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Full Length Research Paper

Assessment of soil quality around the vicinity of selected cement company in Benue State using physicochemical and biotic properties

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The aim of the study was to assess the level of quality of soil around the vicinity of Dangote Cement Company, Gboko, Benue State using physicochemical and biotic parameters, and compare the results with the control soil samples and available permissible limits. The experimental site was partitioned into 5 major locations (L1-L5). Each location was further partitioned into 4 plots. Both the topsoil (0-15cm) and subsoil (15-30cm) were collected. Sixteen (16) soil samples were collected from each location totaling 80 soil samples at the experimental site and 16 at the control location. Physicochemical parameters including particle distribution, soil pH, temperature, moisture, organic matter and electrical conductivity were determined. The total viable bacteria and fungi were obtained in cfu/g of soil samples following appropriate dilution and standard microbiological practices. Detritivores such as ants, termites and worms were physically counted per soil sample. The experimental site was largely composed of sand followed by silt and clay while the control soil collected from Annune market area in Tarka L. G. A. of Benue state was largely made up of silt followed by clay and sand. On average, percentage clay varied from 18.8±1.3to 22.0±1.2 in the experimental site while the control location had a higher amount of clay with a mean value of 30.9±0.3. The control location had a higher amount of soil moisture with a mean value of 52.8±1.7. The soil at the experimental site was largely acidic and it varied from 5.7±0.2 to 6.0±0.1 whereas the control location possessed fairly neutral soil (7.1±0.1). The soil temperature was reduced in the control location (31.1±0.4). All electrical conductivity (E.C) values except those of the control location exceeded permissible limits of 1 dS/m. Consequently, organic matter level was much reduced in all locations ranging between 8.2±0.5 and 9.1±0.7 in the study area whereas the control soil samples had higher values of 15.7±0.5 as the average O.M level and only this fell within the permissible range of <15% O.M for arable soil. The control sample (3.33 x 10^8cfu/g) contained a higher quantity of bacteria and total detritivores than the experimental samples. Thus, the quality of soil at the experimental site was compromised in all parameters evaluated. This could be as a result of the environmental impact of the cement factory within the vicinity of the experimental site, hence a need for regulatory measure and full environmental audit of the impact assessment on a continuous basis for decision making.

Keywords: Cement factory, soil, physicochemicals, biotic properties, pollution

INTRODUCTION

In the constitution of biosphere of our planet the pedosphere is an important component. The earth eco-system has a conglomeration of different organisms, which fix and hold the solar energy in the form of bio-tope. Hence, the soil cover becomes a vital part of the eco-system and varies from one region to another, according to the varying dynamic equilibrium of eco-systems (Brady and Weil, 2002). The concomitant massive utilization of natural resources to achieve industrial and technological growth had resulted in situations whereby modern society is faced with problems related to air, water and soil pollution which needs to be solved (Okae-Anti, 2005). For example, the combustion of fossil fuel usually contaminates the earth's atmosphere resulting to changes in global climate.

Industrial pollutants may be present in the soil as a result of long term effect of road usage, agricultural operations, soil erosion, aerial deposition and some other climatic effects (Petradis, 2007).Industrial activities and urbanization in developing countries including Nigeria has led to deterioration and contamination of the natural environment in the recent years (Adedotun, 2018). Environmental pollution is encountered when the carrying capacity, that is, the optimum ability of the environment to assimilate wastes and residues at any level is exceeded (Isirimah, 2000). Clean air, water and soil are becoming increasingly precious resources in the world owing to high rate of pollution and contamination of soil, water and air which somehow have become inevitable due to several anthropogenic activities. Cement dust when incorporated into the soil at low concentration may be beneficial to crops (Stiller and Reides, 1999), while its continuous build-up in the soil as is the case in the soils close to cement factories may appreciably reduce crop growth and development due to its adverse effects on soils (Oyedele *et al*., 1991). The production process of cement factories discharge dust particles which settle on the soil, in and around the vicinity of the industries. Soil biota (plant, animal, microbes, detritivores) within the confines of this area are easily liable to contamination with these emissions (Oyedele *et al*., 1991; Laniyan *et al.,* 2004; Ayeni, 2010). The impact of these activities on the soil chemistry in the area also needs to be investigated. Soil physichochemical properties such as texture, particulate matters, reaction, temperature, moisture and conductivity may be affected by industrial pollutants discharged directly or indirectly on the soil (Laniyan *et al.,* 2004). Those industrial pollutants degrade soil quality around cement factories and other industries thereby altering the soil's natural ecosystem (Ayeni, 2010). The aim of the study was to assess the level of quality of soil around the vicinity of Dangote Cement Company, Gboko, Benue State using physicochemical and biotic parameters, and compare the results with the control soil samples and available permissible limits.

MATERIALS AND METHODS

Study area

Gboko is a town, and also a Local Government headquarters in Benue State of Nigeria. The topography is mainly that of undulating plains with occasional elevation of between 150 – 300 meters above sea level. There are four main geological formations of sandy loam, sheaves, basement complex and alluvial plains coupled with its location in the transitional zone between the North and South ecologies, as well as favorable rainfall pattern accounts for its capacity to support a wide variety of crops (Avav, 1999). The selected cement factory site is located at kilometer 72 along Makurdi–Gboko road, adjacent to Tsekucha Market. The company's production process discharges dust particles high in the air from its exhaust pipes. The dust which is air borne is carried in all directions depending on the direction of the wind. It then settles on the soil, in and around the vicinity of the factory. There are no other industrial developments within the area except the cement factory. The area set as control was Annune Market area in Tarka Local Government Area, Benue State situated at Km 50 Makurdi – Gboko road.

Study design

The experimental site was approved and partitioned into 5 major locations (L1-L5). Each location was further partitioned into 4 plots. Soil samples were collected from each plot using soil auger. Both the topsoil (0-15cm) and sub soil (15-30cm) were collected separately into well labeled and sterilized polythene bags, from each plot of a location, 2 soil samples were collected from two different points: 2 top and 2 sub soils making a total of 4 soil samples per plot. Sixteen (16) soil samples were collected from each location totaling 80 soil samples at the experimental site and 16 at the control location. A total of 96 soil samples were collected for the study. Soil preparation followed a standard protocol (Udo *et al.*, 2009).

Determination of soil physicochemical properties

Particle distribution

Soil particles were distributed into clay, silt and silt using Bouyoucos, (1951) hydrometer method as given by (Udo *et al.*2009). Results were obtained in triplicates.

Soil pH

Procedure of Waldemar, (2005) was used. Soil pH was determined in the laboratory with Suntex TS-2 pH meter at 25°C. Before use, the pH metre was calibrated with standard buffer solutions of pH for 7 and 9. Each soil sample was sealed in clean jar to prevent it from drying before the reading was taken. The pH was measured using a soil to water ratio of 1:2 whereby 10g of soil sample was weighed into a plastic container and 20 cm^3 of the ionized water added. A mixture was stirred severally for 30 min. The suspension was allowed to stand for 30 min undisturbed. The pH electrodes were then inserted into the settled suspension and the pH of the soil measured in triplicates.

Soil temperature

The mercury in glass thermometer calibrated in degrees Celsius was used in the measurement of soil temperature. Prior to collection of each soil sample, soil temperature was determined *insitu* by inserting the thermometer to about 5cm depth in the required soil for 5 min of stabilization of the instrument before temperature readings was taken in degrees Celsius (°C) in triplicates (Waldemar, 2005).

Soil moisture

Soil samples was sealed in clean polyethylene bottles or jars to retain their moisture and transported to the laboratory to determine plant available water by approximate loss in weight of soil at field capacity then air-dried by spreading the soil samples on a newspaper for one week. The weighing method was used. The determined soil moisture content was expressed in percentage water loss. Readings were taken in triplicates (Waldemar, 2005).

Soil organic matter

Procedure of Miyazawa *et al.* (2000) was used. Approximately 1.0 g of oven dried soil sample was weighed into a dry crucible and placed in a muffle furnace and the temperature adjusted to 450°C before transferring it into the descicator to cool to room temperature and then weighed. The percentage (%) organic matter of soil was calculated as the percentage (%) loss in weight on ignition during combustion. Result was obtained in triplicates.

Soil Electrical conductivity (E.C)

Electrical conductivity for soil samples was determined in the laboratory with a HACH conductivity meter CO-150. This was determined by mixing one part soil by volume with two parts distilled water (pH 7) for about 10 min at 25°C. Soil conductivity reading was taken in milli-Siemens (mS) (Miyazawa *et al.*, 2000).

Determination of soil biotic composition

The enumeration of total viable bacteria and fungi was conducted by the use of standard methods contained in APHA, (1998). Triplicate results were obtained in cfu/g of soil samples following appropriate dilution and standard microbiological practices. Detritivores such as ant, termites and worms were physically counted per soil sample (Jackson, 2018).

Data analysis

Data were analyzed using statistical tools such as descriptive and inferential methods. One way ANOVA was applied. Means separation was done using the DMR (Duncan Multiple Range) method at 95% confidence limit (P≤0.05).

RESULTS AND DISCUSSION

Table 1 gives the particle distribution and texture of the composite soil samples both at the experimental site and the control location. Soil particles distribution revealed that the experimental site was largely composed of sand followed by silt and clay while the control soil was largely made up of silt followed by clay and sand. On the average, percentage clay varied from 18.8±1.3to 22.0±1.2 in the experimental site while the control location had higher amount of clay with mean value of 30.9±0.3. Average level of sand varied from 46.9±1.7 to 49.4±2.0 in the experimental locations and these values were higher than the result of the control soil with about 50% reduction in sand level as low as 23.2±0.9 on the average. Silt level varied between 30.2±1.1 and 33.0±2.8 in the study area compared with higher amount of silt in the control soil with a mean value of 45.8±0.8.

Table 2 gives the result of the soil chemistry. On the average, soil moisture was 42.9±1.6 as the highest percentage recorded followed by 42.3±1.7. The control location had higher amount of soil moisture with mean value of 52.8±1.7 but all values were within permissible range (30-60%) of good soil. Soil was largely acidic and it varied from 5.7±0.2 to 6.0±0.1 in the study area whereas the control location possessed fairly neutral soil (7.1±0.1) but all readings were within permissible range (5.1-7.3). In the study area, the lowest mean soil temperature was 33.6±0.3 while it was as high as 34.9±0.3. Soil temperature was reduced in the control location (31.1±0.4). As given in (Table 2), the control soil had higher moisture but lower pH and temperature than the soil around the study location.

Soil electrical conductivity (E.C) varied between 2.2±0.2 and 3.1±0.2 in the study area and values were higher than the E.C readings of the control soil sample (0.9±0.1). All E.C values except those of the control location exceeded permissible limits of 1 dS/m. Consequently, organic matter level was much reduced in all locations ranging between 8.2±0.5 and 9.1±0.7 in the study area whereas the control soil samples had higher values of 15.7±0.5 as the average O.M level and only this fell within the permissible range of <15% O.M for arable soil. Using One way ANOVA, statistically significant differences were observed in the values of each of the physicochemical parameters described above (P<0.05).

Based on the result obtained, the quality of soil at the experimental site has been comprised possibly due to the

Table 1. Soil texture and particle distribution at experimental and control sites.

Sample code	Clay%	Sand %	Silt %
	18.2	43.6	38.2
CSS@L1	16.8	54.5	28.7
	21.3	46.7	32.0
Mean±S.E	18.8±1.3[b]	48.3±3.2[a]	33.0±2.8[b]
	19.5	49.6	30.9
CSS@L2	23.7	48.3	28.0
	18.4	50.0	31.6
Mean±S.E	20.5±1.6[b]	49.3±0.5[a]	30.2±1.1[b]
	25.4	48.5	26.1
CSS@L3	20.3	42.9	36.8
	17.1	51.7	31.2
Mean±S.E	20.9±2.4[b]	47.7±2.6[a]	31.4±3.1[b]
	22.6	44.1	33.3
CSS@L4	23.8	46.7	29.5
	19.7	49.8	30.5
Mean±S.E	22.0±1.2[b]	46.9±1.7[a]	31.1±1.1[b]
	20.3	45.7	34.0
CSS@L5	20.7	52.7	26.6
	19.9	49.9	30.2
Mean±S.E	20.3±0.2[b]	49.4±2.0[a]	30.3±2.1[b]
	31.4	21.6	47.0
CSS@LC	30.9	24.7	44.4
	30.5	23.4	46.1
Mean±S.E	30.9±0.3[a]	23.2±0.9[b]	45.8±0.8[a]

F (Clay) =9.75, P= 0.001
F (Sand) = 25.33, P= 0.000
F (Silt) = 8.86, P= 0.001
CSS@Ln=Composite soil sample at location n

environmental impacts of the cement factory. For instance, the soil was largely composed of sand and silt with reduced clay content while the control soil was largely made up of silt and clay with reduced sand level. Sand was 49.4% in the study area but 23.2% in while clay was 22.0% in study area but 30.9% in the control soil. Thus, the texture and structure of soil around the factory are affected. According to Gilbert (2005), soil structure and aggregates is of the highest importance in plant growth in soils. This is because aeration, moisture content, fertility and erosion resistance are all dependent upon the soil structure. Aggregation of particles is important for maintaining porosity and water movement, and for improving fertility in the soils (Nichols *et al*., 2004; Ojeniyi *et al*., 2010). Circulation of water in the soil varies greatly according to structure. Water movement in the soil influences plant's water use and growth.

Soil moisture level of 42.9% in the study was lower than the 52.8% recorded in the control location. This parameter was not largely affected since values are within tolerable range of 30-60% for arable soil. Moreover, crops such as tomato flourish better in soil with moderate level of moisture as observed in the experimental site. The reduction in moisture may be due to the lowered quality of soil structure and particle distribution around the factory. Soil moisture is one of the determinants of the health or stress on land surface ecosystem (Mahdi and Lowery, 2017). The level of moisture within the site is enough to facilitate heavy metal uptake because plants absorb minerals and other nutrients in solution from the soil in a water medium. The soil pH of the experimental site was acidic unlike the neutral soil reaction observed in the control soil. This is a pointer to a high level of soil deterioration around the cement factor, possible due to heavy metal pollution impacting on the overall soil chemistry. Heavy metals can accumulate to toxic levels, especially in low pH soils, which may reduce plant growth and enter the food chain when plants are consumed by animals (Chaney, 1994). This position was established in the present study because the vegetable plants of the experimental site were not as flourishing as those in the control location.

Table 2. Soil chemistry at experimental and control sites.

Sample code	Moist. %	pH	Temp. °C	EC mS	OM %
	41.4	5.9	34.6	2.8	8.35
CSS@L1	45.6	5.3	34.8	3.5	10.5
	39.8	5.8	34.6	3.1	8.58
Mean±S.E	42.3±1.7^{b}	5.7±0.2^{b}	34.7±0.1^{a}	3.1±0.2^{a}	9.1±0.7^{b}
	40.7	6.0	34.7	2.4	9.21
CSS@L2	35.6	5.4	33.9	3.5	8.57
	42.3	5.6	33.4	1.8	9.54
Mean±S.E	39.5±2.0^{b}	5.7±0.2^{b}	34.0±0.4^{a}	2.6±0.5^{a}	9.1±0.3^{b}
	39.7	5.8	34.9	2.2	9.87
CSS@L3	41.2	5.7	35.4	2.4	10.1
	40.8	6.0	34.5	2.7	8.55
Mean±S.E	40.6±0.4^{b}	5.8±0.1^{b}	34.9±0.3^{a}	2.4±0.1^{a}	9.5±0.5^{b}
	42.2	6.1	33.1	3.0	9.17
CSS@L4	40.5	5.9	34.0	2.5	7.68
	46.0	5.9	34.5	2.6	7.69
Mean±S.E	42.9±1.6^{b}	6.0±0.1^{b}	33.9±0.4^{a}	2.7±0.2^{a}	8.2±0.5^{b}
	37.6	6.0	33.7	2.4	8.22
CSS@L5	40.0	5.5	33.1	1.9	8.87
	38.6	5.8	34.1	2.4	8.17
Mean±S.E	38.7±0.7^{b}	5.8±0.1^{b}	33.6±0.3^{a}	2.2±0.2^{a}	8.4±0.2^{b}
	53.7	6.9	31.1	0.9	14.67
CSS@LC	55.1	7.2	30.3	1.0	16.19
	49.6	7.2	31.8	0.8	16.24
Mean±S.E	52.8±1.7^{a}	7.1±0.1^{a}	31.1±0.4^{b}	0.9±0.1^{b}	15.7±0.5^{a}
LIMITS	30-60	5.1-7.3	25-32	1	>15

F (Moisture) = 12.11, P= 0.000
F (pH) = 16.7, P=0.000
F (Temperature) = 17.41, P= 0.000
F (EC) = 19.84, P= 0.000
F (Organic matter) = 15.21, P= 0.000
CSS@Ln=Composite soil sample at location n
E.C= Electrical conductivity
O.M= Organic matter

According to Nichols *et al.* (2004), soil pH affects plants nutrient availability by controlling the chemical forms of the different nutrients and influencing the chemical reactions they undergo. Reports exist that low pH results in lower rate of Nitrogen mineralization, a process dependent on viable microbial population in the soil. As a rule, the availability of heavy metals usually increases as soil pH decreases. Thus, the current report on heavy metal pollution in soil of the study area is justified, and it must have been responsible for the high level of heavy metals quantified in vegetable samples.

The difference in temperature between the experimental and control site was found to be 2.5°C as all readings were high at the two sites, although a bit lowered in the control location. This may be due to the effect of time of sampling and the in situ temperature measurement adopted. The slightly elevated temperature in the study location could be attributes to differences in soil structure in the two locations. Despite being high, temperature was still within normal range needed for normal physiological process in the vegetable crops. This is because vegetables in the control site performed well and they were not affected by abiotic factors but biotic influences such as pest and disease influence cannot be ruled out (Table 3). However, the slight temperature changes in soils of the two sites might have serious influences on the plants. This observation aligns with popular view that soil temperature drives germination and blooming of plants (Yolcubal and Wilson, 2004; Mahdi and Lowery, 2017). The perfect for planting varies depending upon the plant type and its varieties. For example, *Abelmoschusesculentus* thrives well between 20 – 30°C (Tilley, 2018). Varietal factors were eliminated in this work since each location received the same type of plant and varieties. Most important to fertility, electric conductivity is an indication of the availability of nutrients

Table 3. Biotic properties of composite soil samples.

Composite soil samples	Total bacteria count (cfu/g)	Total fungi (cfu/g)	Total detritivores
	3.5×10^6	8.7×10^4	3
CSS@L1	2.0×10^6	8.2×10^4	5
	3.6×10^6	6.5×10^4	0
	3.03×10^6	7.8×10^4	2.7
	1.8×10^6	6.0×10^4	5
CSS@L2	2.0×10^6	6.0×10^4	2
	2.5×10^6	7.0×10^4	9
	2.1×10^6	6.3×10^4	5.3
	7.4×10^6	8.5×10^4	0
CSS@L3	6.5×10^6	8.0×10^4	6
	5.0×10^6	5.5×10^4	5
	6.3×10^6	7.33×10^4	3.7
	6.5×10^6	8.0×10^4	12
CSS@L4	7.9×10^6	8.0×10^4	7
	6.5×10^6	7.0×10^4	6
	6.97×10^6	7.67×10^4	8.3
	2.5×10^6	6.5×10^4	9
CSS@L5	3.5×10^6	7.0×10^4	5
	4.0×10^6	6.8×10^4	6
	3.33×10^6	6.77×10^4	6.7
	2.5×10^8	4.0×10^5	8
CSS@LC	4.5×10^8	5.0×10^5	6
	3.0×10^8	5.0×10^5	10
	3.33×10^8	4.67×10^5	8.0

in the soil (Al wabel *et al.,* 2002). It is often used as a measure of salinity of the soil. Plants are detrimentally affected both physically and chemically by excess salt in some soils (Carla, 2003). Soil E.C level was higher in the experimental site (as high as 3.1) than the control site with <1. This confirms the saline nature of soil in the study location, an indication of too much of salts caused by heavy metal pollution. The study site contained lower amount of organic matter (9.1%) than the control soil (15.7%). This indicates comprised fertility level in soil around the cement factory. This is not surprising since the affected soil was deficient in good soil structure and texture. This position was earlier upheld among soil scientists (Brady and Weil, 2002; Sodhi, 2005) who advocate adequate organic matter >15% in soil for good structure, aggregation, water retention, soil biodiversity, absorption and retention of pollutants, buffering capacity as well as cycling and storage of plant nutrients. Perie and Ouimet, (2008) found out that aggregation is important for good soil structure, aeration, water infiltration and resistance to erosion and crusting. No doubt, the overall results of physicochemical properties in the study allocation must have affected the level of soil bionts since the control location contained higher quantity of decomposers and detritivores than the control site.

Soil living organisms are known to thrive well under optimal environmental conditions as discussed above using fundamental knowledge of physiology. They decompose dead matter and aggregate mostly in the topsoil where they contribute to the fertility of the soil (Gilbert, 2005). Changes in physicochemical properties may drastically alter the soil properties, changing its nature and ability to support life (Pickering and Owen, 1995). The above positions are fully supported by the outcome of this research.

Conclusion

The quality of soil at the experimental site was comprised in all parameters evaluated. The soil was largely composed of sand and silt with reduced clay content. There was reduction in the moisture, reaction and organic matter content with elevated level of temperature and E.C. The microbes and detritivores content were also lowered. This could be as a result of the environmental impact of the cement factory within the vicinity of the experimental site, hence a need to regulatory measure and full environmental audit of the impact assessment on a continuous basis for decision making.

Authors' declaration

We declared that this study is an original research by our research team and we agree to publish it in the journal.

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