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Impact of Cement Dust on Physical and Chemical Nutrients Properties of Forest Topsoil

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ABSTRACT: The study examined the impact of Cement dust on physical and chemical nutrients properties of forest topsoil in close proximity to a major private cement industry in Obajana, Kogi State, Nigeria using standard methods by collecting Topsoil samples for physical and chemical properties analyses which are particle size, moisture content, pH, carbon, nitrogen, phosphorus, potassium, sodium, calcium, magnesium, cation exchange capacity and organic matter.Data revealed a strong influence of the particulate pollutants on the forest topsoil in close proximity to the Cement factory. It was observed that the soil properties; moisture content and soil pH varied at distances away from the factory. The result showed that the Cement dust particles entering the soil increased the pH of the soil, it more alkaline. The highest pH (6.03) was observed from hundred and fifty meters sample indicating the highest particulate pollution. There were also variations in the other soil nutrient properties; carbon, nitrogen, phosphorus, potassium, sodium, calcium, magnesium, cation exchange capacity and organic matter arising from the effect of cement dust. High organic matter content was recorded in the location samples compared with the control sample. This is attributed to the addition of cement dust to the soils, resulting in improved organic-matter cycling and plant growth. The result also showed that the chemical properties; organic carbon (OC), organic matter (OM), phosphorus (P), potassium (K), sodium (Na), calcium (Ca) and magnesium (Mg) are significantly higher in the study areas than the control. The study therefore concludes that the emission of cement dust on the forest stands over the years was found to have significantly affected the topsoil properties.

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Generally, the natural environment is made up of air, water and soil. The release of emission of industrial waste such as cement dust into anyone of the components of the environment causes pollution. The presence of pollutants in the environment tampers with the natural environmental media (air, water, and land) thus, affecting plant, animal and human lives (Vhahangweli and Khathutshelo, (2018).Cement dust is one of the industrial wastes that affect the soil properties. Cement manufacturing includes mining and quarrying of raw materials, which are principally oxides and carbonates of metals. It also involves grinding the raw materials into fine particles, such as limestone, shale, sand, clay, iron ore, and fly ash, and mixing them in appropriate proportions. Mild heating is applied to drive off any water and carbon dioxide available in the limestone (Inibabi et al., 2013). It is a very dusty and energy-consuming process, constituting a very serious source of air pollution. Cement dusts influence the ecosystems including soil and plants, cause the imbalances in soil nutrients and reduce biodiversity (Gheorghe, and Barbu, 2010). Because of its high carbonate content, the dusts tend to be highly alkaline. The dust particles discharged into the atmosphere during grinding, crushing, and blending of the raw materials in the cement factory eventually reach the soil as dissolved substances during rains as fallouts (Russell, 2007). Once in the soil, the metals contained in the dust undergo reactions that affect the chemical, physical, and biological properties of the soil. Pathak and Khan, (1994) reported that treating the soil with one of the raw materials of cement (fly ash) had effect on the physical and chemical as well as the biological properties of soil. They determined that the water holding capacity, electrical conductivity, and pH of the soil were affected. The fly ash also neutralized the acidity of the soil by raising the soil pH. Its application enhanced the metabolic rates and growth and increased the photosynthetic pigments of crops. However, the ash contains toxic substances, such as dibenzofuran and bibenzo-p-dioxane mixtures which may interfere with the normal physiological development of agricultural crops (Heerden *et al.,* 2007). Brigden and Santillo

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(1987) also discovered the presence of nickel, arsenic, cadmium, chromium, lead, selenium, zinc, and copper in fly ash. Deposition of industrial wastes on soils has both advantages and disadvantages. Hence, this study aimed at examining the effect of cement dust on the physiochemical properties of forest topsoil around private cement factory at Obajana in Kogi State, Nigeria.

MATERIAL AND METHODS

Study area: The study was carried out at the forest stands in the surroundings of private cement factory, Obajana, Kogi State, Nigeria. It is on a latitude 7.92635ºN and longitude 6.41456ºE with elevation of 41m.

Data collection: Soil samples in the vicinity of the cement factory where the dust is visually evident to fall predominantly were collected to obtain maximum dust particulates and in the adjoining forest. A 500 x 500m plot was established in a forest at 50m distance to the cement factory. The starting point coordinate is +07.92736ºN, +006.41306ºE and elevation of 209m and ending point coordinate is +07.92772ºN, +006.41069ºE and elevation of 228m. A 100 x 100m plot was also established in an adjoining forest to serve as control. A ten small quadrant of 25 x 25m was laid inside the 500 x 500m and a four small quadrant of 25m x 25m was laid in 100 x 100mestablished plots respectively. A small quadrant of 5 x 5m was laid inside each of the 25x25m established plots. Topsoil samples were collected along the diagonal of each quadrant using the soil auger. The soil samples were collected in five points on each quadrant diagonally with soil auger at the depth of 0 – 10 cm and bulked. The samples were air dried and sieved with a 2mm sieve for the laboratory analysis. All samples were subjected to the physical and chemical laboratory analysis.

Determination of the physicochemical characteristics of the soil sample: The soil mechanical analysis and moisture content were established by the hydrometer method of Ibitoye (2008), while the soil pH was determined according to IITA, (1979). The organic carbon was established by the standard method of AOAC, (1999). The total Nitrogen and available Phosphorus content of the soil were evaluated by the micro Kjeldahl digestion and distillation method as described by Biey *et al.*,(2000) and Debosz*et al*., (2002) respectively.The exchangeable bases (Na, K, Ca and Mg) were estimated according to Barker, (2001) and AOAC, (1999). Emission against concentration was recorded both in standard and sample solution using flame photometer for Ca and Mg while K and Na were read off using a flame photometer. Cation Exchange Capacity (CEC) was determined by ammonia saturation method coined by Ibitoye, 2002) while Organic matter was determined according to Walkey and Black, (1934) methods.

Experimental design and data analysis: The experiment was laid out in a Randomized Complete Block Design (RCBD). Transects formed the block while the distances are another source of variation and the soil nutrients are the treatment. The statistical data was carried out based on the data obtained. The results from all laboratory experiments were subjected to ANOVA test for significant difference in their nutrient contents. All analyses were carried out using SPSS software.

$$Y_{ijk} = \mu + B_i + T_j + \varepsilon_{ijk}$$

Where Y_{ijk} = individual observation; μ = general mean; B_i = effect of Block (soil depth); T_j= effect of treatment; ε_{ijk} = experimental error

RESULTS AND DISCUSSION

Soil Physical Analysis: Table 1 showed the result of the physical properties of the topsoil in each transect and the control. The result showed higher percentage of sand in the three locations as it ranges from 98.42 - 99.81. The highest percentage of sand (99.81±1.57) in the topsoil is recorded in control. This is followed by the topsoil from transect 1 (98.42±2.8) and the least percentage of sand in the topsoil is from transect 2 (98.41±2.78). The percentage proportion of clay is found in transect 1 and transect 2. The clay contents are 0.143±0.03 and 0.142±0.03 respectively. Control has the least percentage proportion of clay (0.14±0.03). The result of the percentage proportion of silt content in the topsoil of transect 1 and transect 2 is the same 1.44±2.80. The result also revealed the moisture content present in topsoil of the locations. The results showed that the topsoil from transect 2 has the highest percentage of moisture content (8.668±2.63). This is followed by the moisture content in the topsoil from transect 1 (6.692±7.72) and control has the least percentage of moisture content (4.83±1.570).

Soil Chemical Analysis: Table 2 showed the result of the chemical nutrient properties of forest topsoil from transect 1, transect 2, and control. The chemical properties are as follows: For Transect 1, the mean pH is 4.36 at fifty meters to the cement factory while the Sodium (Na), Potassium (K) and Magnesium (Mg) are 13.04ppm, 37.44ppm and 0.85cMol/kg respectively. At this point also, the amount of calcium (Ca) is 1.56ppm and the Phosphorus is 12.83ppm. The level of the Nitrogen (N), Organic carbon, and Organic matter are 0.42%, 3.55%, and 6.12% respectively. Seventy meters away from the factory, the forest topsoil has the following nutrients mean values: the mean pH is 5.18 while the Sodium (Na), Potassium (K) and Magnesium (Mg) are 12.17ppm, 31.03ppm and 0.40cMol/kg respectively.

Table 1: Physical Properties of Forest Topsoil

Location	Clay (%)	Silt (%)	Sand (%)	Moisture (%)
Transect 1	0.143±0.029	1.44±2.795	98.42±2.79	6.692±7.72
Transect 2	0.142±0.032	1.44±2.80	98.41±2.784	8.668±2.631
Control	0.14±0.032	0.055±0.033	99.81±1.570	4.83±1.570

At this point also, the amount of calcium (Ca) is 3.12ppm and the Phosphorus is 25.90ppm. However, the level of Nitrogen (N) at this point is 0.49%, the Carbon (C) is 1.58%, the Organic matter (OM) is 2.72% and CEC is 28 cMol/kg. Ninety meters away from the factory, the forest topsoil has the following nutrients mean values: the mean pH is 5.94 while the Sodium (Na), Potassium (K) and Magnesium (Mg) are 10.00ppm, 9.49ppm and 0.64cMol/kg respectively. At this point also, the amount of calcium (Ca) is 3.60ppm and the Phosphorus is 15.24ppm. However, the level of Nitrogen (N) at this point is 0.56%, the Carbon (C) is 2.36%, the Organic matter (OM) is 4.07% and CEC is 21cMol/kg. Hundred and ten meters away from the factory, the forest topsoil has the following nutrients mean values: the mean pH is 5.98 while the Sodium (Na), Potassium (K) and Magnesium (Mg) are 11.30ppm, 30.26ppm and 1.24cMol/kg respectively. At this point also, the amount of calcium (Ca) is 1.72ppm and the Phosphorus is 10.58ppm. However, the level of Nitrogen (N) at this point is 0.42%, the Carbon (C) is 3.82%, the Organic matter (OM) is 6.59% and CEC is 21 cMol/kg. Hundred and thirty meters away from the factory, the forest topsoil has the following nutrients mean values: the mean pH is 5.54 while the Sodium (Na), Potassium (K) and Magnesium (Mg) are 11.74ppm, 23.08ppm and 0.44cMol/kg respectively. At this point also, the amount of calcium (Ca) is 1.48ppm and the Phosphorus is 11.20ppm. However, the level of Nitrogen (N) at this point is 0.56%, the Carbon (C) is 2.29%, the Organic matter (OM) is 3.95% and CEC is 22.40 cMol/kg. Hundred and fifty meters away from the factory, the forest topsoil has the following nutrients mean values: the mean pH is 6.03 while the Sodium (Na), Potassium (K) and Magnesium (Mg) are 14.78ppm, 37.69ppm and 0.68cMol/kg respectively. At this point also, the amount of calcium (Ca) is 1.64ppm and the Phosphorus is 29.17ppm. However, the level of Nitrogen (N) at this point is 0.56%, the Carbon (C) is 3.53%, the Organic matter (OM) is 6.09% and CEC is 19.60 cMol/kg. The mean values for the nutrients chemical properties of forest topsoil at hundred and seventy meters, hundred and ninety meters, two hundred and ten meters, and two hundred and thirty meters away from the factory are recorded as shown in table 2. The control has the following mean values: the mean pH is 5.91 while the Sodium (Na), Potassium (K) and Magnesium (Mg) are 11.52ppm, 23.08ppm and 0.32cMol/kg respectively. At this point also, the amount of calcium (Ca) is 1.75ppm and the Phosphorus is 45.05ppm. However, the level of Nitrogen (N) at this point is 0.47%, the Carbon (C) is 2.00%, the Organic matter (OM) is 3.45% and CEC is 24.50 cMol/kg. For Transect 2, the mean pH at fifty meters to the cement factory is 5.61 while sodium (Na) is 10.87ppm. At this point also, the amount of Potassium (K) is 23.08ppm, the magnesium (Mg) is 0.52cmol/kg, the Calcium (Ca) is 2.24ppm and phosphorus (P) is 22.71ppm. At the same point, the level of Nitrogen (N) is 0.63%, the Carbon (C) is 1.04%, Organic Matter (OM) is 1.79% and CEC is 28cmol/kg. Seventy meters away from the factory, the forest topsoil has the following nutrients mean values: the pH is 5.58 while sodium (Na) is 9.13ppm. The amount of potassium (K) at this point is 18.72ppm, the Calcium (Ca) is 1.36ppm, and Phosphorus (P) is 24.11ppm. Furthermore, the Nitrogen (N) level is 0.42%, the Carbon (C) is 2.77%, Organic matter (OM) is 4.78 and CEC is 21.00cmol/kg. The nutrients mean values for the ninety meters away from the factory are: the mean pH is 5.97 while the Sodium (Na) is 10ppm. Also at this point, the Potassium (K) is 25.64ppm, the Magnesium (Mg) is 0.35cmol/kg, the Calcium (Ca) is 1.48ppm and Phosphorus (P) is 14.78ppm. The Nitrogen (N) level at the point is 0.49%, the Carbon (C) is 1.98 (%), Organic matter (OM) is 3.41% and CEC is 21 cMol/kg. Hundred and ten meters away from the factory, the forest topsoil has the following nutrients mean values: the mean pH is 5.61 while the Sodium (Na), Potassium (K) and Magnesium (Mg) are 11.74ppm, 27.95ppm and 1.28cMol/kg respectively.

Table 2: Chemical Nutrients Properties of Forest Topsoil

Location	Elements	50m	70m	90m	110m	130m	150m	170m	190m	210m	230m	Control
Transect 1	**Ph**	4.36	5.18	5.94	5.98	5.54	6.03	5.83	5.98	5.56	5.96	5.91
	Na (ppm)	13.04	12.17	10.0	11.30	11.74	14.78	9.57	41.74	12.17	17.39	11.52
	K (ppm)	37.44	31.03	9.49	30.26	23.08	37.69	16.92	40.51	30.26	52.56	23.08
	Mg(cMol/Kg)	0.84	0.40	0.64	1.24	0.44	0.68	0.32	0.20	1.04	1.36	0.32
	Ca (ppm)	1.56	3.12	3.60	1.72	1.48	1.64	1.20	1.56	1.36	2.30	1.75
	P (ppm)	12.83	25.9	15.24	10.58	11.2	29.17	16.8	62.53	23.33	47.68	45.05
	N (%)	0.42	0.49	0.56	0.42	0.56	0.56	0.49	0.49	0.59	0.49	0.47
	Oc (%)	3.55	1.58	2.36	3..82	2.29	3.53	2.50	2.36	4.30	3.87	2.00
	Om (%)	6.12	2.72	4.07	6.59	3.95	6.09	4.31	4.07	7.41	6.67	3.45
	CEC(cMol/Kg)	28.00	28.00	21.00	21.00	22.40	19.60	28.00	25.20	94.67	28.00	24.50
Transect 2	**Ph**	5.61	5.58	5.97	5.61	5.75	5.80	5.59	5.83	5.90	5.93	5.91
	Na (ppm)	10.87	9.13	10.0	11.74	13.10	14.78	16.52	14.35	14.78	13.04	11.52
	K (ppm)	23.08	18.72	25.64	27.95	35.85	41.54	38.46	23.33	38.46	32.82	23.08
	Mg (cMol/Kg)	0.52	0.40	0.36	1.28	1.00	1.04	0.56	0.64	0.68	0.44	0.32
	Ca (ppm)	2.24	1.36	1.48	1.12	1.00	2.08	2.48	2.28	2.44	2.60	1.75
	P (ppm)	22.71	24.11	14.78	23.02	13.69	30.25	50.79	76.22	56.47	31.11	45.05
	N (%)	0.63	0.42	0.49	0.56	0.56	0.56	0.56	0.42	0.56	0.63	0.47
	Oc (%)	1.04	2.77	1.98	2.68	2.63	3.28	3.29	3.47	4.23	4.30	2.00
	Om (%)	1.79	4.78	3.41	4.62	4.53	5.66	5.67	5.98	7.29	7.41	3.45
	CEC(cMol/Kg)	28.00	21.00	21.00	28.00	28.00	28.00	28.00	21.00	21.00	28.00	24.50

Table 3: Summary of Chemical Nutrients Properties of Forest Topsoil

Elements	50m	70m	90m	110m	130m	150m	170m	190m	210m	230m	Control
Ph	4.99^{a}	5.38^{b}	5.96^{c}	5.80^{c}	5.65^{c}	5.92^{c}	5.71^{cd}	5.91^{cd}	5.73^{cd}	5.95^{cd}	5.91^{cd}
Na (ppm)	11.96^{ab}	10.65^{ab}	10.00^{ab}	11.52^{ab}	12.42^{ab}	14.78^{ab}	13.05^{ab}	28.05^{c}	13.48^{ab}	15.22^{ab}	11.52^{ab}
K (ppm)	30.26^{cd}	24.875^{bc}	17.57^{ab}	29.105^{cd}	29.465^{cd}	39.615^{de}	27.69^{c}	31.92^{cd}	34.36^{cde}	42.69^{e}	23.08^{bc}
Mg (cMol/kg)	0.68^{bc}	0.40^{b}	0.50^{b}	1.26^{d}	0.72^{bc}	0.86^{c}	0.44^{b}	0.42^{b}	0.86^{c}	0.90^{c}	0.32^{b}
Ca (ppm)	1.90^{abc}	2.24^{bc}	2.54^{c}	1.42^{ab}	1.24^{a}	1.86^{abc}	1.84^{abc}	1.92^{abc}	1.90^{abc}	2.44^{c}	1.75^{abc}
P (ppm)	17.77^{ab}	25.01^{bc}	15.01^{ab}	16.80^{ab}	12.45^{a}	29.71^{cd}	33.80^{cd}	69.38^{e}	39.90^{d}	39.40^{d}	45.05^{de}
N (%)	0.53^{bcd}	0.46^{ab}	0.53^{bcd}	0.49^{abc}	0.56^{cd}	0.56^{cd}	0.53^{bcd}	0.46^{ab}	0.58^{d}	0.56^{cd}	0.47^{ab}
Oc (%)	2.30^{c}	2.18^{bc}	2.18^{bc}	3.25^{de}	2.46^{cd}	3.41^{ef}	2.90^{cde}	2.92^{cde}	4.27^{f}	4.09^{ef}	2.00^{b}
Om (%)	3.96^{c}	3.75^{bc}	3.74^{bc}	5.61^{de}	4.24^{cd}	5.88^{ef}	4.99^{cde}	5.03^{cde}	7.35^{g}	7.04^{fg}	3.45^{bc}
CEC(cMol/Kg)	28.00^{a}	24.50^{a}	21.00^{a}	24.50^{a}	25.20^{a}	23.80^{a}	28.00^{a}	23.10^{a}	57.83^{a}	28.00^{a}	24.50^{a}

Means followed by the same alphabet in the column are not significantly different (P>0.05)

At this point also, the amount of calcium (Ca) is 1.12ppm and the Phosphorus is 23.02ppm. However, the level of Nitrogen (N) at this point is 0.56%, the Carbon (C) is 2.68%, the Organic matter (OM) is 4.62% and CEC is 28 cMol/kg. The nutrients mean values for the chemical properties of the remaining distances in meters are recorded as shown in table 2. The control has the following nutrients mean values: the mean pH is 5.91 while the Sodium (Na), Potassium (K) and Magnesium (Mg) are 11.52ppm, 23.08ppm and 0.32cMol/kg respectively. At this point also, the amount of calcium (Ca) is 1.75ppm and the Phosphorus is 45.05ppm. However, the level of Nitrogen (N) at this point is 0.47%, the Carbon (C) is 2.00%, the Organic matter (OM) is 3.45% and CEC is 24.50 cMol/kg. The results of summary of chemical nutrients properties and One-way analysis of variance for comparison of chemical properties of forest topsoil at different distances away from cement factory are presented in Table 3andTable 4.The study of physicochemical properties of topsoil around the cement factory revealed a strong influence of the particulate pollutants on the topsoil in close proximity to the cement factory.

It was discovered that the topsoil properties; moisture content and soil pH varied at the distances away from the factory. There were also variations in the other soil nutrient properties; carbon, nitrogen, phosphorus, potassium, sodium, calcium, magnesium, cation exchange capacity and organic matter arising from the effect of cement dust. The cement dust particles entering the soil increased the pH of the soil, making it more alkaline. The highest pH (6.03) was observed in the hundred and fifty meters sample, indicating highest particulate pollution. Bilen (2010) reported that the soil pH changes are connected with content of cement dust. Cement dust affects soil pH directly, and soil acid phosphatase enzyme activity indirectly. For Transect 1, the data of soil chemical analysis as shown in Table 2 revealed that the soil pH moved from highly acidic to moderately or slightly acid, with a range of 4.36 to 6.03. This is followed by hundred and ten, and hundred and ninety with the pH value of 5.98 and 5.98 respectively. From the summary of chemical nutrients properties of forest topsoil Table 3, other nutrients elements in Hundred and fifty meters are higher compared with the nutrients from control sample with the exception of phosphorus which is lower than the phosphorus content in the control sample. The soils are not as acidic as is typical of most soils in the area derived from acid sands of southern Nigeria (Ubi *et al.*, 2013). The higher pH could be attributed to the continuous addition of cement dusts from the cement factory over the years. For Transect 2, the result of the chemical analysis showed that pH ranges from 5.58 to 5.97. In this transect, ninety meters in to the adjoining forest have the highest pH value of 5.97 while the seventy meters has the lowest pH value of 5.58. The higher pH could as well be attributed to the continuous addition of cement dusts from the cement factory over the years.The exchangeable potassium (K) contents for transect 1 and transect 2 ranged from 9.49 to 52.56 ppm and 18.72 to 41.54 respectively. Values less than 0.2cmol/kg were determined to be lower than the average obtainable for other coastal plain soils (Agboola and Gorea, 1973; Adepetu *et al*,. 1979). It was as well discovered that the changeability in K content between the two transect did not follow any regular pattern (Table 2). Exchangeable magnesium (Mg) contents for transect 1 and transect 2 ranged from 0.20 to1.36 cMol/kg and 0.32 to 1.28 respectively. Most of these values were high because they were more than 0.3 mg/kg, considered average for most Nigerian soils (Sobulo, 1999; Lombin, 1973). The Potassium (K) and Magnesium (Mg) concentration are higher in the site location samples than in the control sample. Table 2 also showed that the value of calcium content in transect 1 and transect 2 ranged from 1.2 - 3.6 ppm and 1.00 to 1.60 respectively. The standard saturation of calcium range in soil which is acceptable by agronomists is 25 - 37.5 ppm. The moderate to high Ca contents of the soils in the study area might be attributed to the calcareous nature of cement dust depositions on the soil surface and not necessarily derived from the coastal sand parent materials, which are always deficient in Ca. Available P content is lower in almost all the soils across the distances compared with the control except in some cases (one hundred and seventy, one hundred and ninety, two hundred and ten and two hundred and thirty) meters where the phosphorus falls below the control value. Transect 2 shows the mean ranges of available P to be greater than the optimum value of between 25 and 36 ppm for tropical soils (Dean and Olson, 1965) except for ninety meters and hundred and thirty meters which is rated less than the optimum. The Nitrogen and Organic carbon content were high in the samples than in the control. Organic-matter content derived from the organic carbon followed the same trend (Table 2). The values range from 1.79 to 7.41% in the soil samples and 4.35% in the control. The high organic-matter content can be as a result of increased microbial activities in the topsoil of the locations, thus resulting in the rapid rate of organic matter decomposition and incorporation into the soil. Therefore, the high organic matter content in the soils of the cement area has been attributed to the emission of cement dust to the soils, resulting in improved organic-matter cycling and plant growth.

Conclusion: The results obtained for the physical and chemical characteristics of topsoil in the study area indicated a strong influence of cement dust that settled on the forest soil. The result showed that the most of the chemicals were significantly higher in the study areas than the control. The emission of cement dust over the years was found to have contributed significantly to raising the pH to a range of 4.95 to 6.5, which will likely favour plant uptake of many essential nutrients (both macro and micro) and reduce the fixation of soil phosphorus, which is a common feature of acid tropical soils. The high organic matter content in the study location samples was attributed to the addition of cement dust to the topsoil, resulting in improved organic-matter cycling and plant growth. It is established that cement dust affects the soil nutrients properties of the forest soil in close proximity to the cement factory. Although the present levels of the soil properties do not pose immediate threat to tree growth, accumulation over time can lead to greater danger.

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