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ASSESSMENT OF CEMENT DUST EMISSION ON SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOILS FOR AGRICULTURE IN GBOKO, BENUE STATE, NIGERIA

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ABSTRACT

Some physical and chemical properties of soils around the Dangote Cement Factory operational area (longitude 8036' and 8045'E and latitudes 7045' and 8000'N) were assessed from three locations sited at 0.5km, 1.0km and 1.5km distance from the factory. Infiltration capacity test was carried out in the fields. Soil samples were taken from 0 – 30 cm depth for laboratory analysis and subjected to salinity and fertility related parameters. The research was carried out in June, 2017. The soils of the study area were of dominantly sandy loam textures at Tse-Kucha (0.5km), while Amua (1.0km) and Amua (1.5km) were of loamy sand textures. The soils had high values of infiltration capacities (0.003 – 0.009 cm/s). The soils indicate no salinity problem as the values of pH (7.17 – 7.69), electrical conductivity (0.76 – 1.37 ds/m), sodium (0.34 – 1.30 Cmol/kg), exchangeable sodium percentage (4.02 – 7.53 %) and sodium absorption ratio (0.17 – 0.47) fall within the tolerable limit. The soils are rated moderate in fertility status due to moderate levels of cation exchange capacity (9.65 – 18.36 Cmol/kg), organic matter (0.69 – 2.84 %), nitrogen (0.23 – 0.81 %), phosphorus (2.80 – 5.80 mg/kg), calcium (4.10 – 8.80 Cmol/kg), magnesium (3.60 – 6.20 Cmol/kg), potassium (0.41 – 0.96 Cmol/kg) and high base saturation (87.56 – 94.01 %). The soils around the cement factory (Tse-Kucha) are prone to salinity due to continuous emission of cement dust on the surface of the soil which resulted in abnormal (contamination) increased in soil mineral values such as Ca, Mg, Na and K compared to other locations. The soil contamination due to cement dust reduced sharply with distance from the factory.

Keywords: Cement dust emission, soil properties, infiltration, salinity, contamination

1. INTRODUCTION

The pollution problem in the cement industry is dust, which is emitted from various parts of the production process such as the raw materials crusher, rotary kiln, cranes, mills, storage silos and packing sections. Air-bone respirable dust levels from less than 5 to more than 40 mg/m^3 have been recorded in the workplace air of cement factories (Chaurasia *et al*., 2014). Cement factories are major source of pollutions on crops around it as the dust deposition affect photosynthesis, stomata functioning and productivity.

Air pollutants such as heavy metals (HM), generated in the process of crushing limestone, bagging, and transportation of cement are carried by wind and deposited on soil, plants and water bodies (Kabir and Madugu, 2010). Globally, the problem of environmental pollution due to heavy metals has been a concern in most cities for it leads to geoaccumulation, bioaccumulation and biomagnifications in ecosystem (Princewill *et al*., 2011).

Some researchers investigated the impact of the cement dust on soil properties and plant growth (Princewill *et al*., 2011; Addo and Darko, 2012). Determining the physicochemical properties of soil is important to monitor environmental pollution related to cement industries. Arpita and Mitko (2011) reported that top soils near a cement factory are enriched in heavy metals which are released into the air from the cement kilns. Estifanos and Degafa (2012) revealed that the area close to cement factory in southern Jordan has highest lead, zinc and cadmium level. Zerrouqi *et al*. (2008) accounted that calcium oxide and sulfur oxide are the principal component of pollution on soil surrounding cement factory on Morocco. The results of elementary chemical analysis, expressed in weight percent of oxides, conducted by (Young-Chull and Jae-Min, 2014) showed that the raw material dust of the first grinding process primarily consisted of CaO (41.77), SiO_2 (11.72%), Al_2O_3 (3.45%), and Fe_2O_3 (1.47%). From Ca/Si ratios computed by Asubiojo (1991), it was found that soil contamination due to cement drops sharply with distance from the factories, and with increasing depth from the surface.

Recently, Dangote Cement Company, Tse-Kucha, Gboko Local Government Area of Benue State built new plant that has technology for reducing emission, but has visible impact on the surrounding environment through, mainly dust from towers, quarry mines and crusher. The expansion of Gboko Town, and Tse-Kucha and Amua Settlements towards the factory vicinity, other impacts on the environment include gases (air pollution), heat (thermal pollution mainly through hot effluents) and noise pollution.

However, not enough information available in relation to the assessment of cement dusts emission on the nature of soils around Dangote Cement Factory, Tse-kucha, Gboko, Benue State. This paper presents results of assessment of the impact of cement dust from the cement factory on the physical and chemical characteristics of soil in the surrounding area. The pollution assessment would help to present the existing soil quality for agriculture and to predict possible additional impact due to the emissions expected from the factory.

2. MATERIALS AND METHODS

Study Area

The research was carried out at three selected locations; 0.5, 1.0 and 1.5 km distance in Tse-Kucha, Amua and Amua settlements respectively from Dangote Cement Factory (formerly known as Benue Cement Company PLC), Tse-Kucha, Gboko Local Government Area of Benue State. The factory is sited on the Tse-Kucha Limestone Formation which is the major raw material for cement production. Dangote Cement Factory is located at about 8 km NE from Gboko Town along Gboko – Makurdi road. The study area is located in the North – East side of

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Dangote Cement Factory, Tse-Kucha, Gboko Local Government Area of Benue State. The area under consideration falls on the north – east side of the cement plant where the dust predominantly blows to driven by the wind. The study area is bounded by longitudes $8^0 36'$ and $8^0 45'$E and latitudes $7^0 45'$ and $8^0 00'$N (Fig. 1).

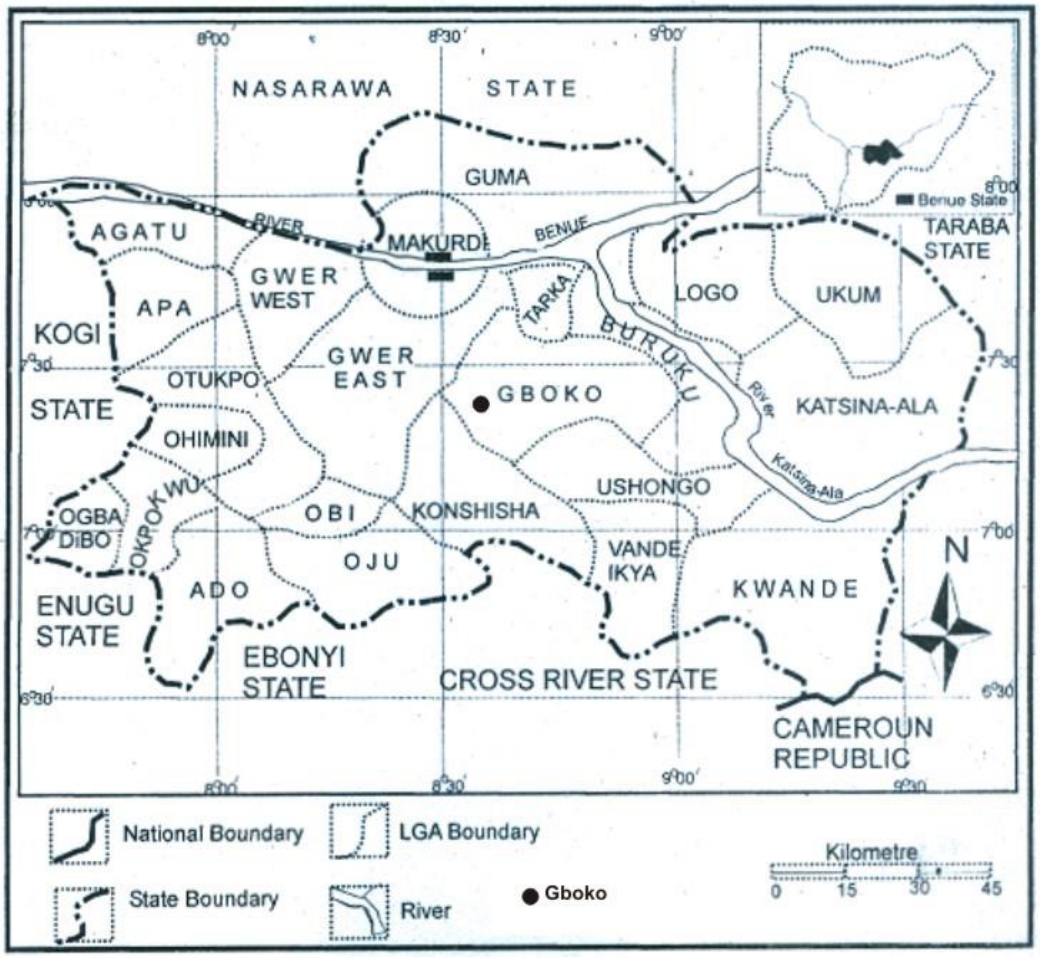

Fig. 1: Map of Benue State showing Gboko
Source: Ministry of Land and Survey, Makurdi (The NAFRN, 1978)

Wind in the Gboko Area normally blows strongly from SW to NE for eight months of the year (April to November) during the rainy season, and reverses its direction in the dry season from December to March (harmattan period).

The vegetation in the study area is Guinea Savannah type, characterized by grasses with few scattered shrubs and trees. The land in the study area is used for cultivation of crops such as yam, cassava, guinea corn, maize, millet, groundnut, soyabean, benniseed, rice, melon, and other vegetable crops. Trees crops such as mango, palm trees, citrus, cashew and other economic trees are also found in the area.

3. FIELD METHODS

Infiltration capacity

Infiltration capacity tests were carried out at three locations of the study area. Three (3) infiltration tests were determined in each location. Infiltration test was done by digging 10cm x 10cm x 10cm pit at each location. Water volume of 250cm^3 was poured into the pit and the time in second was taken and recorded for water transmission into the soil. This was repeated four times at each pit. Infiltration capacity 'K' in each location was computed using Darcy formular:

$K = Q/A \times t$ (Brady and Weil, 1999)

Where;

K = Infiltration capacity (cm/sec), Q = Volume quantity of water used (cm^3)

A = Cross sectional area of soil (cm^2), t = time taken for water to infiltrate (second)

The results of the infiltration capacity were compared with hydraulic conductivity classes (Marshall and Holmes, 1988).

Soil sampling

Soil sampling in the vicinity of Dangote Cement Factory where the dust is visually evident to fall predominantly was conducted in June, 2017. The random sampling technique was used to collect soil samples from six (6) different points in each location. Nine of the sampling points fall on farm land while nine were on fallow land. Soil auger was used for collection of the soil samples. Composite soil samples were taken at the depth of 0 – 30cm at the distance of 0.5, 1.0 and 1.5 km away from the industry. The 6 samples in each location (distance) were air dried, bulked accordingly and gently crushed. A total of 3 soil samples from the three locations were sieved using 2.0mm sieve for physical and chemical analysis.

Laboratory Methods

Soil samples were analyzed in the laboratory as shown in Table 1:

Vol. 3, No. 03; 2018

ISSN: 2456-8643

Table 1: Methods used for Determination of Physical and Chemical Properties of Soils

	Soil Properties	Methods of Determination
i.	Texture	Hydrometer method (Udo *et al*., 2009)
ii.	Infiltration capacity	Permeability pit method
Iii	Soil pH	pH meter
iv.	Organic carbon (%)	Walkley and Black method (Udo *et al*., 2009).
v	EC	Electrical conductivity meter
vi	Ca, Mg	Titration method (Udo *et al*., 2009)
vii.	Na, K	Flame Photometry (Udo *et al*., 2009)
viii	Nitrogen	Micro-kjeldahl distillation method
ix	Phosphorus	Bray and Kurtz (1945) (Udo *et al*., 2009)
x	EA	Titrimetric method (Udo *et al*., 2009).
Xi	CEC	Summation (TEB + EA) method
Xii	EB	Summation method ie ∑ (K, Na, Mg, Ca)
xiii.	B.S, ESP, SAR	By calculation (Udo *et al*., 2009)

The chemical properties of the soils were compared with USDA soil degradation standards (USDA, 2001) and discussed under salinity and fertility related parameters.

4.RESULTS AND DISCUSSION

Infiltration Capacity

Infiltration is the process by which water enters into the immediate soil surface (Obi, 2000). Infiltration capacity is the maximum rate at which water can enter the soil under given conditions (Brady and Weil, 1999; Obi, 2000). Table 2 shows the results of the infiltration capacity tests carried out at kilometers 0.5 (Tse-kucha), 1.0 (Amua) and 1.5 (Amua) away from the factory. The values of the infiltration capacity fall within the range suitable for crop and irrigation

(Marshall and Holmes, 1988). The soils of the study area would transmit water at a rate of nearly 10m/day (Table 2). According to Hillel, (1980) a coarse sandy soil with K value of 10^{-2} cm/s would lose water at the enormous rate of nearly 10 m/day while a fine loam soil with a K value of 10^{-4}cm/sec would lose "only" about 10 cm/day. In a saturated soil of stable structures as well as a rigid porous medium such as sandstone, the hydraulic conductivity is characteristically constant. Its order of magnitude is about 10^{-2} to 10^{-3} cm/sec in a sandy soil and 10^{-4} to 10^{-7} cm/sec in a clayey soil (Hillel, 1980).

The soils of Tse-Kucha and Amua show high transmission of water and moderate water holding capacity. They are well drained and of good quality for irrigation. Marshal and Holmes, (1988) reported that in a saturated soil material of K values ranging from 10^{-7} to 10^{-4} m/s, the soil was associated with wide range of soils for irrigation including those of fine texture with stable aggregates.

Table 2. Infiltration Capacity (K) of the Study Area

Location	K (cm/s)	Effect on land use under agric.
Tse-Kucha (0.5km)	0.006	Wide range for crops/irrigation
Amua (1.0km)	0.003	Wide range for crops/irrigation
Amua (1.5km)	0.009	Wide range for crops/irrigation

Mechanical Composition of Soils of the Study Area

The particle size distribution of the soils of the study area is presented in Table 3.

The soils of the study area were of dominantly sandy loam texture at Tse-Kucha (0.5km), while Amua (1km) and Amua (1.5km) were of loamy sand textures. The sand dominant fractions in the three locations indicate low water holding capacity and rapid water and air transmission. The soils possess good drainage and aeration. The soils are moderately suitable for crop production but may be prone to drought and cement dust pollution.

Table 3. Mechanical Composition of Soils of the Study Area.

Location	Depth (cm)	Particle size Distribution (%)			Textural Class
		Sand	Silt	Clay	(USDA)
Tse-Kucha (0.5km)	0 – 30	66.0	19.0	15.0	Sandy loam

Amua (1.0km)	0 – 30	85.0	7.0	8.0	Loamy Sand
Amua (1.5km)	0 – 30	83.0	7.0	10.0	Loamy Sand

Chemical Properties of the Soils of the Study Area

Chemical properties of the soils of the study area are presented in Table 4 for Tse-Kucha (0.5km), Amua (1.0km) and Amua (1.5km). The results of the soil chemical compositions at the depths of 0 – 30cm indicated that the concentration of minerals decreased with increase in distances.

Salinity status of the soils

Salinity is the measure of total salt content of the soil; usually the concentration of salts when measured is above 4mmhos/cm. Electrical conductivity (ECe) values of the soils of the three locations ranged from 0.76 – 1.37 ds/m. These values are generally moderate to high in terms of soil degradation. The high EC values of the soils could be attributed to high concentration of the major cations (K, Na, Mg and Ca) and salt in the soil caused by dust emission from the cement factory. Although the soils are non-saline according to the limits set by Schoeneberger *et al.* (2002). All the soils have ECe values of less than 2 ds/m.

The soil around Dangote Cement Factory of less than 1km distance is calcareous in nature as calcium concentration in the soil was generally high (Table 4). The high amount of calcium in the soils was from the cement dust emission and the presence of limestone within the lithology. The ratio of Ca/Mg is greater than one. Therefore, potential effect of sodium is reduced. The SAR and ESP would also decrease. Estifanos and Degafa (2012) also reported that, soils around cement factory are calcareous in nature.

Sodium, which determines the sodicity status of a soil, was generally low to moderate (0.34 – 1.30 Cmol/kg). The moderate sodium value of 1.30 Cmol/kg at Tse-Kucha may be toxic to some crops, and beyond 2.0 Cmol/kg may lead to soil sodicity. The low to moderate sodium level in the soils was further confirmed by the low to moderate exchangeable sodium percentage (ESP) (4.02 – 7.53 %). Soils with ESP of less than 15% are said to be non-sodic and thus good for agriculture. Sodium absorption ratio (SAR) of the soils was low (0.17 – 0.47) and falls below USDA standard value of less than 15.

The soil pH values of the study areas showed that the soils were generally slightly alkaline (7.17 – 7.69). Alkalinity in the wet season was due to the appreciable quantities of exchangeable base-forming cations (Ca, Mg, K and Na) on the surface layers of the soils and low buffering capacity. The dominant cations were Ca and Mg which might come from cement dust emission. Soils around cement factory can be easily overlimed due to pollution from the cement dust emission from industry and low buffering capacity.

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Fertility status of the soil

Fertility is the total capacity of a soil to supply plant nutrients and other growth factors for the optimum performance of a particular crop (Agbede, 2009).

The values of organic matter in the soils of the study areas were generally low to moderate (0.69 – 2.84 %). The organic matter of most soils ranges from 1-5% mostly in the top 25cm of soil (Agbede, 2009). The soil is considered moderately suitable for agriculture due to moderate organic matter contents of the soils. Water holding capacity, granulation, cation exchange capacity, supply and availability of nutrients would improve.

The nitrogen content of the soils of the study area was low (0.23 – 0.81 %). This may be as a result of rapid rate of organic matter decomposition, excessive leaching of nutrients down the soil profile, and crop removal and erosion during the rainy season. Most savanna soils of Nigeria have very low total N content (0.04 – 0.05%) as against the normal range of 1 – 6% N (Adetunji and Adepetu, 1990).

The available P content of the soils during the study ranged from 2.8 – 5.8 mg/kg (Table 4). The moderate to high level of phosphorus content of the soils may be due to moderate organic matter content, parent material and degree of weathering. The available phosphorus forms are $H_2PO_4^-$ and HPO_4^{2-}. The combined concentration is high in soils with a range of <1 – 4 mg/kg (Agbede, 2009).

The exchangeable bases (EB) are generally moderate in all the soils of the three locations. Calcium and magnesium are the dominant cation. Potassium and sodium are low and moderate respectively in concentration. The total exchangeable bases range from 8.45 – 17.26 Cmol/kg.

The exchangeable acidity (EA) of the soils was low and ranged from 1.10 – 1.20 Cmol/kg. The cation exchange capacity (CEC) is moderate in all soils of the study area and ranged from 9.65 – 18.36 Cmol/kg. The moderate CEC was as a result of the combined effect of the organic matter, total exchangeable bases and exchangeable acidity of the soils.

The base saturation (BS) of the soils of the study area is generally high and ranges from 87.56 to 94.01%. Base saturation values greater than 50% indicate fertile soils while values less than 50% indicate low fertility (FAO – UNESCO, 1998). Based on this, the soils of the three locations could be considered fertile.

Table 4. Chemical Properties of the Soils

Parameters	Tse-Kucha (0.5 kilometer)	Amua (1.0 kilometer)	Amua (1.5 kilometer)	USDA Soil Std Ranges

Vol. 3, No. 03; 2018

ISSN: 2456-8643

pH (H_2O)	7.17	7.55	7.69	5.5 – 8.5
O.C (%)	1.64	0.78	0.40	1.0 - >2.0 %
O.M (%)	2.84	1.35	0.69	2.0 – 20
N (%)	0.81	0.28	0.23	0.2 - >1.0 %
P (mg/kg)	5.80	3.40	2.80	8 – 20 mg/l
K (Cmol/kg)	0.96	0.74	0.41	0.2 – 2 Cmol/kg
Na (Cmol/kg)	1.30	0.68	0.34	0.1 – 2 Cmol/kg
Mg (Cmol/kg)	6.20	4.0	3.60	0.3 – 8 Cmol/kg
Ca (Cmol/kg)	8.80	5.60	4.10	2 – 20 Cmol/kg
EB (Cmol/kg)	17.56	11.18	8.45	NA
EA (Cmol/kg)	1.10	1.12	1.20	NA
CEC (Cmol/kg)	18.36	12.30	9.65	6 – 40 Cmol/kg
BS (%)	94.01	90.89	87.56	20 – >80 %
ESP (%)	7.53	6.08	4.02	<15 %
EC (ds/m)	1.37	1.04	0.76	0 – 2 ds/m
SAR	0.47	0.31	0.17	0 – 15

NA = Not available

CONCLUSION

Based on the results of the research, it could be concluded that among the three locations assessed, less than 1.0km distance (Tse-Kucha) is heavily contaminated with cement dust emission from the factory. The sever contamination is evident to the north – west direction towards which the wind blow predominantly. The soil contamination due to cement reduced sharply with distance from the factory.

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ISSN: 2456-8643

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Vol. 3, No. 03; 2018

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