Quality Evaluation and Physico-Chemical Properties of Soils around a Cement Factory in Gombe State, Nigeria

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***Abstract*—**This work was carried out to evaluate the effect of deposition of cement dust on the physico-chemical properties of soil around a cement factory and its suitability for the cultivation of some cereals and ground nut using the arithmetic and limiting condition models. Soil samples were collected from 0 – 30 cm depth covering 6km radius round the factory. The results of the physico-chemical parameters show that the soil is sandy and of very low humus and organic matter, with surface crusting that may delay seedling emergence and water infiltration. The pH is generally acidic with pH decreasing with distance away from the factory. The cation exchange capacity was low, indicative of low buffering and nutrient capacity of the soil. Modeling of the physico-chemical parameters using the arithmetic and the limiting condition models shows that the soil suffered physicochemical damage and might not be suitable for the cultivation of maize, millet, sorghum and groundnut Except where large quantity of fertilizers are applied.

***Keywords*—**Cement dust, physicochemical parameters, farmlands, soil quality and crops.

I. Introduction

SOIL characteristic parameters have always been used to define quality of soil and often with biological processes influence soil fertility in a variety of ways, each of which can have an ameliorating effect on the main soil-based constraints to productivity. Soil texture provides the classes of particle size possessed by a soil which plays a significant role in the development and stability of soil structure[1]. Metals have to be in an available form for plants to take up or plant must have mechanism to make the metals available. Due to the hydroxyl groups and electron pairs of oxygen in the structure of clay minerals and to the carboxyl and phenolic groups of organic substances, the soils are negatively charged [2] and, as such, attract positive metal ions. Organic ligands act as carriers to the plant root [3].Factors affecting the metals release from the soils and colloids influence the bioavailability of metal to plants. The factors known to affect the solubility and plants availability of the metal to plants include their chemical characteristics, loading rate, pH, cation exchange capacity (CEC), redox potential, soil texture, clay content and organic matter content [4, 5, 6, 7, 8]. Chang et al. [9] found soil temperature to be one of the major factors accounting for variations in metal accumulation by plants. The total amount of the metal in the soil, crop species and variety, free lime ($CaCO_3$) and soil moisture have been reported to influence the metal availability[10]. Low pH increases the metal availability since the hydrogen ion has a higher affinity for negative charges on the colloids thus competing with the metal ions of these sites, thus releasing the metals. The metals become less available as the soil becomes more alkaline. High organic matter content means immobilization of the metals which bind to the fulvic or humic substances and high CEC suggests that the possibility of binding to negative charges increases. Therefore, the higher the clay and/or organic matter content and pH, the more firmly bound are the metals and the longer is their residence time in soil. Free lime (CaCO3) precipitates and adsorbs the metals making them less available to plants. Cool/wet soils can also reduce the rate and amount of metals taken up by plants. Plant type, variety and growing conditions can be affected whether or not a metal deficiency will occur [10]. The presence of inorganic anions (carbonate, phosphate, sulphide) in the soil water can also influence the soils ability to fix metals chemically [11]. These anions can form relatively insoluble complexes with metal ions and cause metals to add/or precipitate in their presence. The particle size distribution can be determined using the method adopted by Sillanpa [12]. Cation exchange capacity (CEC) provides information on soil permeability, buffering ability and the ease of adsorption and desorption of metals. Mahasneh and Shawabkeh [13] have evaluated the permeability of sand-cement-clay composite by determining CEC. Soil pH gives the acidic or alkaline condition of soil which is determined by mixing soil with water or calcium chloride solution in various ratios [12]. Cement dust has been considered to be one of the major sources of pollution in the environment due to the emission of particulate matter to air. This has been a major problem in most third world countries mostly due to

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economic constraints [14]. Ashaka Cement Company is the only factory that produces cement in the north eastern part of Nigeria. Its activities have been suspected to decrease agricultural yield despite the application of fertilizers on farmlands. past activities of the cement industries have left the environment battered and destroyed as a result of excavation and emission of dust from crushing of limestone, and production in spite efforts put in place to suppress dust emissions.

II. Experimentals

A. The study Area

Ashaka Cement Company is located in Jalingo Village of Bajoga, Funakaye local government area of Gombe State, north eastern Nigeria. It was established in 1967, with an installed capacity of 500,000 MT [15] to meet the needs of construction works in the Northeastern part of Nigeria. The factory lies in the Northern part of Gombe between longitude 10^0 45'N and 11^0 00'N and latitude 11^0 15'E and 11^0 30'E. The company produced huge amount of dust and gaseous pollutants to the unsuspecting communities scattered in the area in time past. Prior to now, large proportion of the dust was deposited on farmlands, homes and water bodies including the River Gongola.

B. Sample Collection

Soil samples were collected from cultivated soils around the cement factory starting from the factory fence and at every 2km intervals covering 6km radius. Soils from 0-30cm depth were sampled at each point. This provides the depth roots of grain crops can access. Sorghum and millets are the common plant crops cultivated by the communities. Stalks of sorghum and millet were collected at each soil sampling points.

C. Sample Treatment

Soil samples were dried at 105^0C in an oven until constant weight was obtained. It was ground and sieved through a 2mm screen plastic sieve. The plant samples were washed before drying. It was ground in a ceramic mortar and stored in plastic bottles.

D. Reagents and Chemicals

All analysis were performed with Analar grade chemicals and distilled water through out, unless otherwise stated.

E. Determination of Soil pH

Soil pH was determined using a Philips pH meter model PW9418 after mixing 5.0g of the soil with 5ml water and allowing to stay overnight [16].

F. Measurement of Electrical conductivity

Electrical conductivity was determined in a 1:5 soil water extract at 25^oC using Alpha 800 conductivity meter, model 800 [12].

G. Determination of Moisture

5.0g of soil sample was weighed into a watch glass and placed inside an oven regulated at 110^oC. It was heated, cooled in a desiccator and weighed, repeating these steps until constant weight was obtained. The difference in the weight was read as the weight of the moisture.

H. Determination of Organic matter content

Porcelain crucible was used to weigh 5.0g of oven dried soil. It was placed in a furnace and heated to 500^oC for 1 hour. The sample was allowed to cool in a desiccator and the loss in weight of the residue after removal of moisture gives the total organic matter [16].

I. Determination of Sand/Silt/Clay Content

50g of the sieved sample was weighed into a polythene bottle containing 2.5cm^3 of 5% sodium hexametaphosphate and 400cm^3 of tap water. The soil was stirred with a magnetic stirrer for 15 minutes and the sample transferred to a one litre plastic measuring cylinder and diluted to the mark. Hydrometer was inserted into the suspension and reading was taken at 40 seconds and 2 hours. The temperature of the suspension was taken after each reading. The amount of the silt and clay was evaluated as follows;

Calculations:

If A = hydrometer reading (gL-1) after 40 seconds

B = hydrometer reading (gL-1) after 2 hours

Then, % clay = [A(gL-1) x 100__________] - 1

(Weight of soil (g) – moisture)

Where 1 is the calgon correction factor

Silt + clay (%) = [B (gL-1) x 100________] -1

(Weight of soil (g) – moisture)

% silt = (Silt + clay) % -% clay

An estimate of the total sand fraction is given as

Total sand = 100 – (silt + clay) % [16]

J. Determination of Cation exchange capacity (CEC)

10g of soil sample was weighed into a 500cm^3 beaker containing 250cm^3 1M ammonium acetate (NH_4OAC) and shaken for 1 hour using the Edmund Bahler Swip mechanical shaker. It was filtered through a Whatman filter paper No. 44 into a plastic bottle. Excess ammonium acetate on the residue was removed by repeated washings of the residue with industrial alcohol and the filtrate discarded. The washed residue was leached with 30cm^3 potassium chloride solution (5% w/v) for 10 minutes to enable the displacement of adsorbed NH4¬¬¬¬¬¬¬¬¬¬¬N. The leaching was repeated until 250cm^3 of leachate was collected. The displaced NH4N was determined by distillation of the leachate followed by titration of the distillate with 0.01M HCl [16]. The CEC was then calculated as follows;

Calculations:

If V1 is the required volume for the titration, then

CEC (Meq /100g-1) = V1 (cm3) x final leachate volume (cm3)

1.4 x distillate (cm3) x weight of sample (g)

III. Result And Dicussion

The mean physicochemical properties of cultivated soils around the Cement Factory are given in Table I, for 0-30cm soil depth. The soil was found to be sandy-clay for the depth sampled.

TABLE I
MEAN CHARACTERISTICS OF CULTIVATED SOILS (0–30CM) AROUND ASHAKA CEMENT FACTORY

Property Measured	No. of Samples	Mean Values	Standard Deviation	Range
pH (1:1 water)	62	6.76	0.85	4.7- 9.84
CEC (cmol/kg)	62	10.72	1.86	8 - 14
Moisture (%)	62	11.44	8.66	0.00-64.50
Organic matter (g/kg)	62	1.88	0.94	0.5- 5.36
Sand (%)	62	57.94	22.73	0.42-87.15
Silt (%)	62	20.71	10.59	3.52– 52.76
Clay (%)	62	21.35	15.60	5.58- 52.76

A. *Physicochemical Characteristics of the Soils*

Soil Texture

The soils around the cement factory vary over a wide range texturally. However, the mean texture of the soil indicates that the soil is sandy clay (TableI) with sand having 57.94%, clay 21.35%, and silt 20.71% at soil depth 0-30cm.. The texture of a soil influences its productivity or health. Consequently, soil health impacts directly on plant health. This sandy nature of the soil might be due to the depletion of humus and organic matter; this character is typical of the Nigerian savanna [17] . Surface crusting (caking) is a common observed feature of these soils and may delay seedling emergence and water infiltration [18].

Soil pH

The mean pH is strongly acidic varying over a wide range (TableI). The observed pHs are similar to those earlier reported for Savanna soils [17]. Some authors [19, 20] have reported earlier that most savanna soils are acidic. The pH values suggest that a wide variety of crops can be grown on the soils. Soil acidity is caused by the removal of basic elements through leaching and crop uptake, organic matter decomposition, acid rain, nitrification of ammonium nitrogen, and by natural soil forming processes [21]. Cement factory emissions when they settle on soil could alter soil pH. In another work around a cement factory in turkey, dust emission was reported to have a pH of 6.5 – 8.6[22]. This is similar to the pH range obtained in this work; Balasubramaniam et al. [23] reported 4.86 – 7.13 for fallow and 5.18 – 6.69 for cultivated savanna soils. The acidic pH values obtained here may have been due to the partial neutralization of the soil by high acidic gas emissions that may have been produced at the plant. This was observed by Aslan and Boybay [22] in a work they did in the vicinity of a cement factory. This notwithstanding, the pH decreases with distance away from the factory, while the factory fence soil recorded slight alkalinity.

Soil Organic matter

The organic matter content of the soils in terms of organic carbon varied as 0.5 – 5.36 g/kg with a mean of 1.88g/kg (TableI). The mean value of the organic carbon shows that organic matter content of the soil around the cement factory is generally low. This agrees with Balasubramanian et al. [23] who reported upland savannah soils organic carbon of 0.0059 to 1.53% and increased organic carbon content from Sudan savannah to southern savannah as a result of the increasing production of organic matter. However, the low levels of organic matter in savannah soils arise from their predominantly sandy nature probably caused by high dust deposition and the relatively low rainfalls [24]. The low organic carbon may also suggest probably a reflection of a generally low annual biomass production[18, 17, 25]. An implication of low organic carbon is low retention of micronutrients in both plants – available and unavailable forms. Low organic matter soils usually have less available copper, iron, manganese and zinc than soils with moderate amounts of organic matter [10].

Cation Exchange Capacity (CEC)

The effective cation exchange capacity of the soil varied over 8.0 – 14.0 cmol/kg and has a mean of 10.72cmol/kg (TableI). The CEC for the soil around the cement factory is low and this has been supported by the low clay and organic matter contents. This was observed earlier by Balasubramanian et al. [23] in savannah soils where CEC increased with increasing clay and organic carbon content. The low CEC may result in low buffering capacity of the soils and low nutrient retention, meaning that crops will not benefit much from applied nutrients; this will in turn reduce crop yield.

Soil Quality Evaluation

The physicochemical parameters were used to determine the quality of the soil for the growth of maize, millet, sorghum and groundnut using the limiting condition and arithmetic modeling methods. In both the limiting condition and arithmetic modeling methods, the suitability of the soil was merged with the crop requirement and the suitability index obtained for a particular factor. The least durable assessment found limiting was taken as the land suitability class for the limiting condition model. In the arithmetic modeling, each factor was assigned a suitability class ranging from S1 to N as follows; S1 = 0.5, S2 = 0.8, S3 = 0.5 and N = 0.0 (FAO, 1976). The overall suitability was then obtained by multiplying the individual assessment and the product used for the classification as highly suitable (S1 = 0.8 – 1), moderately suitable (S2 = 0.4 – 0.8) marginally suitable (S3 = 0.2 – 0.4) and currently not suitable (N = 0.0 – 0.2). The Rating of Land Use Requirement for Maize, Millet, Sorghum and Groundnut is given in table III as extracted from FAO, [26] and Yayock et al., [27].

Table II shows the suitability classification computed for the crops considered based on the limiting conditions and arithmetic modeling. The result shows that the land is currently not suitable for any of the crops considered, according to the two models. There seems to be close agreement on land suitability using the two models, suggesting that the land could have been affected by the activities of the cement factory. However, despite the non-suitability of the land for the growth of the crops considered, the farmers still grow them with some measure of success by applying large quantity of fertilizers. The land evaluation model seems to affirm the physicochemical damage done to the environment around the factory and expresses it in terms of suitability of the soils for the growth of maize, millet, sorghum and groundnut.

TABLE II
RESULT OF THE SUITABILITY CLASSIFICATION BASED ON THE LIMITING CONDITION AND ARITHMETIC MODELING METHOD

Land Quality	**Crop Plants**			
	Maize	**Millet**	**Sorghum**	**Groundnut**
Rooting condition	S_3	S_3	S_3	S_3
Toxicity	S_1	S_1	S_1	n_1
CEC	S_2	S_2	S_2	S_2
Nutrient retention	n_1	n_1	n_1	n_1
Rooting condition	S_3	S_3	S_3	n_1
Overall suitability limiting condition	n_1	n_1	n_1	n_1
Arithmetic modeling	N(0.0)	N(0.0)	N(0.0)	N(0.0)

TABLE III
RATING OF LAND USE REQUIREMENT FOR MAIZE, MILLET, SORGHUM AND GROUNDNUT

	Crop	Soil	Rating			
			S_1	S_2	S_3	N
A.	Maize:	Texture*	SL, SCL	Si, CL, CL	Si,Sl, SC	hc,ls,s
		pH (1:1 water)	6 – 7	5.8 – 6, 7 – 7.5	5.8 – 5.5	<5, 5, >8
		CEC (Cmol(t)kg^{-1})	>12	9 – 12	5 – 8	<5
		Organic carbon (g/kg^{-1})	>10	10 – 5	5 – 2	<2
		Soil depth (cm)	>120	50 – 120	30 – 50	<30
B.	Millet:	Texture*	SCL,SL	Cl, S, Cl	Sl, Si, Sc	ls, s, hc
		pH (1:1 water)	5.5 – 7.5	4.8 – 5.5	4.5 – 4.0, 8 – 8.3	<4, >8.3
		CEC (Cmol(t)kg^{-1})	>12	9 – 12	5 – 8	<5
		Organic carbon (g/kg^{-1})	>10	10 – 5	5 – 2	<2
		Soil depth (cm)	>120	50 – 120	30 – 5-	<30
C.	Sorghum:	Texture*	SL, L	CL, SL	SC, LS	S
		pH (1:1 water)	5.5 – 7.5	4.8 – 5.5, 7.5 – 8	4.5 – 4.0, 8 – 8.3	<4, >8.5
		CEC (Cmol(t)kg^{-1})	>12	9 – 12	5 – 8	<5
		Organic carbon (g/kg^{-1})	>10	10 – 5	5 – 2	<2
		Soil depth (cm)	>120	50 – 120	30 – 50	<30
D.	Groundnut:	Texture*	SL, SIL	S, CL, CL, SCL	Sl, S, Sc	C
		pH (1:1 water)	5.8 – 6.25	5.55	<5	<7
		CEC (Cmol(t)kg^{-1})	>12	9 – 12	5 – 8	<5
		Organic carbon (g/kg^{-1})	>10	10 – 5	5 – 2	<2
		Soil depth (cm)	>100	70 – 100	40 – 70	<40

*SL = sandy loam; SiCL = silty clay loam; CL = clay loam; Si = silt; Sc = sandy clay; hc = heavy clay; LS = loamy sand; S = sand; L = loam; SiL = silty loam; CS = coarse sand, C = clay; SCL = sandy clay loam; SiC = silty clay [26, 27].

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