrialized and agricultural. Composite soil samples were collected between April to October 2018. Concentration levels of Benzene, Toluene, Ethyl-benzene, and Xylene (BTEX), Total Petroleum Hydrocarbon (TPH), Percent Total Organic Carbon (% TOC), Lead (Pb), Iron (Fe), Copper (Cu), Cadmium (Cd), Zinc (Zn), Calcium (Ca), Nickel (Ni), Sodium (Na), Potassium (K), Chromium (Cr), Magnesium (Mg), Manganese (Mn), and Sulphur (S) in soil was measured using standard analytical procedures. The study evaluates the impact magnitude (IM) of the obtained test values against control values. In industrial area, BTEX recorded the highest Impact Magnitude (IM) of 100% while TOC and TPH recorded 100.00% and 88.89%

**Corresponding author: E-mail: piwanjala@gmail.com;*

respectfully, and were classified as severely impacted (S). In the agricultural areas, TOC and Ni recorded IM of 88.89% while BTEX had an IM of 77.78% which were highest and were classified as severe impact (S). In urbanized areas, Ni and (Phosphate) PO_4^{3-} recorded the highest IM of 88.89% and were classified as severe (S). The study establishes that urbanization, industrialization and agricultural activities do affect the level of physicochemical parameters in the study areas. Activities in industrial areas negatively impact on levels of BTEX, % TOC and TPH in soils. Activities in agricultural areas negatively impacted on levels of BTEX, NO_3^-, NO_2^- and SO_4^{2-} in soils, and activities in urban areas negatively impact on levels of Ni, PO_4^{3-}, Zn, Mn, TPH, % TOC and Ca in soils of the study areas. These findings form a reliable baseline data for future researchers in EM in the study areas. The study recommends EM of soil physicochemical parameters in the study area in order to ensure a healthy soil for food production in order for realization of Sustainable Development Goals (SDGs); Good Health and well-being, and sustainable cities and communities.

Keywords: Petroleum; environment; monitoring; soil; pollution; ranking; prediction.

1. INTRODUCTION

Environmental Monitoring (EM) is a continual process that identifies, predicts and evaluates impacts to the environment [1]. Environmental Monitoring (EM) is commonly a requirement to determine levels of effects of existing project on natural environment [2]. Most if not all activities have effect to the environment where they are being conducted and therefore EM is relevant for decision making of stopping or continuation of particular activities in a particular area [2]. Environmental Monitoring (EM) provides a baseline for implementation of necessary mechanisms to monitor, mitigate and manage a particular effect, and hence appropriate alternatives in determination of impact can be proposed and adopted [3]. Environmental status reports provide assurance for financiers of major projects [3], for example international agencies like World Bank, World Health Organization and United Nations Development Program (UNDP). The effects of an activity are commonly quantified and can be rated, ranked and scaled accordingly. Rau and Wooten Scheme [4] has been adopted in Nepal 1993 guidelines and provides a guideline to score impact extent, duration and magnitude [3], this scheme has hardly been applied in Nigeria and other parts of Africa. In Rau and Wooten Scheme [4], impacts can be ranked based on the significance they carry, which can be positive or negative and can also be assessed against prescribed standards. Environmental Monitoring can be done in the course of implementation of projects or can also be done post project implementation, or during operation of the project in order to enhance project sustainability [5]. Environmental Monitoring (EM) done in course of implementation of the project provides a progressive outlook of implementation of measures that were agreed upon before implementation of the project. Environmental Monitoring (EM) done after project approval and implementation is essential to identify impacts that occur, to check that parameters are within recommended limits, to determine the adequacy of mitigation measures put in place and to ensure they are implemented as agreed or as outlined in legislation. Further, EM is done to ensure that benefits from the project is achieved without compromise of environmental health and to provide data for future EM processes. Setting up of urban settlements and industries and agricultural activities are cascaded with positive and/or negative impacts to environment [2]. Industrial evolution is also associated with a wide range of benefits including, jobs, largescale production of goods, quick modes of transport and substitutes in consumer goods, however, it has negative impacts to the environment, for example, disappearing of natural resources and emergence of hazardous wastes or unhealthy conditions. It has been forecasted that by the year 2050, 66% or more of the population will dwell in urban centers [6]. This will increase quantity of wastes with impervious pollutants which will be washed through runoffs to pollute natural ecosystems [7]. Most supplies of the industries emanate from the environment, and is vital that the integrity of the environment is kept intact to ensure food is not contaminated. Increased population calls for increased demand for food and hence enhanced food production. Good Agricultural practices have been applied to intensify food production. However, there are cases of misuse of herbicides, acaricides, pesticides and fertilizers which contaminate the environment and are a health risk to consumers of farm products. Rivers State in Nigeria has intensified in urbanization, industrialization and agricultural activities, and agricultural land could be contaminated with pollutants. This study focuses on assessment of impacts of urbanization, industrialization and agricultural activities on soils of selected areas of Port Harcourt and its environment in Rivers State. The findings provide baseline data on current status level of soil physicochemical parameters that are useful for reference for future researchers and policy makers.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

This study was conducted in 9 selected areas of Port Harcourt, the Capital of Rivers State, Nigeria (Fig. 1). The areas of interest were grouped into 3; urban, Industrial and agricultural areas. The urban areas of interest include; GRA phase 2, Diobu- Mile 1 and Mguoba, Agricultural areas of interest include; Aluu, Oquwi- Eleme, Emuoha-Eu. Industrialized areas include; Eleme which hosts the NNPC Refinery, Agbada-SPDC- flow station in a rural setting and Trans-Amadi. Economic activities (Table 1) conducted in the study areas include; drilling and mining, fishing, fish farming, horticulture, dairy farming and crop farming, industrial processing. The study areas were assigned codes as in Table 1 [8,9].

2.2 Sampling

Composite samples were collected by random sampling from each of the three areas; urbanized, industrialized and agricultural in the wet season (April to October 2018). Five (5) individual samples were collected following a random pattern around each test field. The five individual samples were thoroughly mixed by coning and quartering in a sterile container to attain a homogenous composite mixture. A total of 12 composite samples; A1, A2, A3, I1, I2, I3 U1, U2 and U3 as test samples, and CA, CI and CU as control samples (Table 1), were collected from the topsoil within a depth of 0 to 15 cm using a standard auger 3 times in the rainy season. Homogenized composite samples (400 gm) were then packed in polyethylene bags using a sterile wooden shovel. Samples for microbial analysis were collected using pre-sterilized materials to prevent contamination of the samples. Locations of the sampling sites were identified using a GPS and the GPS readings recorded. Samples were transported to the laboratory for analysis [8,9].

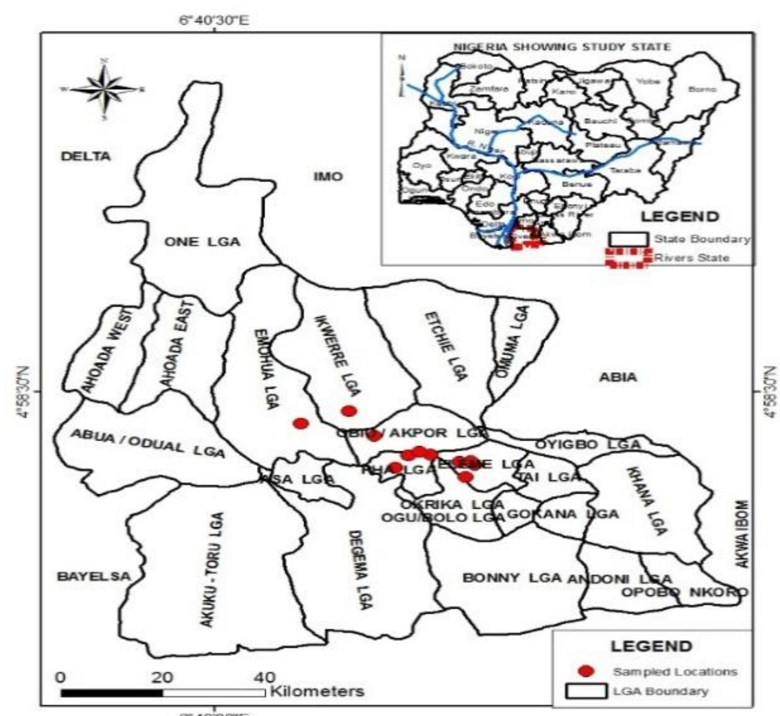

Fig. 1. Map of Nigeria showing sampled locations in Rivers State [8,9]

Table 1. Table showing study areas and economic activities [8,9]

No	Selected study areas	Study area coding	Coordinates/ N latitude E longitude	Economic activities
Agricultural areas				
1	Aluu	A1	4° 56' 11.160' 6° 57' 52.248'	Flow station
2	Eleme	A2	4° 44' 09.874' 7° 08' 58.494'	Village close to refinery
3	Emuoha	A3	5° 00' 00.018' 6° 49' 13.032'	Flow station
4	Control	CA	5° 00' 21.384' 6° 49' 00.000'	>1 km away from suspected areas
Industrial areas				
1	Onne	I1	4° 46' 00.402' 7° 05' 43.092'	Hosts the NNPC Refinery
2	Agbada	I2	4° 56' 03.444' 6° 58' 42.060'	Hosts SPDC- flow station in a rural setting
3	Trans-Amadi	I3	4° 48' 20.455' 7° 02' 17.646'	Schlumberger/, Hallburton
4	Control	CI	4° 47' 13.788' 7° 07' 44.620'	>1 km away from suspected areas
Urban areas				
1	GRA phase 2	U1	4° 49' 53.574' 6° 59' 45.552'	Inhabited areas Perecuma street
2	Diobu- Mile 1	U2	4° 47' 20.382' 7° 00' 13.164'	Petroleum refinery
3	Mguoba	U3	4° 50' 39.864' 6° 58' 20.232'	NTA
4	Control	CU	4° 49' 17,040' 6° 59' 24.168'	>1 km away from suspected areas

2.3 Laboratory Analysis

2.3.1 Determination of levels of physicochemical parameters and heavy metals in soil

Particle size was determined using weighing method (British standard, BS1377) [10]. Nitrate was determined using APHA 1995 methods [11], where absorbance was measured at a wavelength of 470 nm using UV 721D Spectrophotometer (APHA, 45-NO_3B) [11]. Phosphate was determined using absorbance (UV 721D Spectrophotometer) at a wavelength of 690 nm (APHA, 4500 - PD) [11]. Sulphate was measured using absorbance method at 425 nm (UV 721D Spectrophotometer) [APHA 4500 – SO_4^2] [11]. Benzene, Toluene, Ethyl-benzene, and Xylene (BTEX) and Total Petroleum Hydrocarbon (TPH) was determined using Gas Chromatography (Hewlett Packard 5890 Series II Gas Chromatograph FID). Total Organic Carbon (TOC) was determined using ASMD standard methods of analysis (ASMD 2579). Concentration levels of Pb, Fe, Cu, Cd, Zn, Ca, Ni, Na, K, Cr, Mg, Mn, and S in soil was determined using Atomic Absorption Spectrophotometry [AAS] (APHA, 1995) [11]. The heavy metals were then determined at specified wavelengths; Lead: 283.2, Copper: 324.7, Cadmium: 228.9, Zinc: 213.9, Nickel: 341.5, Calcium: 422.7, Sodium: 589.00, Potassium: 766.5, Manganese: 279.5, Magnesium: 285.2, Chromium: 357.9 (APHA, 301A) [11]. Soil pH and conductivity was determined using the standard; electrical meter method (APHA, 1995) [11].

2.3.2 The Rau and Wooten scheme [4]

Rau and Wooten scheme [4] predicts impacts by magnitude, extent and duration. The ways for prediction include symbolic signs, numerical values and negatives (−ves) or positives (+ves).

Magnitude shows the severity of the impacts and can be grouped as high, medium or low. Rau and Wooten scheme [4] also indicates the spatial extent which indicates zones that have been influenced and can be categorized as local, national, regional or international. Further, Rau and Wooten Scheme [4] indicates the duration of the impact or how long the effect can last. Therefore, each impact is predicted with magnitude, extent and duration. After determination of the physicochemical parameters and heavy metals using standard analytical procedures, the IM values were calculated using the Formula 1 below.

$$IM = \frac{Control\ results - Obtained\ value}{Control\ results} \times 100$$ (Formula 1/Modified from Rau and Wooten [4])

Where

IM= Impact magnitude

Criteria of weighting scale was used to evaluate the significant differences between the values obtained from the controls and the values obtained from the test samples based on Rau and Wooten's scheme [4] (Table 2). Values obtained were expressed as percentage (%), thereafter the scale were reduced to 1-5. Decrease in the concentration of physicochemical parameters in test sample as compared to control sample is considered a positive change (positive impact magnitude) and regarded as an improvement while a significant increase in the concentration is considered a negative change (negative impact magnitude). Direct transformation of impact ranking into impact significance was done and reported as magnitude [12]. Individual values in the column was divided by the total value of the column which gave relative weighting of each character [12].

3. RESULTS AND DISCUSSION

3.1 Physicochemical Parameters

Tables 3, 4 and 5 show the results of the physicochemical parameters obtained through standard laboratory analytical procedures. Table 3 shows physicochemical parameters obtained in the month of April, Table 4 shows the results obtained in the month of July and Table 5 shows results obtained in the month of September. The results in Tables 3, 4 and 5 are presented in 3 categories of Industrial, Agricultural and urbanized areas.

3.2 Impact Assessment

In industrial area, BTEX recorded the highest Impact Magnitude (IM) of 100%while TOC and TPH recorded IM values of 100.00%, 88.89% and were classified as severely impacted (S). Magnesium (Mg) recorded IM of 77.78%, while Cu, Mn and Particle Size recorded IM of 66.67%, 66.67% and 66.67% and were classified as highly impacted (H). Lead (Pb) recorded IM of 55.56% while PO_4^{3-}, SO_4^{2-}, Cr and 'S' recorded % IM of 44.44% and were classified as medium (M) IM. Electrical Conductivity (EC), pH, Ni, Ca, Na recorded IM of 33.33%, while Zn, NO_3^- and NO_2^- had % negative IM of 22.22% and 22.22% respectively, and were classified as low impact (L). Cadmium (Cd) and K recorded IM of 0% and were classified as negligible impact (Table 6).

In the agricultural areas, TOC and Ni recorded IM of 88.89% while BTEX had an IM of 77.78% which were the highest and were classified as severe impact (S). Nitrate (NO_3^-) and NO_2^- recorded a high IM of with value of 66.67% and were classified as high impact (H). Sulphate (SO_4^{2-}) recorded IM of 55.56% while Pb, Na, S

Table 2. Impact evaluation and weighting scheme [4]

IM	IE	IC	Definition of impact classification
0 - 20	1	Negligible (N)	No significant impact of parameter on soil. Does not require remediation at all.
21 - 40	2	Low (L)	No significant impact of parameter on soil. It does not require remediation at all.
41 - 60	3	Medium (M)	Significant impact of parameter on soil. The soil requires remediation technique.
61 - 80	4	High (H)	Severe significant impact of parameter on soil. It requires remediation techniques.
> 80	5	Severe (S)	Persistent severe significant environmental impact on soil. Requires more extensive remediation techniques.

Key: Impact Magnitude (IM), Impact Evaluation (IE), Impact Classification (IC)

Table 3. Concentration of physicochemical parameters in soil samples in April

Parameter	SI unit	Industrial				Agricultural				Urbanized			
Study area		**I1**	**I2**	**I3**	**CI**	**A1**	**A2**	**A3**	**CA**	**U1**	**U2**	**U3**	**CU**
pH		10.14	8.62	9.24	10.1	8.04	9.13	9.34	10.3	6.99	10.26	9.74	10.09
EC	µS/cm	0.06	0.09	0.19	0.13	0.04	0.07	0.03	0.13	0.13	0.06	0.25	0.20
TOC	%	7.42	6.04	7.94	6.21	6.56	4.14	6.90	1.21	11.56	6.21	6.38	6.04
Pb	ppm	0.71	0.33	2.01	0.16	0.34	0.43	0.45	0.30	0.82	2.09	0.28	0.83
Cu	ppm	0.19	0.18	0.35	0.06	0.17	0.19	0.23	0.51	0.12	1.10	0.01	0.06
Cd	ppm	0.04	0.06	0.06	0.07	0.03	0.01	0.05	0.07	0.05	0.03	0.02	0.04
Zn	ppm	0.72	0.68	1.80	2.28	0.24	0.65	1.64	2.96	1.36	2.84	0.99	0.67
Ni	ppm	0.22	0.32	0.26	0.25	0.2	0.27	0.35	0.23	0.24	0.38	0.11	0.10
Ca	ppm	18.00	0.44	3.34	105.00	0.29	0.91	1.51	69.00	6.17	127.00	15.90	0.77
Na	ppm	81.00	3.69	107.00	136.00	53.00	46.00	3.52	83.00	56.00	144.00	179.00	108.00
K	ppm	1.68	2.96	2.58	24.00	1.04	2.30	1.11	19.00	2.91	19.00	49.00	3.66
Mn	ppm	4.63	7.00	1.63	2.66	4.00	5.00	15.00	16.00	1.70	13.00	0.64	0.45
Mg	ppm	2.90	0.48	0.47	1.60	0.46	1.40	0.48	5.80	7.20	13.90	4.90	0.47
Cr	ppm	0.32	0.66	0.32	0.45	0.24	0.44	0.58	0.68	0.41	0.64	0.54	0.33
PO_4^{3-}	mg/100g	662.50	675.00	685.00	682.50	681.25	682.25	696.25	666.25	687.50	1170.00	656.25	681.25
NO_3^-	mg/100g	71.53	861.47	990.54	729.29	189.71	831.93	807.04	788.39	852.23	614.23	1,136.71	864.58
NO_2^-	mg/100g	53.08	639.29	735.07	541.2	140.78	617.37	598.9	585.06	632.43	455.81	843.54	641.60
SO_4^{2-}	mg/100g	92.50	7.18	70.90	13.13	7.40	360.03	104.58	5.98	36.78	5.50	12.65	131.08
S	mg/kg	30.83	2.39	23.63	4.38	2.47	120.00	3.47	1.99	12.26	1.83	4.22	43.69
BTEX	ppm	4.18	2.40	1.82	1.16	3.03	2.91	1.09	2.86	1.63	0.32	1.65	1.87
Particle size (>75µm)	wt %	96.10	780	81.50	97.20	67.40	103.80	109.20	107.30	87.40	122.30	107.70	75.10
TPH	ppm	9.19	8.57	4.74	4.86	4.43	5.17	6.43	11.51	6.77	9.65	7.64	3.4

Table 4. Concentration of physicochemical parameters in soil samples in July

Parameter	SI unit	Industrial				Agricultural				Urbanized			
Study area		**I1**	**I2**	**I3**	**CI**	**A1**	**A2**	**A3**	**CA**	**U1**	**U2**	**U3**	**CU**
pH		7.40	7.30	8.50	8.40	7.10	7.40	7.40	7.8.	7.17	7.30	8.25	8.10
EC	µS/cm	0.06	0.05	0.11	0.09	0.04	0.09	0.04	0.11	0.17	0.11	0.09	0.11
TOC	%	8.41	8.20	8.97	6.94	6.72	5.17	4.16	3.79	7.34	3.14	5.32	5.17
Pb	ppm	1.49	0.98	3.43	1.53	1.27	1.74	1.57	1.45	1.42	1.74	1.15	1.18
Cu	ppm	0.11	0.18	0.33	0.17	0.17	0.19	0.18	0.27	0.12	0.82	0.02	0.18
Cd	ppm	0.04	0.04	0.05	0.05	0.03	0.02	0.03	0.03	0.04	0.03	0.03	0.04
Zn	ppm	1.86	1.28	11.73	2.87	1.28	1.39	1.32	1.75	1.87	2.76	1.16	1.17
Ni	ppm	0.97	0.87	1.32	1.17	0.83	0.39	1.17	0.37	0.59	1.33	0.78	0.73
Ca	ppm	2.86	3.76	1.39	39.00	0.93	1.57	1.39	33.00	3.73	1.38	3.75	1.73
Na	ppm	138.00	338.71	121.72	107.90	127.52	57.93	109.37	93.53	67.00	133.53	137.40	283.00
K	ppm	1.87	2.42	1.11	13.44	1.11	2.28	2.17	3.74	1.76	8.73	3.67	8.73
Mn	ppm	3.86	5.74	1.70	2.73	3.31	3.79	3.37	4.87	1.20	7.83	1.57	1.39
Mg	ppm	5.64	13.65	17.73	2.67	9.73	2.15	13.15	17.74	3.10	17.93	9.79	19.47
Cr	ppm	0.28	0.37	0.09	0.28	0.09	0.36	0.23	0.58	0.15	0.49	0.18	0.23
PO_4^{3-}	mg/100g	689.00	656.30	657.11	653.41	664.13	643.16	633.15	684.15	652.17	797.30	658.72	233.17
NO_3^-	mg/100g	13.59	475.80	275.31	778.93	117.37	293.72	247.89	289.78	731.41	133.73	384.19	387.44
NO_2^-	mg/100g	11.17	286.73	138.91	579.93	86.91	288.92	267.71	464.82	573.44	167.93	298.93	328.22
SO_4^{2-}	mg/100g	64.89	8.61	37.93	16.74	8.17	47.96	53.77	34.71	33.79	5.77	36.73	45.73
S	mg/kg	24.87	3.13	11.91	13.61	2.49	32.47	3.49	13.29	12.17	2.16	8.71	16.52
BTEX	ppm	3.36	1.57	1.33	1.12	3.10	1.79	1.68	1.31	1.63	1.05	1.48	1.71
Particle Size (>75µm)	wt%	37.20	17.90	16.30	15.50	11.80	13.30	17.20	13.30	17.40	16.50	14.30	19.30
TPH	ppm	6.97	8.45	12.47	4.95	5.48	82.38	6.33	13.43	12.45	6.74	7.53	5.15

Table 5. Concentration of physicochemical parameters in soil samples in September

Parameter	SI unit	Industrial				Agricultural				Urbanized			
Study area		**I1**	**I2**	**I3**	**CI**	**A1**	**A2**	**A3**	**CA**	**U1**	**U2**	**U3**	**CU**
pH		6.50	4.50	7.50	7.20	5.00	6.00	7.00	4.50	7.50	8.00	7.00	7.00
EC	µS/cm	0.06	0.03	0.05	0.06	0.04	0.12	0.07	0.03	0.57	0.11	0.07	0.07
TOC	%	9.14	10.70	11.70	8.80	10.00	6.90	0.35	6. 38	3.97	0.17	3.97	3.97
Pb	ppm	1.60	1.35	5.07	1.75	1.51	2.14	2.09	2.24	2.33	1.31	1.34	1.73
Cu	ppm	0.09	0.15	0.37	0.16	0.18	0.12	0.16	0.09	0.14	0.26	0.03	0.27
Cd	ppm	0.03	0.02	0.03	0.05	0.02	0.04	0.03	0.03	0.04	0.05	0.03	0.04
Zn	ppm	2.12	1.51	13.70	11.10	1.29	2.81	2.76	1.41	2.90	2.79	1.50	2.65
Ni	ppm	1.33	1.17	1.19	1.34	1.18	0.74	1.45	0.68	1.13	1.62	1.01	0.81
Ca	ppm	1.80	4.90	1.66	1.30	1.36	1.83	2.18	0.96	2.27	1.86	1.94	2.64
Na	ppm	240.50	1020.00	132.50	177.00	159.00	107.50	318.00	111.72	82.00	136.50	110.50	940.00
K	ppm	2.05	2.19	1.40	2.20	0.58	3.04	2.26	2.76	1.29	2.50	1.19	16.60
Mn	ppm	4.08	4.95	1.70	2.82	3.87	3.30	4.13	5.41	0.80	1.66	2.98	2.77
Mg	ppm	10.30	26.80	29.90	3.10	12.30	2.60	19.20	46.80	4.00	37.30	13.70	48.60
Cr	ppm	0.10	0.13	0.03	0.04	0.08	0.09	0.02	0.10	0.02	0.11	0.05	0.13
PO_4^{3-}	mg/100g	919.50	640.50	652.88	668.38	657.50	637.38	649.75	888.50	649.75	795.50	659.13	640.50
NO_3^-	mg/100g	0.00	177.25	121.31	1038.75	10.88	208.38	111.94	93.31	632.88	49.75	213.06	101.06
NO_2^-	mg/100g	0.00	131.51	90.00	770.69	8.07	154.60	83.05	69.23	469.56	36.91	158.08	74.98
SO_4^{2-}	mg/100g	57.05	10.28	16.73	49.43	10.50	10.03	15.75	67.58	33.68	7.18	49.90	5.25
S	mg/kg	19.02	3.43	5.58	16.48	3.50	3.34	5.25	22.53	11.23	2.39	16.63	1.75
BTEX	ppm	2.09	1.22	1.27	1.04	3.59	0.59	2.84	0.85	1.61	1.07	1.39	1.72
Particle Size (>75µm)	wt%	2.09	1.22	1.27	1.04	3.59	0.58	2.84	0.86	1.61	1.07	1.39	1.72
TPH	ppm	6.67	8.63	24.47	5.47	6.66	82.56	6.32	22.33	18.58	5.20	8.00	6.94

Table 6. Grouping and ranking of impacts in industrial area [4]

Rank	**Parameter/SI unit**	**Onne**			**Agbada**			**Trans Amadii**			**+**	**-**	**% -ve**	**IM**
	Month	**April**	**July**	**Sept**	**April**	**July**	**Sept**	**April**	**July**	**Sept**				
	Study area	**I1**	**I1**	**I1**	**I2**	**I2**	**I2**	**I3**	**I3**	**I3**				
1	BTEX (ppm)	−	−	−	−	−	−	−	−	−	0	9	100.00	S
2	% TOC	−	−	−	+	−	−	−	−	−	1	8	88.89	S
3	TPH (ppm)	−	−	−	−	−	−	+	−	−	1	8	88.89	S
4	Mg (ppm)	−	−	−	+	−	−	+	−	−	2	7	77.78	H
5	Cu (ppm)	−	+	+	−	−	+	−	−	−	3	6	66.67	H
6	Mn (ppm)	−	−	−	−	−	−	+	+	+	3	6	66.67	H
7	Particle Size (>75µm) [% wt]	+	−	−	+	−	−	+	−	−	3	6	66.67	H
8	Pb (ppm)	−	+	+	−	+	+	−	−	−	4	5	55.56	M
9	PO_4^{3-} (mg/100g)	+	−	−	+	−	+	−	−	+	4	5	55.56	M
10	SO_4^{2-} (mg/100g)	−	−	−	+	+	+	−	−	+	4	5	55.56	M
11	Cr (ppm)	+	+	−	−	−	−	+	+	+	5	4	44.44	M
12	S (mg/kg)	−	−	−	+	+	+	−	+	+	5	4	44.44	M
13	pH	−	+	+	+	+	+	+	−	−	6	3	33.33	L
14	EC (µS/cm)	+	+	+	+	+	+	−	−	−	6	3	33.33	L
15	Ni (ppm)	+	+	+	−	+	+	−	−	+	6	3	33.33	L
16	Ca (ppm)	+	+	−	+	+	−	+	+	−	6	3	33.33	L
17	Na (ppm)	+	−	−	−	−	−	+	−	+	3	6	33.33	L
18	Zn (ppm)	+	+	+	+	+	+	+	−	−	7	2	22.22	L
19	NO_3^- (mg/100g)	+	+	+	−	+	+	−	+	+	7	2	22.22	L
20	NO_2^{--} (mg/100g)	+	+	+	−	+	+	−	+	+	7	2	22.22	L
21	Cd (ppm)	+	+	+	+	+	+	+	+	+	9	0	0.00	N
22	K (ppm)	+	+	+	+	+	+	+	+	+	9	0	0.00	N
+		10	12	10	12	12	13	11	8	11				
−		12	10	12	10	10	9	11	14	11				
IM		54.55 M	45.45 M	54.55 M	45.45 M	45.45 M	40.91 L	50.00 M	63.64 H	50.00 M				

-VE =Increased concentration; +VE = Reduced concentration

Table 7. Grouping and ranking of impacts in agricultural area [4]

Rank	Parameter/SI unit	Aluu			Oquwi			Emohua			+	-	% -ve	IM
	Month	**April**	**July**	**Sept**	**April**	**July**	**Sept**	**April**	**July**	**Sept**				
	Study area	**A1**	**A1**	**A1**	**A2**	**A2**	**A2**	**A3**	**A3**	**A3**				
1	% TOC	−	−	−	−	−	−	−	−	+	1	8	88.89	S
2	Ni (ppm)	+	−	−	−	−	−	−	−	−	1	8	88.89	S
3	BTEX (ppm)	−	−	−	−	−	+	+	−	−	2	7	77.78	H
4	NO_{3-} (mg/100g)	+	+	+	−	−	−	−	−	−	3	6	66.67	H
5	NO_2^{--}(mg/100g)	+	+	+	−	−	−	−	−	−	3	6	66.67	H
6	SO_4^{2-}(mg/100g)	−	+	+	−	−	+	−	−	+	4	5	55.56	M
7	Pb (ppm)	−	+	+	−	−	+	−	−	+	4	4	44.44	M
8	Na (ppm)	+	−	−	+	+	+	+	−	−	5	4	44.44	M
9	S (mg/kg)	−	+	+	−	−	+	−	+	+	5	4	44.44	M
10	Particle Size (>75µm) [% wt]	+	+	−	+	+	+	−	−	−	5	4	44.44	M
11	pH	+	+	−	+	+	−	+	+	−	6	3	33.33	L
12	EC (µS/cm)	+	+	−	+	+	−	+	+	−	6	3	33.33	L
13	Cu (ppm)	+	+	−	+	+	−	+	+	−	6	3	33.33	L
14	Ca (ppm)	+	+	−	+	+	−	+	+	−	6	3	33.33	L
15	Zn (ppm)	+	+	+	+	+	−	+	+	−	7	2	22.23	L
16	PO_4^{3-} (mg/100g)	−	+	+	−	+	+	+	+	+	7	2	22.22	L
17	Cd (ppm)	+	+	+	+	+	−	+	+	+	8	1	11.11	N
18	K (ppm)	+	+	+	+	+	−	+	+	+	8	1	11.11	N
19	Mn (ppm)	+	+	+	+	+	+	+	+	+	9	0	0.00	N
20	Mg (ppm)	+	+	+	+	+	+	+	+	+	9	0	0.00	N
21	Cr (ppm)	+	+	+	+	+	+	+	+	+	9	0	0.00	N
22	TPH (ppm)	+	+	+	+	+	+	+	+	+	9	0	0.00	N
+		16	18	13	13	14	11	14	13	11				
−		6	4	9	9	8	11	8	9	11				
IM		27.27 L	18.18 L	40.91 L	40.91 L	36.36 L	50.00 M	36.36 L	40.91 L	50.00 M				

-VE =Increased concentration; +VE = Reduced concentration

Table 8. Grouping and ranking of impacts in urbanized area [4]

Rank	Parameter/SI unit	GRA phase 2			Diobu			Mguoba			+	-	% -ve	IM
S/N	**Month**	**April**	**July**	**Sept**	**April**	**July**	**Sept**	**April**	**July**	**Sept**				
	Study area	**U1**	**U1**	**U1**	**U2**	**U2**	**U2**	**U3**	**U3**	**U3**				
1	Ni (ppm)	−	+	−	−	−	−	−	−	−	1	8	88.89	S
2	PO_4^{3-} (mg/100g)	−	−	−	−	−	−	+	−	−	1	8	88.89	S
3	Zn (ppm)	−	−	−	−	−	−	−	+	+	2	7	77.78	H
4	Mn (ppm)	−	+	+	−	−	+	−	−	−	3	6	66.67	H
5	TPH (ppm)	−	−	−	−	−	+	−	+	+	3	6	66.67	H
6	% TOC	−	−	+	−	+	+	−	−	+	4	5	55.56	M
7	Ca (ppm)	−	−	+	−	+	+	−	−	+	4	5	55.56	M
8	pH	+	+	−	−	+	−	+	−	+	5	4	44.44	M
9	EC (μS/cm)	+	−	−	+	+	−	−	+	+	5	4	44.44	M
10	Pb (ppm)	+	−	−	−	−	+	+	+	+	5	4	44.44	M
11	Cr (ppm)	−	+	+	−	−	+	−	+	+	5	4	44.44	M
12	NO_{3-} (mg/100g)	+	−	−	+	+	+	−	+	−	5	4	44.44	M
13	NO_2^{--} (mg/100g)	+	−	−	+	+	+	−	+	−	5	4	44.44	M
14	Cu (ppm)	−	+	+	−	−	+	+	+	+	6	3	33.33	L
15	Mg (ppm)	−	+	+	−	+	+	−	+	+	6	3	33.33	L
16	SO_4^{2-} (mg/100g)	+	+	−	+	+	−	+	+	−	6	3	33.33	L
17	S	+	+	−	+	+	−	+	+	−	6	3	33.33	L
18	Particle Size (>75μm) wt%	−	+	+	−	+	+	−	+	+	6	3	33.33	L
19	Cd (ppm)	−	+	+	+	+	−	+	+	+	7	2	22.22	L
20	Na (ppm)	+	+	+	−	+	+	−	+	+	7	2	22.22	L
21	K (ppm)	+	+	+	−	+	+	−	+	+	7	2	22.22	L
22	BTEX (ppm)	+	+	+	+	+	+	+	+	+	9	0	0.00	N
+		10	13	11	7	8	14	8	16	15				
−		12	9	11	15	14	8	14	6	7				
IM		54.55	40.91	50.0	68.18	63.63	36.36	63.63	27.27	31.81				
		M	M	M	H	H	L	H	L	L				

-VE =Increased concentration; +VE = Reduced concentration

and Particle Size recorded IM of 44.44% and were classified as medium impact (M). Electrical conductivity (EC) pH, Cu, Ca recorded IM of 33.33% while Zn, PO_4^{3-} recorded IM of 22.22% respectively and were classified as low impact (L). Cadmium (Cd) and K recorded IM of 11.11% while Mn, Mg, Cr, and TPH recorded IM of 0.00% and were classified as negligible impact (N) [Table 7].

In the urbanized areas, Ni and PO_4^{3-} recorded the highest IM of 88.89% and were classified as severe (S). Zinc (Zn) recorded IM of 77.78% while Mn and TPH recorded IM of 66.67% and were classified as medium impact (M). Copper (Cu), Mg, SO_4^{2-}, S, Particle Size recorded IM of 33.33% while Cd, Na and K recorded IM of 22.22 and were classified as low impact (L). BTEX recorded IM of 0% and was classified as negligible (N) [Table 8].

4. DISCUSSION

BTEX recorded an IM of 100% in industrial area (S), 77% in agricultural areas (H) and 22% in urbanized areas (L). Contamination of soils with BTEX in the industrial areas could be associated with petroleum industry as the area is host to NNPC Refinery, SPDC flow station and other industries like Schlumberger and Hallburton. There is possible link of the industries to contamination of the soils as seen by a lesser IM of 77% in the agricultural and 22% in the urban areas. BTEX is easily dispersed by water from points of original contamination to different locations [13]. BTEX is associated with petroleum industry and has serious implications with pollution of the environment which is health risk as they can cause nervous disfunction, cancer and renal and olfactory impairment [14]. Percent (%) TOC in industrial and agricultural areas had an IM of 88.89% and were classified as (S). Urbanized areas had an IM of 55.56% in urbanized areas and was classified (M). TOC indicates soil fertility as well as quality thus has great influence on sustainability of agriculture [15]. The current findings of TOC ranged from 1.2 to 11.70% (Table 3, 4 and 5) where the highest values were recorded in the industrial as compared to urbanized and agricultural areas. The current findings are in agreement with findings of Cambou [16] who demonstrated that soils in the open city hold more carbon stocks as compared to agricultural areas. TOC in agricultural areas are more beneficial in food production as compared to those in open soils in cities or urban setups which is not the case in this finding. Total Petroleum Hydrocarbon (TPH) had an IM of 88.89% in industrial areas (S), 0% in agricultural areas (N) and 66.67% in urbanized areas (H). Total petroleum hydrocarbon (TPH) can be attributed to accidental spills, industrial wastes or as byproducts in processing of crude oil [17]. The findings are in agreement with the findings of Kuang [17], which revealed that TPH were detected in soils which were closest to aging oil sludge as the study areas are host to petroleum companies (Table 1).Therefore, the current findings demonstrate that the petroleum industries in the industrial areas and the urbanized areas contribute to contamination of soils as contrasted to flow stations in agricultural setup which recorded 0% IM. Magnesium (Mg) had an IM of 77.78% in industrial area (H), 0% in agricultural areas (N) and 33.33% in urbanized areas (L). Sources of Mg in soils include; parent rock, water runoffs and industrial wastes and loss from the soil through fixation by colloids and water runoffs. The results demonstrated that variation in the levels of Mg in the soil was impacted with activities in industrial areas as compared to agricultural and urbanized areas. Quantity of Mg decreases as pH increases and therefore pH is a major contributing factor to levels of Mg in the soil [18]. High levels of exchangeable Al may also influence the levels of Mg. Levels of other exchangeable ions, for example, Ca, K^+ and NH_4^+ can also affect levels of Mg [18]. The findings reveal that industrial activity impacts higher to levels of Mg in soils as compared to activities in the agricultural as well as the urban areas in the study areas. Copper (Cu)recorded an IM of 66.67% in industrial area (H), 33.33% in agricultural areas (L) and 33.33% in urbanized areas (L). The findings of this study are in agreement with those of Chen et al., [19] who demonstrated that contamination of soil with Cu was associated with proximity to the sources of the copper which were the roads [19]. In the current study copper is associated with industrial areas as is demonstrated by the findings. Agricultural and urban areas recorded lower IM as compared to industrialized areas. Manganese (Mn) recorded an IM of 66.67% in industrial area (H), 0% in agricultural areas (N) and 66.67% in urbanized areas (H). Manganese is generally considered a major component of soil [20]. The findings of this study are in agreement with those of Yang [21], where manganese primarily originates from natural sources, however can be skewed by human activity in designated areas as demonstrated in the industrial areas in the current study. Chromium (Cr) had an IM of 44.44% in industrial area (M), 0% in agricultural areas (N) and 44.44% in urbanized areas (M).These findings of Pb and Cr are in agreement with the findings of Yang [21] where they described the top soil of the study areas have noncontaminated to moderately contaminated and therefore indicate moderate pollution. All activities in the study areas have moderate impact on the levels of Chromium in the study areas. Sulphur (S)recorded an IM of 44.44% in industrial area (M), 44.44% in agricultural areas (M) and 33.33% in urbanized areas (L). Sulphur is found in organic and mineralized ($SO_4^{2-} \leftrightarrow S^0 \leftrightarrow S^{2-}$) forms in soil. SO_4^{2-} had an IM of 55.56% in industrial area (M), 55.56% in agricultural areas (M) and 33.33% in urbanized areas (L). The findings of this research are in agreement with those of Abel [5], who demonstrated that urbanized and industrial activities have impact on levels of soil Sulphur as well as mineralized forms of Sulphur [5]. Mineralized Sulphur in form of sulphate is available for plants [22]. Sulphur can leave soil through rainwater, plant residues and animal residues. Sulphur can also be removed from soils through leaching, and volatilization [22]. Sulphur is introduced to soils through fertilizers and pesticides [22]. Soils are a sink of Sulphur and can exist in other forms for example Organic Carbon Sulphide [OCS] [23]. The IM of pH in industrial and agricultural areas was 33.33% and 44.44% in urbanized areas (M). Soil pH is determined by concentration of hydrogen ions [H^+] [24]. Soil pH determines nutrient availability for plants and therefore it is important to monitor soil pH [24]. Activities that can influence pH in soil include, microbial decomposition of carbohydrates, volatilization and loss of ammonia gas, amount of plant residue, misuse of nitrogenous fertilizers, use of lime and Sulphur [24]. Availability of Sulphur and calcium are relatively less in acidic environment but increases with increase in pH [25]. Manganese and zinc are more soluble in acidic conditions but their solubility decreases with increase in pH [25]. Potassium is optimally available over a range of pH but less available in acidic and basic conditions [25]. Nickel (Ni) recorded an IM of 33.33% in industrial area (L), 88.89% in agricultural areas (S) and 88.89% in urbanized areas (S). Variation in concentration of nickel in soil can be influenced by type of soil [26]. This results are in agreement with those of Issn, [27] which demonstrate that wastes from human activities influence levels of heavy metals in soil [27]. Calcium had an IM of 33.33% in industrial area (L), 33.33% in agricultural areas (L) and 55.56% in urbanized areas (S). Calcium is found in soils in different forms for example, $CaCO_3$, exchangeable Ca and simple salts [$CaCl_2$, $CaSO_4$, $CaNO_3$]. Calcium varies in soil according to the parent rock materials. Activities in the study areas pose medium to low IM on calcium levels in the soils. Zinc (Zn) had an IM of 22.22% in industrial area (L), 22.22% in agricultural areas (L) and 77.78% in urbanized areas (H). Zinc had an IM 77.78% and was classified as highly impacted (H) in urbanized areas as compared to agricultural and industrialized areas with IM of 22.22% which were classifieds as low IM (L). This can be attributed to heavy wash off from human settlements [28]. Nitrate (NO_3^-) and Nitrite (NO_2^-) recorded IM of 22.22% in industrial area (L), 66.67% in agricultural areas (H) and 44.44% in urbanized areas (M). Overuse of nitrogenous fertilizers and disposal of nitrogenous wastes cause elevated levels of nitrogenous complexes in the environment [29]. Therefore, it is necessary to continuously monitor quantities of Nitrogen and its complexes in the environment. The high IM in agricultural areas as compared to industrial and urbanized areas demonstrates that activities in the different study areas impact differently on levels of nitrogen in the soils in the study areas. Removal of nitrogen from one place to another involves leaching, plant uptake, ammonia volatilization, denitrification and through runoff and erosion [30,31,32]. The results are in agreement with results of Zhou [33], who demonstrated that NO_3^- accumulates in humid croplands [33]. Cadmium (Cd) had an IM of 0% in industrial area (N), 11.11% in agricultural areas (N) and 22.22% in urbanized areas (L). The findings can be related to findings of [28]. Contamination of soils with cadmium is closely related to industrial activities in a particular area, for example metal processing industries. As revealed by the findings, there was minimal IM as related to the findings classified as negligible in industrial and agricultural areas and low IM in urbanized areas. In contrast to the study by [19], Cd recorded low impact while Pb recorded moderate impact from human activities in the three study areas, which revealed minimal impact from human activities. Lead (Pb) had an IM of 55.56% in industrial area (M), 44.44% in agricultural areas (M) and 44.44% in urbanized areas (M). The findings of this study are in agreement with those of Woszczyk [34], who described soils in urban and industrial areas to have strong polymetallic pollution [Cd, Cu, Pb and Zn] [34]. Atmospheric deposition of dusts from industries, fuel and gasoline combustion and smelting of metals is primary source of metal pollution in soils [35]. Potassium (K) recorded an

IM of 0% in industrial area (N), 11.11% in agricultural areas (N) and 22.22% in urbanized areas (L). The findings are in agreement with findings of Guan et al., [36], who demonstrated that levels of P and K can be influenced by both intrinsic and extrinsic factors [36]. Phosphates (PO_4^{3-}) had an IM of 55.56% in industrial area (M), 22.22% in agricultural areas (L) and 44.44% in urbanized areas (M). Results demonstrate that human activity in all study areas has low to negligible impact on levels of K but demonstrated that activities in urban areas have impact on levels of phosphates in soils. Activities in industrial and agricultural areas showed moderate and low impact respectively.

5. CONCLUSION AND RECOMMENDATION

In order to give special attention to waste management for Sustainable Development Goal (SDG11), it is important to determine the level physicochemical parameters in soil. Further, EM of impacts of anthropological activities on the levels of the physicochemical parameters is important for determination of measures to be considered in case mitigation is required. In this study, impact of human activity on levels of soil physicochemical parameters was determined using Rau and Wooten Scheme [4]. The study concludes that urbanization, industrialization and agricultural activities do affect the level of physicochemical parameters in soils of the study areas. The study summarizes the findings as:

- Activities in industrial areas negatively impact on levels of BTEX, % TOC, TPH, Mg, Cu and Mn in soils.
- Activities in agricultural areas negatively impact on levels of % TOC, Ni, BTEX, NO_3^-, NO_2^- and SO_4^{2-} in soils.
- Activities in urban areas negatively impact on levels of Ni, PO_4^{3-}, Zn, Mn, TPH, % TOC and Ca in soils.

These findings form a baseline that is reliable for future researchers in monitoring of pollution by physicochemical material in the study areas. Further, the findings foster application of Rau and Wooten [4] Scheme in environmental monitoring in order to minimize pollution for sustainable development. The study recommends continual monitoring of these parameters in the study area in order to ensure a healthy soil for food production and hence a healthy population (SDG3).

ACKNOWLEDGEMENT

This work was carried out within the PhD Program of World Bank African Centre of Excellence for Oilfield Chemicals Research, in line with the World Bank's mandate for establishing the African Centre of Excellence in University of Port Harcourt in Nigeria. The authors further acknowledge the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) through Doctor Odogwu A. Blessing and Professor Ikechukwu O. Agbagwa of University of Port Harcourt for their continual mentorship and financial support under the Carnegie Post-Doctoral funding.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bhatt RP, Khanal SN. Environmental impact assessment system and process: A study on policy and legal instruments in. 2010;586–594. Available:http://www.academicjournals.org/AJEST
2. Ghasemian M, Poursafa P, Amin MM, Ziarati M, Ghoddousi H, Momeni SA, Environmental impact assessment of the industrial estate development plan with the geographical informatio environmental impact assessment of the industrial estate development Plan with the Geographical Information; 2014. Available:https://doi.org/10.1155/2012/407162
3. Khadka RB, Mathema A, Shrestha. U. S. Journal of Environmental Protection, Determination of the significance of environmental impacts of development projects: A Case Study of Environmental Impact Assessment of Indrawati-3 Hydropower Project in Nepal. 2011; 1021–1031. Available:https://doi.org/10.4236/jep.2011.28117
4. Rau JG, Wooten DC. Environmental Impact Analysis Handbook, McGraw-Hill Book Company, New York; 1980. Available:https://www.amazon.com/Environmental-Impact-Analysis-Handbook-John/dp/0070512175

5. Abel S, Nehls T, Mekiffer B, Mathes M, Thieme J, Wessolek G. Pools of sulfur in urban rubble soils. Journal of Soils and Sediments. 2014;15(3):532–540. Available:https://doi.org/10.1007/s11368-014-1014-1
6. Population Division of United Nations, Department of economic and social affairs (desapdun). world urbanization prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352); United Nations: New York, NY, USA; 2014. Available:https://esa.un.org/unpd/wup/publications/files/wup2014-report.pdf
7. Nadia Mirabella KA. The assessment of Urban environmental impacts through the city Environmental Footprint: methodological framework and first approach to built environment. 2018;69: 83–88. Available:https://doi.org/10.1016/j.procir.2017.11.063
8. Wanjala PM, OOL, Ramkat RC, Etela I. Oil-Gas and environmental nexus: Impact of Human Actions on selected Soil Physicochemical Parameters in Port Harcourt and its environment, Nigeria. 2018;22(11):1863–1870. DOI:https://dx.doi.org/10.4314/jasem.v22i11.23
9. Wanjala PM, OOL, Ramkat RC, Etela I. Assessment of soil metals status in parts of rivers state, Nigeria. J. Appl. Sci. Environ. Manage. 2019;23(3):545–550. DOI:https://dx.doi.org/10.4314/jasem.v23i3.26
10. BSI. BS 1377: 1990—Methods of Test for Soils for Civil Engineering Purposes. British Standards Institute; 1990. Available:http://worldcat.org/isbn/058018030
11. American Public Health Association (APHA, 1995). Standard Method for Examination of Water and Waste Water. 19th Edition, Published by E and F N Poan, Washington D.C.; 2-56.
12. Odokuma Obukowho Lucky, KWR, Rep Opinion, Post Impact Assessment of Urbanization on Microbial Abundance and Diversity of Soils in Port Harcourt Area. 2017;9(4):48–56. Available:https://doi.org/10.7537/marsroj090417.05.Key
13. Cheng Y, Chen Y, Jiang Y, Jiang L, Sun L, Li L, Huang J. Migration of BTEX and Biodegradation in Shallow Underground Water through Fuel Leak Simulation, BioMed Research International. 2016;1–9. Available:https://doi.org/10.1155/2016/7040872
14. Lamplugh A, Harries M, Xiang F, Trinh J, Hecobian A, Montoya LD. Occupational exposure to volatile organic compounds and health risks in Colorado nail salons *. Environmental Pollution. 2019;249: 518–526. Available:https://doi.org/10.1016/j.envpol.2019.03.086
15. Tamburini E, Vincenzi F, Costa S, Mantovi P, Pedrini P, Castaldelli G, Effects of moisture and particle size on quantitative determination of total organic carbon (TOC) in soils using near-infrared spectroscopy. Sensors (Switzerland), Sensors. 2017;17(10):1–15. Available:https://doi.org/10.3390/s17102366
16. Cambou A, Shaw RK, Huot H, Vidal-beaudet L, Hunault G, Cannavo P, Schwartz C. Science of the Total Environment Estimation of soil organic carbon stocks of two cities, New York City and Paris. Science of the Total Environment. 2018;644:452–464. Available:https://doi.org/10.1016/j.scitotenv.2018.06.322
17. Kuang S, Su Y, Wang H, Yu W, Lang Q, Matangi R. Soil Microbial Community Structure and Diversity around the Aging Oil Sludge in Yellow River Delta as Determined by High-Throughput Sequencing, Archaea; 2018. Available:https://doi.org/10.1155/2018/7861805
18. Liu GD, Hanlon E. Soil pH Range for optimum commercial vegetable production. HS1207. Gainesville: University of Florida Institute of Food and Agricultural Sciences; 2012. Available : http://edis.ifas.ufl.edu/hs1207
19. Chen X, Xia X, Zhao Y, Zhang P. Heavy metal concentrations in roadside soils and correlation with urban traffic in Beijing, China. Journal of Hazardous Materials. 2010;181(1–3):640–646. Available:https://doi.org/10.1016/j.jhazmat.2010.05.060
20. Socha AL, Guerinot MLou. Mn-euvering manganese: The role of transporter gene family members in manganese uptake and mobilization in plants. 2014;1–16.

Available:https://doi.org/10.3389/fpls.2014.00106

21. Yang Z, Lu W, Long Y, Bao, X., & Yang, Q. Assessment of heavy metals contamination in urban topsoil from Changchun City, China. Journal of Geochemical Exploration. 2011;108(1): 27–38.
Available:https://doi.org/10.1016/j.gexplo.2010.09.006
22. Cornell University Cooperatve Extensions. Sulfur for Field Crops. Agronomy Fact Sheet Series. 2007;1–2. Available:http://nmsp.cals.cornell.edu/publications/factsheets/factsheet34.pdf
23. Meredith LK, Boye K, Youngerman C, Whelan M, Ogée J, Sauze J, Wingate L. Soil Systems, Coupled Biological and Abiotic Mechanisms Driving Carbonyl Sulfide Production in Soils. 2018;2(3): 37.
Available:https://doi.org/10.3390/soilsystems2030037
24. Mccauley A, Jones C, Olson-Rutz K. Soil pH and organic matter. Nutrient Management, Module No.(4449–8). 2017;16.
Available:http://landresources.montana.edu/nm/documents/NM8.pdf
25. Grattan S. Soil pH Extremes; 2016. Available:https://doi.org/10.1079/9781845939953.0194
26. Zhang X, Li J, Wei D, Li B, Ma Y. Predicting soluble nickel in soils using soil properties and total nickel. PLoS ONE. 2015;10(7):1–13.
Available:https://doi.org/10.1371/journal.pone.0133920
27. Imarhiagbe EE, Osarenotor O, Obayagbona ON, Eghomwanre AF, Nzeadibe BN. Evaluation of Physicochemical, microbiological and polycyclic aromatic hydrocarbon content of top soils from oka market waste collection site, benin city, Nigeria. J. Appl. Sci. Environ. Manage; 2017. Available:http://dx.doi.org/10.4314/jasem.v21i1.12
28. Lu CA, Zhang JF, Jiang HM, Yang JC, Zhang JT, Wang JZ, Shan HX. Assessment of soil contamination with Cd, Pb and Zn and source identification in the area around the Huludao Zinc Plant. Journal of Hazardous Materials. 2010;182(1–3):743–748.
Available:https://doi.org/10.1016/j.jhazmat.2010.06.097
29. Payne RJ, Dise NB, Field CD, Dore AJ, Caporn SJM, Stevens CJ. Nitrogen deposition and plant biodiversity: past, present, and future, Frontiers in Ecology and the Environment. 2017;15(8):431–436.
Available:https://doi.org/10.1002/fee.1528
30. Gu B, Ju X, Chang J, Ge Y, Vitousek P M. Integrated reactive nitrogen budgets and future trends in China, Proceedings of the National Academy of Sciences. 2015;112(28):8792–8797.
Available:https://doi.org/10.1073/pnas.1510211112
31. Shan J, Zhao X, Sheng R, Xia Y, Ti C, Quan X, Yan X. Dissimilatory nitrate reduction processes in typical chinese paddy soils: rates, relative contributions, and influencing factors. Environmental Science and Technology. 2016;50(18): 9972–9980.
Available:https://doi.org/10.1021/acs.est.6b01765
32. Xia L, Lam SK, Yan X, Chen D. How does recycling of livestock manure in agroecosystems affect crop productivity, reactive nitrogen losses and soil carbon balance? Environ. Sci. Technol. 2017; 51(13):7450–7457,1–28.
Available:https://pubs.acs.org/doi/10.1021/acs.est.6b06470
33. Zhou J, Gu B, Schlesinger WH, Ju X. Significant accumulation of nitrate in Chinese semi-humid croplands. Scientific Reports. 2016;6:1–8.
Available:https://doi.org/10.1038/srep25088
34. Woszczyk M, Spychalski W, Boluspaeva L. Trace metal (Cd,Cu,Pb,Zn) fractionation in urban-industrial soils of Ust-Kamenogorsk (Oskemen), Kazakhstan- implications for the assessment of environmental quality. Environmental Monitoring and Assessment. 2018;190(6).
Available:https://doi.org/10.1007/s10661-018-6733-0
35. Pacyna JM, Pacyna EG. An assessment of global and regional emissions of trace metals to the atmosphere from anthropo-

genic sources worldwide. Environmental Reviews. 2001;9:269-298.
Available:https://doi.org/10.1139/er-9-4-

36. Guan F, Xia M, Tang X, Fan S. Catena, Spatial variability of soil nitrogen, phosphorus and potassium contents in Moso bamboo forests in Yong'an City, China. 2017;150:161–172.
Available:https://doi.org/10.1016/j.catena.2016.11.017

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/47040