EFFECTS OF FARMING ACTIVITIES ON SOIL QUALITY OF OBINNA RIVER WATERSHED, ADANI UZO-UWANI LOCAL GOVERNMEMT AREA OF ENUGU STATE, NIGERIA

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ABSTRACT
Agricultural pollution has become increasingly a prominent pollution problem. The study aimed to ascertain the effects of farming activities on soil quality of Obinna River watershed in Adani community, Uzo-Uwani Local Government Area. Data were collected in the field for analysis through experimentation. Soil samples from Adani agricultural farmland were collected for laboratory analysis of physicochemical parameters which were used to determine the concentration of physical and chemical constituents of Obinna River and the correlation between agricultural effluent and its contribution to the soil quality of Obinna River. The concentration of heavy metals (Fe, Cd, Cr, Pb, Cu, Zc and Ni) in soil from Obinna River were analyzed using atomic absorption spectrophotometer. The results obtained were compared with control area, local and global standards for soil. The study questionnaire was determined using Taro Yamane's formula. The data collected for laboratory analysis were subjected to descriptive statistical analysis (Analysis of Variance Test). Sand was predominant in sediments with highest mean particle size distribution 69.03% sand, 11.70% silt and 15.76% clay across the two seasons. Natural origins, fertilizer application and domestic waste were identified as the major sources of heavy metals in soils.

Key Words: Pollution, Heavy Metals, Soil, Effluents, Farming Activities.

INTRODUCTION

The government of Enugu State in Nigeria set out to prioritize food security towards enhancing the welfare of her citizens. This she did by acquiring the vast land by the Obinna River for mechanized farming activities. Today agricultural activities have been on increase within the surrounding farmlands of Obinna River and this also increases the farmers demand for fertilizers and other chemical inputs which contain volumes of elements ranging from macro nutrients such as nitrates, phosphates and potassium and trace elements such as calcium, magnesium, sulphur boron and copper (Agu *et al.*, 2014). The introduction of pollutants into the Obinna River watershed could be as a result of a number of natural processes or influences by human activities within the area, such as agricultural activities among others. The use of these agricultural chemicals induces pressure on ecosystems and can directly or indirectly, positively or negatively affect the services of a functioning ecosystem.

Agriculture is one of the most important primary economic activities of man and it is the basis of food supply to the entire population of the world (Smith, 2009). It encompasses the production of food, feed, fibre and other goods through the systematic raising of plants and animals (Diao *et al.,* 2010). Although the activity is defined variously in different parts of the world, it mostly includes raising of crops and animals (Hubbard and Gorton, 2011). The history of agriculture in the world dates back to thousands of years and its development has been driven and designed greatly by different climate culture and technologies especially in the developing countries like Nigeria (Olomola, 2007). Consequently, a lot of efforts have been made in improving the agriculture practices in Nigeria, particularly in Adani town of Enugu State. Naturally,

Adani town is endowed with vast agricultural lands with extensive rainfed flood area and forest products such as oil palm and timber wood. Agricultural activity in Adani town is predominantly subsistence, with few commercial which is based on comparatively large scale cultivation of yam, cassava and also fish farming. There have been increases in the number of migrants from the densely settled slow growing and land hungry rural area of Awka, Orlu, Okigwe and Eastern Onitsha areas who have moved into Adani town in exploiting the vast agricultural potentialities of the area which are beyond the capability of the local people (Ani, 2010). Moreover, a number of agricultural enterprises have been established to tap the agricultural potentialities of Adani town. They includes Enugu State River project which is public production project, United palm produce Ltd and private enterprise participation which is maize and cassava farm which are very large scale agricultural enterprises all in Adani town.

With all these farming activities going on around Obinna River, it is therefore pertinent to find out the effects of these activities on the soil within the watershed, hence this study.

STUDY AREA

Obinna River watershed in Adani town, Uzo-Uwani Local Government Area of Enugu State is located between latitudes 6^o 03'N and 6^o 44'N and longitudes 7^o 01'E and 7^o 03'E as shown in Figure 1. It is bounded to the north by Nsukka Local Government Area, to the east by Udi Local Government Area and to the south by Ayamelum Local Government Area in Anambra State. Adani community has a total population of 43264 (forty-three thousand, two hundred and sixty four) persons in 2021 projected from the National population census (NPC, 2006).

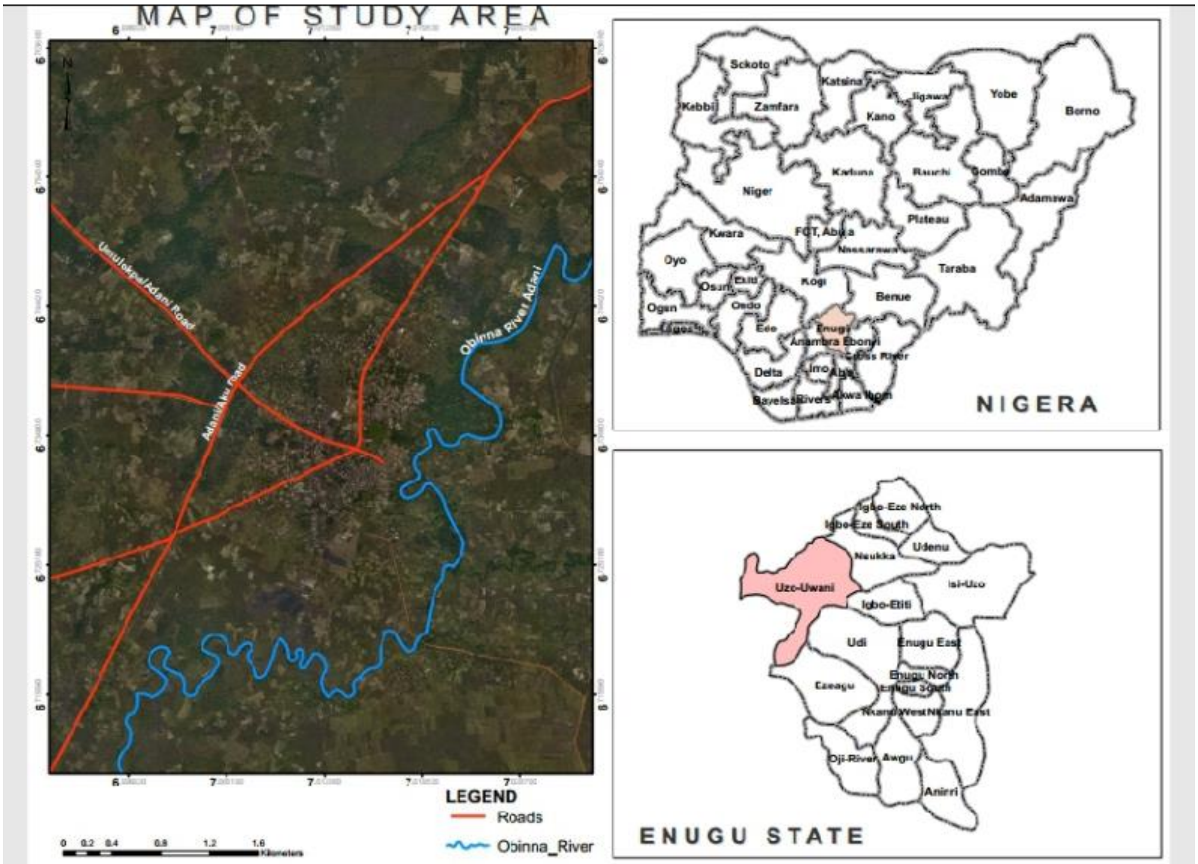

Figure1: Obinna River Watershed
Source: Author, 2023

The climate of Adani in Uzo-Uwani Local Government Area of Enugu State belongs to the tropical wet-and-dry savanna. Two main seasons prevail in this area, dry season and wet season. It experiences an average of eight months rainfall between March to October and four months dry season between November to February. It has an average rainfall amount vary between 1800metres and 2000metres (Anyadike, 2002). Adani is characterized by mean annual rainfall of between 2250 millimeters, which arrives intermittently and becomes very heavy during the rainy season. The area has high relative humidity during the wet season between March and October and low values during the dry season. The average temperature of the area is about 27^0C, with variations throughout the year. Other weather conditions affecting the area include Harmattan, a dusty trade wind lasting for a few weeks during the dry season.

The soil of Adani is underlined by pale brown hydromorphic molted clay soil derived from the impervious Imo shales with the North Section of Anambra plain in the west (Epundu, 2010). The soil is also predominantly clay as well as hydromorphic especially during the rainy season and the water logged conditions tends to prevail (Ofomato, 2002). The inhabitants of Adani town are predominantly farmers. The farmers make use of farmyard, compost and green manures and different combination of NPK and Urea fertilizer. Adani is naturally endowment with large expanse of fertile land. The soil of Adani, like most of the humid tropics is subjects to leaching of the basic materials needed for plant growth. However, the annual flooding of the swamps deposit a layer of very rich silt regularly, thereby helping to restore the fertility of the soil at the lowland.

The geology of the area falls into two main geological groups; The Imo clay shale which occupies the western extremities within the northern section of Anambra plain and the rest of the area is made up of the lower and upper coal measures and false-bedded sandstone (Epundu, 2010). Adani is located on the north lowland area of Nsukka plateau with a gentle and gradual slopping surface down to Anambra plain at the western side. Adani consists of vast area of vegetation and forest. Some vegetation and forest area have been cleared for agricultural use as population increases (Enugu State, 2014).

Adani community is largely made up of farmers. Adani residence relied on agriculture as a major source of income since 1950s and suitable soil and favorable climate conditions enable the area to produce many forms of cash crop. Additionally a smaller proportion of livestock farming exist (Ajani *et al*., 2015). Fishing activities carried out in Obinna River watershed and some depressions pits and canals by different methods which include pumping out water from those depressions and the use of hooks, line, and sinker.

Table 1: soil sampling points

Locations	Co-ordinates of the study locations		Human activities
Station 1	N 6º 43' 30.31"	E 6º 59' 21.589"	Garden egg farmland
Station 2	N 6º 43' 31.814"	E 6º 59' 19.862"	Cocoyam farmland
Station 3	N 6º 43' 33.282"	E 6º 59' 19.362"	Rice farmland
Station 4	N 6º 43' 34.884"	E 6º 59' 19.266"	Maize farmland
Station 5	N 6º 43' 35.472"	E 6º 59' 19.284"	Yam farmland
Station 6	N 6º 43' 37.266"	E 6º 59' 19.224"	Melon farmland
Station 7	N 6º 43' 33.487"	E 6º 59' 19.352"	Cassava farmland
Station 8	N 6º 43' 30.655"	E 6º 59' 22.478"	Tomato farmland
Station 9	N 6º 43' 28.144"	E 6º 59' 22.99"	Pepper farmland
Station 10	N 6º 43 '27.939"	E 6º 59' 23.091"	Cucumber farmland
Control area	N 6º 43' 27.557"	E 6º 59' 22.87"	fallow land

METHODOLOOGY

Soil samples were collected using the soil auger from ten selected stations within the surrounding agricultural farmlands (Table 1) at 10km apart for physicochemical and heavy metals analysis. The sampling bore to depths of 0-15cm, 15– 30cm and 30-45cm. These three samples collected from each of the locations were mixed in a clean bowl to form a composite sample. All the composite samples were air dried at room temperature and sieved using a 2mm sieve. The samples were poured into polythene bags, labeled adequately and were taken to the laboratory for analysis of heavy metals, physical parameters and some nutrients.

For heavy metal analysis, the soil samples were first air-dried at room temperature, ground in a ceramic mortar and sieved through 0.2mm mesh and about one gram of the pulverized sample was digested with HNO_3, HF, and $HCLO_4$ in a microwave device. This was then diluted to 50ml with distilled water. The digested samples were then transferred into separate plastic bottles, labeled and stored for the analysis according to Turkmen and Ciminli, (2007). The heavy metals analyzed were lead (Pb), Zinc (Zn), Chromium (Cr), Copper (Cu), and Iron (Fe) using atomic absorption spectrophotometer after calibration.

RESULTS AND DISCUSSIONS

Table 2: Mean concentration of physical properties of soils surrounding Obinna River stations

Station	Sand %	Silt%	Clay%
S1	27.03 ± 2.09^{b}	11.75 ± 5.12^{ab}	59.54 ± 3.20^{b}
S2	22.06 ± 3.05^{b}	15.66 ± 0.46^{b}	60.02 ± 4.81^{c}
S3	19.75 ± 3.21^{a}	15.37 ± 0.05^{b}	61.69 ± 5.28^{c}
S4	21.67 ± 2.12^{bc}	12.32 ± 3.23^{c}	60.31 ± 4.34^{c}
S5	23.36 ± 4.32^{c}	10.46 ± 2.34^{a}	62.21 ± 3.23^{d}
S6	20.47 ± 1.21^{b}	15.30 ± 1.43^{e}	59.32 ± 2.12^{b}
S7	26.02 ± 3.21^{cd}	13.25 ± 0.23^{cd}	63.43 ± 2.12^{e}
S8	22.04 ± 3.13^{cd}	15.64 ± 3.13^{de}	62.62 ± 3.21^{e}
S9	26.43 ± 2.14^{cd}	14.42 ± 2.14^{cd}	63.65 ± 1.21^{e}
S10	23.32 ± 1.21^{c}	13.32 ± 0.32^{c}	61.45 ± 4.32^{cd}
Control	32.58 ± 1.52^{d}	9.54 ± 0.15^{a}	57.55 ± 3.18^{a}
Mean	24.06	13.37	61.07
CV	15.40	16.10	3.10

Different alphabet superscripts in the same column means there is a significant difference at p>0.05 while same alphabetical superscripts in the same column means no significant difference at p>0.05:

Table 2 presents the particle size composition of the soil at different stations in the study area. It can be seen that in the first station (s_1), the particles size distribution recorded that the samples consist of 27.03% sand, 11.25% silt and 59% clay. Station s_2 has the highest silt mean value of 15.66% when compared with the control mean and average mean value of 9.54% and 13.37% respectively. The sand and clay also recorded 22.06% and 60.02% respectively. With regards to station s_3 the sand particles recorded the lowest mean value of 19.75% in the station. The silt and clay particle showed 15.37% and 61.69% respectively.

At station s_4, the particle size distribution recorded that the soil consist of sand 21.67%, silt 12.32%, and clay 60.31%. Meanwhile, stations s_5 showed sand 23.36%, silt 10.46%, clay 62.21%. Station s_1 and s_6 recorded the lowest clay mean value of 59.54% and 59.32% respectively when compared with the average mean of 61.07%. Station s_6 also recorded 20.49% and 15.30% silt. Station s_7 and s_9 recorded the highest clay mean value of 63.43% and 63.65% respectively when compared with the control mean value of 57.55% and average mean value of 61.07%. At station s_{10} the particle size distribution showed that the soil consist of sand 23.32%, silt 13.32%, and clay 61.45%.

In this study the CV mean value of all the stations from S_1 to S_{10} 15.40% for sand, 16.10% for silt and 3.10% clay. The CV mean value of sand and silt fraction from S_1 to S_{10} is above CV ≥ 15% described as moderate variation. Meanwhile the CV mean value of clay from S_1 to S_{10} was far below CV < 15% described as low variation. Coefficient of variation as used by (Wilding *et al.*, 1994) was used to estimate the degree of variability existing among the soil particles, where CV < 15% = low variation, CV ≥ 15% ≤ 35% = moderate variation, CV > 35% = high variation. The moderate CV variation recorded in silt content could be as a result of the interference of farming activities to the environmental quality. Environmental quality can be strongly affected by farming activities and produce a higher CV of elemental concentration (Lian *et al.*, 2019).

The sand, silt and clay fractions of the soils differed within the soil stations as presented. The most probable reasons for these variations in particle size at different stations may be as a result of difference in topography, slope gradient and parent material. Similarly, (Thangasamy *et al.*, 2005) reported that variation in soil texture may be caused by variation in parent material, topography, in-situ weathering and translocation of clay. Soils of lower elevation sites had higher clay content than higher elevations (Sitanggang *et al.*, 2006).

The soil texture in this study area is generally dominated by sandy clay with some gravel using the textural classification scheme of the United States Soil and Agricultural Conservation (Igwe, 1984). It explains why crops like cassava, rice, vegetables, maize and others grow well in the soil with high clay content. This is because clay is known for its alluvial content which aids in the proper growth of crops.

Table 3: mean concentration of chemical properties soil surrounding Obinna River

	pH	**P**	**N**	**OC**	**OM**	**Ca**	**Mg**	**K**	**Na**	**EA**	**EC**	**BS**
S1	4.83 ± 0.30^{a}	s15.06 ± 7.87^{a}	0.04 ± 0.04^{b}	0.46 ± 0.46^{b}	1.08 ± 0.69^{a}	2.60 ± 0.20^{a}	1.43 ± 0.20^{a}	0.16 ± 0.01^{b}	0.14 ± 0.00^{a}	2.14 ± 0.12^{b}	6.50 ± 0.17^{b}	66.56 ± 1.50^{b}
S2	4.49 ± 0.10^{a}	21.36 ± 3.15^{a}	0.08 ± 0.05^{d}	1.02 ± 0.15^{b}	1.62 ± 0.26^{bc}	2.60 ± 0.20^{a}	1.76 ± 0.20^{ab}	0.15 ± 0.01^{a}	1.66 ± 0.22^{e}	6.51 ± 0.24^{a}	7.43 ± 0.24^{e}	74.43 ± 4.53^{c}
S3	4.66 ± 0.29^{ab}	25.73 ± 6.91^{a}	0.09 ± 0.00^{d}	1.10 ± 0.30^{c}	1.99 ± 0.54^{c}	3.13 ± 0.11^{c}	1.80 ± 0.52^{ab}	0.17 ± 0.01^{b}	0.12 ± 0.01^{a}	1.77 ± 0.01^{a}	6.76 ± 0.47^{b}	72.59 ± 2.31^{c}
S4	4.53 ± 0.12^{ab}	23.43 ± 1.43^{c}	0.03 ± 0.01^{b}	1.12 ± 0.12^{c}	1.50 ± 0.34^{ab}	2.70 ± 0.21^{ab}	1.65 ± 0.01^{ab}	0.14 ± 0.01^{a}	1.22 ± 0.02^{d}	5.64 ± 0.03^{e}	7.75 ± 0.03^{cd}	68.54 ± 3.21^{bc}
S5	5.50 ± 0.34^{bc}	17.63 ± 0.08^{ab}	0.05 ± 0.01^{bc}	1.05 ± 0.04^{b}	1.80 ± 0.21^{c}	2.10 ± 0.32^{a}	1.56 ± 0.02^{a}	0.16 ± 0.02^{ab}	0.20 ± 0.01^{b}	3.45 ± 0.02^{cd}	6.34 ± 0.02^{a}	70.56 ± 3.32^{bc}
S6	4.65 ± 1.21^{ab}	20.45 ± 0.06^{b}	0.06 ± 0.05^{c}	1.18 ± 0.05^{c}	1.07 ± 0.12^{a}	2.40 ± 0.10^{a}	1.75 ± 0.02^{c}	0.15 ± 0.03^{a}	0.10 ± 0.03^{a}	4.53 ± 0.01^{d}	8.56 ± 0.03^{d}	65.00 ± 2.22^{b}
S7	4.54 ± 2.12^{a}	24.34 ± 1.01^{c}	0.05 ± 0.05^{bc}	0.97 ± 0.03^{ab}	1.30 ± 0.21^{b}	3.10 ± 0.22^{c}	1.64 ± 0.01^{ab}	0.14 ± 0.01^{a}	1.10 ± 0.04^{de}	2.34 ± 0.00^{c}	6.45 ± 0.04^{ab}	63.55 ± 1.21^{a}
S8	5.34 ± 1.21^{bc}	19.43 ± 0.23^{a}	0.02 ± 0.03^{a}	1.00 ± 0.03^{ab}	1.65 ± 0.01^{bc}	2.50 ± 0.01^{bc}	2.10 ± 0.12^{d}	0.15 ± 0.03^{ab}	0.30 ± 0.01^{bc}	5.43 ± 0.01^{de}	7.45 ± 0.02^{c}	64.65 ± 3.42^{ab}
S9	4.33 ± 3.21^{a}	23.31 ± 1.21^{b}	0.07 ± 0.00^{d}	1.07 ± 0.21^{ab}	1.89 ± 0.43^{d}	2.45 ± 0.04^{bc}	1.35 ± 0.30^{a}	0.17 ± 0.01^{b}	1.32 ± 0.02^{de}	1.67 ± 0.02^{de}	5.68 ± 0.04^{a}	69.56 ± 4.32^{c}
S10	5.43 ± 1.00^{bc}	25.65 ± 2.11^{c}	0.04 ± 0.01^{b}	1.20 ± 0.12^{b}	2.09 ± 0.01^{e}	3.27 ± 0.32^{d}	2.35 ± 0.10^{de}	0.13 ± 0.03^{e}	0.50 ± 0.03^{c}	2.16 ± 0.01^{c}	6.54 ± 0.05^{ab}	72.65 ± 1.11^{ab}
Control	5.67 ± 0.06^{c}	24.62 ± 1.11^{c}	0.05 ± 0.00^{a}	1.23 ± 0.03^{b}	2.18± 0.02e	3.46 ± 0.15^{e}	2.80 ± 0.10^{e}	0.11 ± 0.00^{a}	0.13 ± 0.00^{a}	0.74 ± 0.02^{a}	7.40 ± 0.04^{c}	90.07 ± 0.50^{d}
Mean	4.91	21.91	0.05	1.04	1.65	2.75	1.84	0.15	0.62	3.31	6.99	70.74
CV	9.80	15.80	39.90	20.10	23.30	15.30	23.30	12.00	95.10	58.10	11.60	10.40

Different alphabet superscripts in the same column means there is a significant difference at $p>0.05$ between treatments while same alphabetical superscripts in the same column means no significant difference at $p>0.05$: between treatments

CV%=coefficient of variation, P= phosphorus, N= nitrogen, OC= organic matter, OM= organic carbon, Ca= calcium, Mg= magnesium, Na= sodium, EA=exchargeable acidity, ECEC= effective cation exchangeable capacity, BS= base saturation.

Hydrogen Ion Concentration (pH): The highest pH value of 5.50 was recorded at S_5 and the lowest value observed at S_9 with pH value of 4.33.The control area recorded pH value of 5.67. The pH values across the samples stations indicated that there is a significant difference in the soil at P >0.05. However, S_5 with pH value of 5.50 and S_9 with recorded pH value of 4.33 are the least and most acidic respectively. pH is one of the most important parameter that serves as an indication for pollution. It is a term used universally to describe the intensity of acidic or alkaline nature of soil. The soil pH of the present work ranged from slightly – strongly acidic across the ten stations according to the rating of (Chude *et al.,* 2011). The pH had an irregular pattern of distribution within the sampled stations.
The soil pH recorded low variation 9.80% which may have resulted from parent material and intensity rainfall which wash off most basic cations. Several researchers (Ndukwu *et al.,* 2012) have reported on low variation of soils of eastern Nigeria and it is the consequence of acidic nature of the parent rocks, coupled with the influence of the leached profile under high annual rainfall condition. The results of the present work indicates that the pH values of the sampled stations, especially S_5, S_8 and S_{10} fall within the normal range of 5.0 – 6.5 that were reported being optimum for the release of plant nutrients (Odunze, *et al.,* 2006). The degree and nature of reaction are influenced by different anthropogenic and natural activities including leaching of exchangeable bases, acid rains, decomposition of organic materials, application of commercial fertilizers and other farming practices (Brady and Weil, 2002). This reason why the pH of the sampled stations is acidic is thus due to anthropogenic and farming activities.

Phosphorus: Available phosphorus recorded the mean values across the stations as follows; S_1 15.06mgkg^{-1}, S_2 21.36mgkg^{-1}, S_3 25.73mgkg^{-1}, S_4 23.43mgkg^{-1}, S_5 17.63mgkg^{-1}, S_6 20.45mgkg^{-1}, S_7 24.34mgkg^{-1}, S_8 19.43mgkg^{-1}, S_9 23.3mgkg^{-1}, S_{10} 25.65mgkg^{-1}, with control mean of 24.63%. The minimum value of available phosphorus was observed in S_1 15.06mgkg^{-1} while the maximum of 25.73mgkg^{-1} was recorded in S_3. The mean values obtained from the stations were high according to the rating (>15 mgkg^{-1}) of (Enwezor, 1990). The available phosphorus recorded moderate variation of 15.80% as the mean CV value across the stations, which could be attributed to organic material deposit, rate of fixation and leaching. Available phosphorus was high, compare with the findings of (Osujieke *et al.,* 2016) in the soil of southeast Nigeria. The result is contrary to the findings of (Busari *et al.,* 2005; Uzoho and Oti, 2005) that have reported high values of available phosphorus deficiency for tropical soils. Therefore, high values of available phosphorus of the soils are attributed to fertilizer application as observed by (Eyong *et al.,* 2008). The variability in the soil available phosphorus contents between the stations might be as a result of different soil management practices, specifically the type and rate of organic fertilizer and the rate of inorganic fertilizer used in the study area.

Nitrogen: The total nitrogen values across the stations varied as presented in Table 3. The maximum numerical value were obtained from S_3 0.09% while the minimum numerical value was obtained in S_8 0.02% respectively. The overall mean value across the stations was 0.05% and CV value of 9.09% were recorded.
The total nitrogen levels obtained from the stations were low according to the rating of (Enwezor, 1990). According to rating given by (Bruce and Rayment, 1982), all the stations were qualified for a very low to low range. This indicated that the variations in total nitrogen across the stations are related to the nature of the organic materials and leaching activities in the soil. The result confirmed the findings of (Jones and Wild, 1978) who reported that the nature and origin of soils as well as inadequate application of nitrogen-based chemical fertilizer influence the nitrogen content of the soil. Moreover, the low content of total nitrogen in the soil could be attributed to low organic matter of these soils, since inorganic nitrogen is accounting for only a small portion of total nitrogen in soil (Almu and Audu, 2001). Abera and Belachew, (2011) also reported that lower nitrogen value observed in the soil could be attributed to the effect of cultivation that could have also aggravated loss of nitrogen. Malo *et al.,* (2005), attributed lower nitrogen values to be imbalance between nitrogen added during fertilizer application and nitrogen lost due to harvest removal, leaching, and humus losses via cultivation. Again, the low total nitrogen values of the soil in the area could be attributed to continuous cultivation, a common practice in the area that is accompanied by nearly crop residue removal (Noma *et al.,* 2011). Therefore, nitrogen can be introduced into the soil by natural processes such as lightening, decay of animal and plant tissues while the main cause of nitrogen deficiency in tropical soil is intense leaching due to the intense tropical rainfall.

Organic matter (OM): The highest of soil organic matter (OM) content was recorded at S6 2.18% and lowest was observed at S1 1.08%, these values were higher when compared with the control value of 1.07%. It also recorded mean value of 1.65 and % CV of 23.30 across the stations. The percentage organic matter (OM) of the soil in the study area showed that it is within the range of 1.08- 2.18% across the stations.
This was rated as low fertility according to (Enwezo *et al.,* 1989). Abdulhamid and Bello (2017) reported that low organic matter content could be due to low humus content of the soil while Gachene *et al.,*

(1997) also reported that decline in soil organic matter and other elements is due to their higher concentration in the surfaced soil, which can be easily removed and washed away by surface runoff. This observation corroborated with (Oyedele *et al.,* 2008) who reported that polluted site had significant higher soil organic matter as compared to the control site. Moreover, the obtained values of organic matter in the study area were also reported low according to the value obtained by (Zauro *et al.,* 2017). An area with relatively high amount of clay had relatively high amount of organic matter, according to report of (Quenea *et al.,* 2009), but the decline in soil organic matter in the study area may be attributed to leaching problem and surface runoff. Organic matter is generally low in the soils according to (Landon, 1991) rating of (>20% very high, 10-20% high, 4-10% medium, 2-4% low and < 2% very low). The low organic matter content of the soils in the study area has been attributed to factors such as continuous cultivation, frequent burning of farm residues commonly carried out by farmers in the area which tends to destroy much of the organic materials that could have been added to the soil (Yakubu, 2001). Therefore, soil organic matter is a principal factor that affects the heavy metal distribution in soil (Van and Maggio, 2015). Increase in soil organic matter (OM) content lead to elevation of soil adsorption capacity hence enhancing the accumulation of trace metals. Organic matter (OM) can therefore be considered as one of the medium through which heavy metals are incorporated into the soil. Ayolagha and Onwugbuta, (2001) also demonstrated that organic matter greater than 2.0% create great conducive medium for heavy metal chelation formation.

Organic carbon (OC): Organic carbon concentration across the sampled stations varied as presented in table 3. The recorded mean values of S_1 0.46% , S_2 1.02% , S_3 1.10% , S_4 1.12% , S_5 1.05%, S_6 1.18%, S_7 0.99%, S_8 1.00%, S_9 1.07%, S_{10} 1.20%. The organic carbon (OC) mean values indicated that there is a significant difference across the stations at P >0.05. The maximum numerical value was obtained in S_{10} 1.20 while the minimum numerical value was obtained from S_1 0.46% with an average mean value of 1.04% and CV of 23.30%.

The organic carbon (OC) was low according to the rating of (Akinrinde and Obighesan, 2000). However, the level of organic carbon (OC) in the studied station was low compared with the findings of (Amannze *et al.,* 2016) on soils of southeast Nigeria. Also, (Ogeh and Ukodo, 2012) reported low OC in the soil rainforest zone of Nigeria. The low content of organic carbon might be attributed to the Iso-hyperthermic temperatures from solar radiation and constant bush burning.

Exchangeable cation bases: The main exchangeable cations in the soils are calcium, magnesium, potassium and sodium. Exchangeable means that they are held loose enough in the minerals which make up soils and organic matter in the soil, so that they can be used by plants. Exchangeable bases are important properties of soil and sediments as they relate information on the ability to sustain plant growth and retain nutrients.

Exchangeable calcium, the highest exchangeable calcium content of soils at different stations were obtained from S_{10}, S_3 and S_7 with respective mean value of 3.27, 3.13 and 3.10cmol/kg and the lowest values was observed at S5 which recorded 2.10cmol/kg with control mean value of 2.10cmol/kg. The overall mean value of and percentages CV were recorded 2.75cmol/kg and 15.30 respectively. The overall mean value of Ca is within 2 – 5 soil critical limits (Esu, 1991). The exchangeable calcium showed significant difference at P >0.05 across the ten stations. The level of exchangeable calcium observed in the study area may be due to its source from organic matter and it is one of the most abundant basic cations surrounding the colloidal soil surface (Gebreyohannes, 2001). According to the ratings recommended by FAO (Xuli *et al*., 2012). Calcium is the dominating plant nutrient among the actions it contributed to give the plant strong cellular walls, aid in the cell-division and is responsible for the activation of different enzymes (Marschner and Marschner, 2012)

Exchangeable magnesium, S_{10} recorded the highest exchangeable magnesium with 2.35cmol/kg while the lowest mean value was obtained at S_9 with mean value of 1.35cmol/kg. Exchangeable Mg recorded 2.80cmol/kg at control area with overall mean value of 1.84cmol/kg. Mg^{2+} also recorded 23.30 coefficient of variance. Exchangeable Magnesium showed a significant different across the ten stations at P >0.05. Generally, the concentration of exchangeable Mg^{2+} was higher than the critical level of 0.5cmol/kg in soil as suggested by (Landon, 1991). A critical concentration of 0.2cmol/kg in soil is required for tropical soils (Landon, 1991) and this would indicated that exchangeable Mg^{2+} is not limiting in the soil of the study area

Exchangeable potassium (K) levels varied from station S_1 to station S_{10} with mean value of 0.16cmol/kg and 0.13cmol/kg respectively. The highest exchangeable potassium was observed from S_3 and S_9 with recorded equal mean value of 0.17cmol/kg while the lowest value was recorded at S_{10} with value of 0.13cmol/kg. The K values obtained at the study site are higher than 0.11cmol/kg recoded value at control area. The CV is recorded 12.00% which describes low variation. The exchangeable K^+ content significantly varied across the stations at P > 0.05 with the overall mean less than 0.6cmol/kg critical limit (Landon, 1991).

The values of exchangeable potassium obtained across the ten stations are lower than the critical level of exchangeable potassium of most soil which was given as 0.20cmol/kg (Agboola and Obighesan, 1994). This means that potassium in agricultural soils is low. Potassium in soil may exist in unavailable, slowly available (exchangeable and available form in solution) and available forms. The exchangeable form becomes available when the potassium in solution is removed by crops (Ijaz *et al.,* 2006). Plant utilizes potassium for photosynthesis (in the form of carbohydrate), plant metabolism, regulation of enzymes activity and for increases of sugar, starch and oil content in plant storage organs (Egharevba *et al.,* 2003).

Exchangeable sodium, station S_2 recorded the highest exchangeable sodium of 0.66cmol/kg the lowest value of 0.10cmol/kg was obtained at station S_6 and control mean value of 0.13cmol/kg was observed at control area. The overall mean value of 0.62cmol/kg and CV of 90.10% was observed across the stations. The levels of exchangeable cations depend on the nature of parent materials and extent of weathering. The exchange bases were within the range reported by (Amanze *et al.,* 2016) in the soil of southeast Nigeria. In soil cation exchange sites are invariably occupied by calcium ions followed by magnesium, potassium and sodium in decreasing order. This is in agreement with Fenny's potassium-sodium theory (1993) that the leaching causes preferential loss of mono-valent ions and at same time greater loss of sodium than potassium.

CEC (Cation exchange capacity): In this study the maximum value of CEC was observed in S_6 with recorded value of 8.56cmol/kg while the minimum value was observed in S_9 with recorded value of 5.68cmol/kg. CEC had an average mean value of 6.99cmol/kg across the stations. CV of 11.60% recorded was rated low as used by (Wilding *et al.,* 1994), which estimated the degree of variability of soil CV < 15%as low variation. The percentage cation exchange capacity (CEC) represents the total exchange cation held within the soil.

However, the cation exchange capacity values obtained in this study were below the value of 20cmol/kg reported as being suitable for crop production (FAO, 1995), and low ECE can be attributed to the fact that soil in this study area might be strongly weathered, have little or no content of weathered materials in sand and silt fractions and have predominantly kaolinite in their clay fraction. This is in line with (Eyon *et al.,* 2008) which stated that at CEC <15cmol/kg, the soil will suffer from significant cation losses through leaching. ECEC values obtained were lower when compared to the work reported by (Zauro *et al.,* 2017). Based on the rating suggested by (Hazelton and Murphy, 2007), CEC values across the stations were qualified for the low range. The variation in CEC values across the stations may be because of variation in the nature and type of clay minerals. This result also agree with the findings of (Oades *et al.,* 1989) which reported that organic matter is responsible for about 25 – 90% of the total CEC of surface mineral soils. Therefore, soil CEC is expected to increase through the improvement of the soil organic matter content. There is a significant variation on the values of CEC observed across the stations and the variations on the values obtained could be attributed to the high clay content which agrees with the findings of (Lekwa *et al.,* 2001).

Exchangeable acidity (EA): for this study the maximum value of exchangeable acidity was obtained at S_2 with mean value of 6.52cmol/kg and the minimum value was recorded in S_9 with value of 1.67cmol/kg. The overall mean value of 0.13cmol/kg and CV of 58.10%. There is a significant different across the stations at P >0.05. Exchangeable acidity less than 1.05cmol/kg obtained from farmland in Kano (Adamu *et al.,* 2014). This may result to an increase in soli acidity that will lead to toxic effects on the plant root development (Adamu *et al.,* 2014)

Base saturation (BS): The highest base saturation values across the ten stations were recorded in S_3 with 72.59% and the lowest was observed at S_7 of 63.65%. It also recorded 90.07% at control area and average mean value of 70.74% across the stations. It had percentage CV of 10.40 which is described as low variation. There is a significant difference across the stations at P > 0.05. The mean values of base saturation were recorded higher (> 50%) in all the stations.

The values obtained imply that base saturation tends to be high in the soil. This might be attributed to the virtually devoid of soluble minerals, rocks and rapid weather of the soil due to iso-hyperthermic temperature and abundant moisture and torrential rains which have washed away nutrients from the soil as reported by (Osedeke *et al.,* 2002). In related study by (Snelder, 2001) showed that base saturation was high across the stations. Following the percent BS rating developed by (Landon, 1991), base saturation values greater than 60% are rated high, between 20 to 60% medium and less than 20% low. The percentage base saturation express the relative contribution of the exchangeable bases to the overall exchange capacity and it is an important property of soil acidity, it's also useful for soil fertility evaluation because high percentage base saturation implies desirable nutrient and low soil acidy.

Table 4. Mean concentrations of heavy metal in soil surrounding Obinna River

Parameter Sample	Cd	Cu	Cr	Pb	Fe	Zn
S1	0.36± 0.15^{b}	1.73± 0.15^{ab}	0.10± 0.03^{b}	0.04± 0.02^{a}	1.18± 0.72^{a}	0.21± 0.23^{a}
S2	0.62± 0.06^{d}	2.87± 0.68^{c}	0.13± 0.11^{b}	0.05± 0.02^{a}	2.21± 2.41^{ab}	0.32± 0.21^{a}
S3	0.13± 0.04^{a}	2.16± 1.93^{b}	0.05± 0.01^{a}	0.04± 0.02^{a}	3.36± 0.87^{bc}	0.49± 0.21^{bc}
S4	0.32± 0.02^{b}	2.30± 0.12^{bc}	0.15± 0.04^{bc}	0.03± 0.01^{a}	4.00± 0.54^{c}	0.24± 0.19^{a}
S5	0.21± 0.03^{ab}	1.89± 0.12^{c}	0.14± 0.06^{bc}	0.06± 0.02^{b}	3.75± 0.21^{bc}	0.33± 0.20^{b}
S6	0.19± 0.01^{a}	2.11± 0.43^{b}	0.09± 0.01^{b}	0.09± 0.01^{b}	2.88± 0.32^{ab}	0.31± 0.13^{b}
S7	0.25± 0.00^{ab}	2.32± 0.17^{b}	0.10± 0.00^{b}	0.03± 0.01^{a}	2.10± 0.21^{a}	0.29± 0.12^{b}
S8	0.31± 0.02^{b}	1.68± 0.32^{bc}	0.11± 0.01^{b}	0.07± 0.04^{bc}	3.00± 0.22^{b}	0.25± 0.23^{a}
S9	0.43± 0.03^{cd}	1.43± 0.09^{b}	0.19± 0.03^{c}	0.06± 0.02^{b}	4.12± 0.43^{c}	0.35± 0.21^{b}
S10	0.14± 0.01^{a}	2.11± 0.10^{b}	0.23± 0.02^{c}	0.08± 0.03^{c}	4.00± 0.34^{c}	0.37± 0.26^{b}
Control	0.19± 0.14^{ab}	0.05± 0.00^{a}	0.01± 0.00^{a}	0.01± 0.01^{a}	4.35± 0.52^{c}	3.63± 0.37^{b}
Mean	0.29	1.88	0.12	0.05	3.18	0.62
CV (%)	50.70	38.20	51.60	46.90	31.80	162.30

Different alphabet superscripts in the same column means there is a significant difference at P>0.05 between treatments while same alphabetical superscripts in the same column means no significant difference at p>0.05: between treatments. CV%= coefficient of variation, Cd= cadmium, Cr= chromium, Cu= copper, Fe= iron, Pb= lead and Zn= zinc

The heavy metal concentrations in the soils of study area at the different stations were presented in Table 4. Cadmium concentration varied across the different stations with the overall mean concentration of 0.29mg/l. The lowest mean concentration was obtained at station S_3 with mean value of 0.13mg/l while the highest value was observed in station S_2 with mean value of 0.62mg/l. Thus, the coefficient of variance in cadmium concentration across the studied stations is 50.70. Therefore, there is a significant different at P >0.05 of cadmium concentration across the stations.

The values of cadmium obtained at station one, two, four and nine are within the (UNEP, 2013) permissible limit of 0.35mg/l while the rest stations are lower than the UNEP limit. The overall cadmium values across the stations in the study area were lower than the natural limit of 3.0 – 5.0mg/l in soil, as given by FAO/WHO, 2002). Cadmium is found to be within the range of results obtained in Lagos, Nigeria (Okereke *et al.*, 2019), but lower than the values obtained in soils in Tadla plain Morocco (Oumenskou *et al.*, 2018). Cadmium in soil across the stations might originate from agricultural applications (irrigation water source or the use of organic fertilizer as soil amender). The values of cadmium obtained are also similar to those observed by Asawalam and Eke, (2006); Njoku and Ayoka, (2007); and Oluyemi *et al.*, (2008) who investigated heavy metal concentration and heavy metal pollutants from dump site and agricultural soil in Owerri, Ile-Ife and Osogbo, Nigeria. The accumulation of cadmium in agricultural soils overtime is induced by human activities (Taylor, 1997), such activities include excessive application of phosphate fertilizer, domestic and industrial effluent, waste water and pesticides (Kara *et al.*, 2004). Cadmium sulfide and selenide are commonly used as pigment in plastics, batteries and in various electronic components and when these products are no more serviceable, they are thrown into the dump sites as waste. During decomposition, the cadmium components are leached into the surrounding soil and overtime gets accumulated in the soil.

With regards to chromium (Cr), the maximum mean concentration across the stations was recorded at S_{10} with mean value of 0.23mg/kg while the lowest was observed at S_3 with mean value of 0.05mg/kg. The control area recorded 0.01mg/kg. The overall mean concentration showed 0.12mg/kg with % CV of 51.60.
The result of the Cr is far lesser than the chromium range from 2.28 – 56.00mg/kg with mean value of 11.55mg/kg in e-waste dumpsite in Accra Ghana (Fosu-Mensah *et al.,* 2017). The highest Cr concentration recorded in the current study is far lower than the upper limit of 15.00 from the normal range of 5 - 1500µg/g (Rabata *et al.*, 1984). Chromium is used in metal alloys and pigments for paints, cement paper and rubber. Cr plays a vital role in the metabolism of cholesterol, fat and glucose. Its deficiency causes hyperglycemia, devated body fat, and carcinogenic (Chishti *et al.,* 2011).

Copper concentration in the soil was in the range of 1.43–2.28mg/kg across the ten stations as presented in Table 4. The lowest copper content was found in sample collected in station ten with mean value of 1.43mg/kg while the highest value was obtained at S_2 with recorded value of 2.8mg/kg. The control area recorded 0.05mg/kg with an average mean value of Cu content of 1.88mg/kg and % CV of 38.20.
This values is lower than the result reported by (Tair *et al.,* 2007) for soil samples from Dugan Town (USA) with Cu content of 7.4µg/g. the values is also below the critical soil total concentration of 60 – 125ppm (Kabata-Pendias and Pendias, 1984) who suggested that there is little anthropogenic effect on his study. The overall mean value of Cu is below (WHO/FAO, 2011) permissible limit of 100mg/kg but above 0.2mg/kg of (Esu, 1991). The values of Cu concentration obtained across the stations analyzed is below the (UNEP, 2013) allowed limit of 15mg/kg. Copper is a micronutrient which is essential for plant growth and occurs generally in soil and sediments. Cu content has been reported to differ according to the soil type and pollution source. The level of Cu increased significantly across the stations. Cu can have its way to the soil through various means (Jakienwiez *et al.,* 1998) such as contamination from Cu pipes and wires as well as from condition designed to control algal growth. Cu is indispensable for normal development of living organisms, but its excess and deficiency are harmful. The application of manure to agricultural soil increases soil Cu content (Mullins *et al.,* 1982). Elevated level of Cu may become harmful to plant and can as well effect organisms that feed on these plants adversely and enter water bodies through runoff and leaching (Gupta and Cherlia, 1999). Copper binds strongly to organic matter and minerals in soils and so does not travel far after release (Alloway, 1990; Lenntech, 2009). Therefore, as a result of this, cu applied in the soil has the tendency to accumulate in soil (Slooff *et al.,* 1989).

Zinc (Zn): the maximum concentration of Zn across the stations was obtained at S_3 with mean value of 0.49mg/kg while the lowest numerical value was recorded at S_1 with mean value 0.21mg/kg. These values were lower the control mean value of 3.63mg/kg. The overall mean across the stations recorded 0.02mg/kg and CV of 162.30% which describe high variation was indicated. The concentration of Zn in this study is lower than the permissible limit of 60mg/kg set by (WHO/FAO, 2002). Zn deficiency in soil reduces the efficiency with which the water is used for biomass production and compromised the plant's capacity to respond to water stress by adjustment (Khan *et al.,* 2004).

Iron (Fe): heavy metal iron varied significantly across the stations at $P > 0.05$. The highest concentration of Fe is recorded at S_9 with mean value of 4.12mg/kg while the lowest value was obtained at S_1 with mean value of 1.18mg/kg. The control area recorded mean value of 4.35mg/kg which is high when compare with the sample stations analyzed. The CV value recorded 31.80%. . Its average mean value recorded 3.18mg/kg which is less than the agricultural soil in North China (Yushu *et al.,* 2013). Fe is present in soil vary according to the type of soil. The average iron content in light soil is 0.6% (Kabata- Pendias and Pendias, 1999). The low Fe status of the soil may be attributed to the fact that micronutrient are not applied regularly to the soil in conjunction with common fertilizers. Also the intensification of cropping practices and adoption of high yielding cultivars which have high micronutrient demanding could have led to low levels of Fe. Also the reduction in fallow period could be responsible for low level of Fe in the soil (Kparmwang *et al.,* 1998; Adeboye, 2011). Fe from 0.1 to 50 - 1000µg/g in soil within a few weeks can be a problem in lowland acid soils that is susceptible to weathering (FAO, 2006). Fe is essential for the proper development of plants, Fe is absorbed from the soil in different amounts depending on the form of ferric irons, Fe^{3+}, Fe^{2+} and ferrous iron in the form of chelates (Glinaki, 1999)

Lead (Pb): Lead concentration varied significantly across the ten stations at $P > 0.05$ level except at stations S_1, S_3, S_4 and S_7 that were recorded less. Across the stations Pb varied from 0.03 – 0.09mg/kg with overall mean value 0.05mg/kg different from Pb in soils with range of 0.0001 – 1.41mg/kg reported by (Mohammed and Folorunsho, 2015).

Total Pb content in soils of the study area were below the critical concentration of 300mg/kg (FAO/WHO, 2002). The low lead content of the soils is of course related to the composition of the parent rock and Pb varies considerably with soil type. However, the Pb content obtained across the stations were below the Pb value of surface soil on the global scale as estimated to be 25mg/kg and levels above this suggest anthropogenic influence (Kabata-Pendias, 2001). The level of Pb content obtained in the current study however, is lower than what was observed in Maduguri, metropolis reported by (Kabata-Pendias, 2001), Enugu Metropolis (Ekere and Ukoho, 2013), and Jos Metropolis (Abechi *et al*., 2010). Pd is ranked as one of the most toxic heavy metals affecting man, animal and plant (Zude, 2000), which has been used by mankind for several years because of its wide variety of application.

CONCLUSION

Farming activities continue to go on within the Obinna River watershed in order to improve on the level of food security within Enugu State and beyond. To achieve this, farmers resort to the use of different types of chemicals including fertilizers, herbicides and pesticides. The effects of these farming activities were on soil was looked into by this study. It was be deduced that the soils were contaminated at some points to different levels by the different heavy metals. Natural origins, fertilizer application and domestic waste were identified as the major sources of heavy metals in the soils. Although heavy metals remain in soil for a very long time, there are some steps that can be taken to reduce the level of risk they pose.

The environmental impacts on soil resources caused by farming activities cannot be disassociated from agricultural impact within the areas: therefore, various environmental agencies in Enugu State should make efforts to provide preventive measures, adequate monitoring, and treatment standards to help remedy this situation.

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