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Impacts of Cement Dust Emissions on Soils within 10km Radius in Ashaka Area, Gombe State, Nigeria

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Abstract

This study examines the impacts of cement dust emissions on physicochemical properties of soils within 10km radius from the plant (factory) in Ashaka area, Gombe State. Standard procedures used in soil sampling involves collection of soil samples along a transect aligned in the north-east to south-east direction in order to reflect the dominant two opposing air masses direction; the north-easterly (November-April) and south-westerly (May-October) air masses. Physicochemical analysis of the soils was carried out using standard laboratory procedures in the laboratory. Results of the analysis has revealed that the cement dust which contains high calcium has impacted the soils by increased soil pH, calcium (Ca) content, total bases, base saturation and pH dependent cation exchange capacity (CEC). The impact is observed most within the radius of 0-5km from the plant with a diminishing impact from the 5km towards the 10km radius. Similarly, results of the analysis has shown also that there are signs of slight impaction of bicarbonate (HCO_3) and electrical conductivity (EC) arising from the cement dust on the soils. Recommendations were offered to monitor the dust falling on the soils through trapping and utilizing the dust emissions to cement.

Keywords: atmosphere, cement dust, impact, plant, soils

1. Introduction

The impact of the atmospheric pollution on the ecosystems was demonstrated at several times (Bliefert & Perraud, 2001). Otherwise, this form of pollution is caused by industrial activities including the cement industry. Zerrouqi *et al* (2008) reported that the main impacts of the cement activity on the environment are the broadcasts of dusts and gases. These particles or dusts are very numerous and varied. There are basically two types of particles thus: primary particles that are cleared directly in the atmosphere and secondary particles that are formed in the atmosphere following chemical transformation. The particles can enter into soil as dry and humid deposits and can undermine its physiochemical properties (Hosker & Lindberg, 1982). Similar studies have revealed that atmospheric particles can lead to the reduction of biodiversity and the quality of goods and services offered by the ecosystems. Indeed, the dusts can be emitted at every stage of the manufacturing process of the cement production.

Studies revealed that changes in soil properties have been associated with environmental alteration resulting from human activity (Ibanga, 2008). Cement contacts the soil surface and its constituents usually alters the physical and chemical constituents of the soil. Cement has high carbonate content, the dust tends to be highly alkaline. Therefore, it is revealed that soil contaminated by cement will have high pH. The biological, physical and chemical properties of soil, such as water content, electrical conductivity, and pH, were all found to be affected when treated by raw materials of cement (Khan, 1996).

Agriculture remains the central economy activity of the people of Ashaka area with more than 70% of the population engaged in farming activities (the cultivation of cereal crops) such as millet, sorghum, maize and beans. Farmers of the area are also involved in the rising of livestock like sheep, goats and cattle. Soil is the medium through which these activities are made possible. Therefore sustainable soil management is requisite to sustain agriculture (Julio & Carlos, 1999).

Previous studies have reported that chemical and physical degradation affect most of the present agricultural land in Africa in general and of the area in particular. The soils have poor nutrient retention capacity, and many are heavily leached and eroded (Stoorvogel & Smaling, 1990; Smaling, 1993).

Before the establishment of Ashaka cement factory in 1979 there was no environmental impact assessment in order to establish baseline data for the purpose of monitoring the effects of the industrial activities on the environment. The impact of the activities is glaring on the ecosystem components: air, soils, water and vegetation (Adefila, Malgwi, & Balarabe, 2004).

The impact of cement dust was reported to have effects on the microbial population and other soil properties. In comparison to gaseous pollutants, relatively little is known about the effects of particulate pollutants on vegetation, soil microbial population and other soil properties. The determination of soil physical and chemical properties are very important parameters in monitoring environmental pollution. Adefila *et al* (2004) in their study of some elements within the vicinity of the study area reported that the degree of impaction of the cement dust on the soils has not reached the critical stage of soil degradation. However, the soil pH is at the border in the highly and moderately impacted areas. Further emissions of the cement dust will bring about soil degradation. Table 1 to 2 provide details of the dust emissions monitored over a period of time.

Table 1. Dust Emissions from stationery sources

Source	FEPA Limit	Dec '03	Jul '03	Dec'02	Jul '02	Jan '02	Oct '01
No. 1 Kiln	600	980**	320	10,523	NIO	1570	1,700
No. 2 Kiln	600	740**	782	18,000	1,100	750	NIO
Cement Mill 1	500	425	-	-	1,290	535	420
Cement Mill 2	500	465	-	-	NIO	410	425
No. 1 Packer	500	510	-	530	NM	530	510
No. 2 Packer	500	580	-	470	NM	470	580

Source: Adefila *et al* (2004)

Table 2. Atmospheric dust deposition

Sampling Stations	Approx. Distance from Source (km)	Atmospheric Burden (mg/m3)			
		Jun '04	Dec '03	Jul '03	Dec '02
Clinic	0.5	0.110	0.142	0.139	0.0314
CAB	0.3	0.147	0.155	0.154	-
Workers' Village	1.5	0.122	0.148	0.142	0.025
Management Estate	4.0	0.06	0.013	0.008	0.003
Power House	0.1	0.137	0.023	0.016	0.006
Quarry Pit Office	2.0	0.067	0.072	0.065	0.078
Jalingo	2.0	0.146	0.145	0.121	-
Bajoga	10.0	0.08	0.120	0.098	0.0017
Badabdi	5.0	0.07	0.151	0.178	-

Source: Adefila *et al* (2004)

Long-term food productivity is threatened by soil degradation, which is now enough to reduce yields on approximately 16% of the agricultural land, especially cropland in the area. It is estimated that losses in productivity of cropping land if the limestone mining activity continuous unchecked are in the order of 0.5-1% annually. Therefore there is a need for monitoring and evaluation of the activity of limestone mining in order to mitigate the possible negative effects of the activity on the environment (Adefila *et al,* 2004). The main objective of this research is to assess the impact of the dusts given out by a cement factory on the physicochemical characteristics of the soils within 10km radius from the plant in the study area.

2. Study Area

The study area (Figure 1) is located approximately within Latitude $10^0\ 50^{'}$N to $10^0\ 60^{'}$N and Longitude $11^0\ 25^0$E to 10^0 35'E which is some 112km North of Gombe. This makes the area within the northern part of the present Gombe State and close to its border with Yobe State. Figure 1 shows the location of the study area. The population of the area is about 236,087 (Federal Republic of Nigeria, 2010).

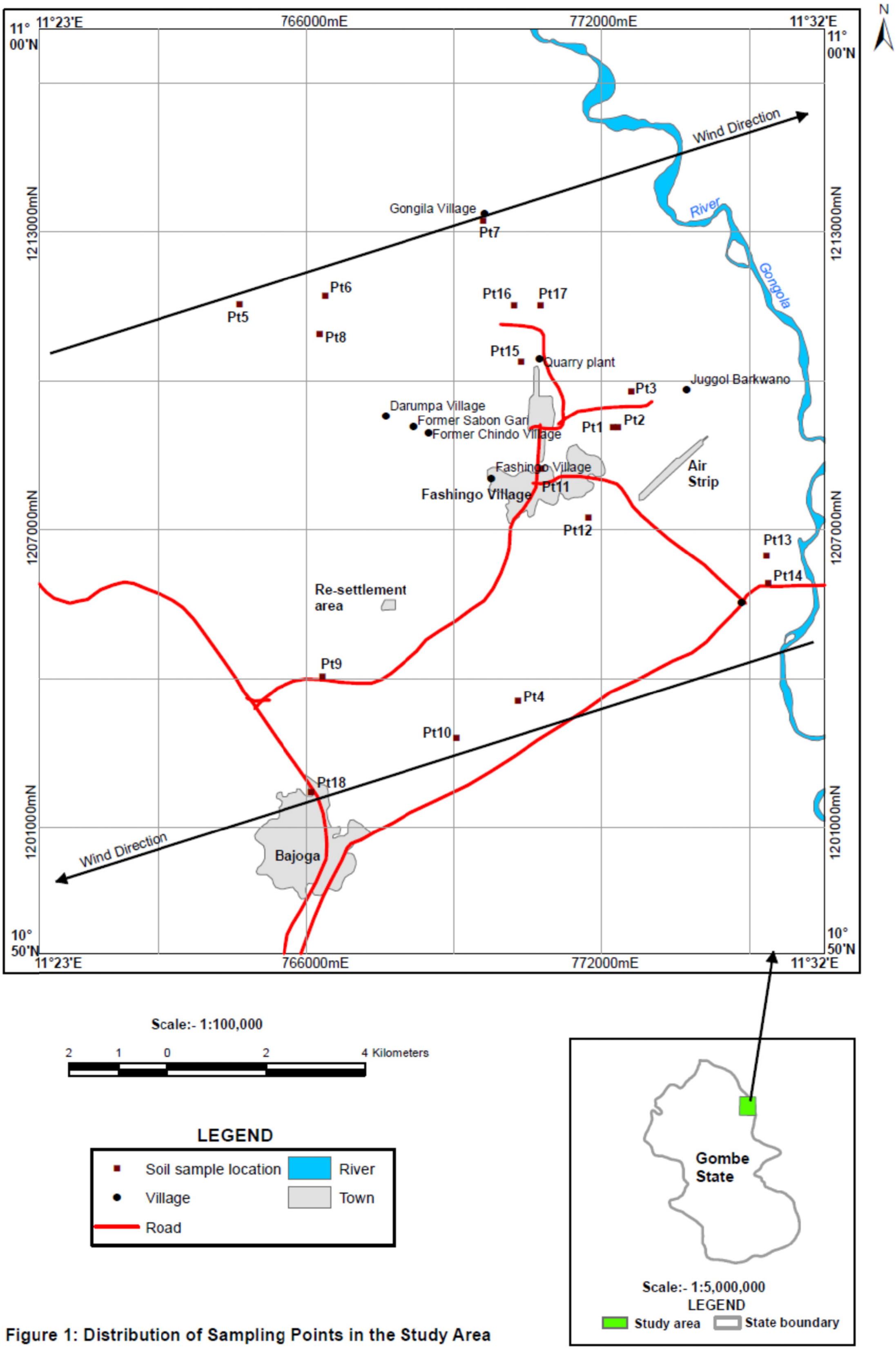

Figure 1: Distribution of Sampling Points in the Study Area

The climate of the area is the seasonally wet and dry type, classified by Koppen as Aw climate (Abaje, Ati, Iguisi & Jidauna, 2013). Like the rest of Nigeria, it is dominated by two air masses. These bring with them the rain bearing south-westerly winds and the cold, dry and dusty North-easterly wind, locally known as the ''Harmattan''. At different times of the year, one or the other of the winds prevail and the area experiences either rainfall or the dry harmattan depending on the advance or retreat of the other (Nyong & Kanaroglou, 1999). The types of soils in the study area are closely related to the parent rock. Where the parent rock is homogenous relatively simple soil association are recognized. The shale give rise to grey heavy loams and clay derived from homogenous mudstones give rise to olive brown clay loam or loamy sand. The dominant soil type is grey mottled, sand and loams with some grey clay. The surface texture of the soils in the study area range from loamy sand, loam, sandy loam, sandy clay loam and sandy clay. The whole area is covered by Sudan vegetation with the density of trees and other plants decreasing as one move northwards (Abaje, 2007; Abaje, Ati & Iguisi, 2012).

3. Material and Methods

The Physicochemical properties of the soils were studied within the radius of 10km from the plant to assess the impact of the cement dust on the soils. Soil samples were mainly collected along a transect aligned in the north east to south east direction. The Global Positioning (GPS) system Garmin 76 with 15m accuracy was used to determine the sampling points. Soil samples were collected at two depths using auger at 0-30 and 30-50cm depths respectively. A total of 46 soil samples were collected at 23 locations in the study area. Soil samples collected from the field were air-dried, grinded and sieved to remove materials larger than 2mm diameter. The less than 2mm fraction was analyzed for the following parameters: Particle size distribution by hydrometer method; pH in water and 0.01 $CaCl_2$ solution at 1:25 soil/liquid ratio using pH meter; Exchangeable bases (Ca, Mg, K, Na) using Ammonium Acetate (1N NH_4OAc) solution; Potassium and Sodium were read on a flame photometer; Calcium and magnesium were read on the atomic absorption spectrophotometer (AAS); exchangeable acidity(H^++Al^{3+}) by leaching of soil samples by 1MKCL followed by titration with NAOH; Effective cation exchange capacity (ECE) by summation of total exchangeable bases and extractable acidity; Cation exchange capacity by the neutral 1N NH_4OAc solution saturation method; Base saturation equal Total exchangeable bases/CEC multiply 100; Electrical conductivity (EC) was determine on a 1:2 soil water saturation extract using conductivity meter; organic carbon by the dichromate wet combustion method; total nitrogen (N) by the Microkjeldah technique; available phosphorus (Ap) by Bray No.1 method and chloride(Cl) was determined from soil saturation extract titrated with silver nitrate.

4. Results and Discussion

The composition of the dust generated from the plant has been analyzed and presented in Table 3. The most important components of the dust that can affect soil properties are oxides of Ca, Mg, Fe, Na and Al in order of significance. The impact of Ca has been significant on the soil properties such as pH and base saturation.

Table 3. Composition of dust around the factory (Weight %)

S/No	Component	Weight %
1	SiO_2	14.24
2	NaO	0.06
3	Al_2O_3	4.11
4	Fe_2O_3	1.89
5	SO_3	0.54
6	MgO	0.54
7	CaO	41.71

Source: Field Analysis, 2013

The results of the physical and chemical analysis are presented in table 4. The dominant texture of the soils are sandy clay loam, sandy loam and pockets of loam sand and clay loam. The direct impact of the dust on the soil texture cannot be assessed without the pre-plant evaluation of the soil texture. However, the different textural class vary in their accumulation and retention of the dust from the plant. The amount of Ca and its impact on the soil pH are clearly evident in the sandy clay loam soils which are fine as compared to the loam sand soils which are coarse.

Table 4. Results of physical and chemical analysis

Sample Depth (cm)	pH		Ca	Mg	K	Na	Total Bases	Al + H	ECEC	CEC
	H_2O	$CaCL_2$								
1	Lat. 10^0 55 637N Long. 11^0 29 433'E									
0-30	7.0	6.2	6.8	3.2	0.59	0.32	10.91	0.10	11.01	12.30
30-50	6.8	6.2	7.1	3.4	0.21	0.12	10.83	0.05	10.88	12.00
2	Lat. 10^0 55 637N Long. 11^0 29 492'E									
0-30	7.1	6.4	5.8	3.0	0.79	0.08	9.67	0.05	9.72	9.90
30-50	7.2	6.4	6.6	2.4	0.46	0.08	9.54	0.05	9.59	9.00
3	Lat. 10^0 56 025N Long. 11^0 29 643'E									
0-30	7.2	6.5	5.8	2.6	0.44	0.07	8.91	0.10	9.01	11.50
30-50	7.1	6.4	4.0	2.6	0.16	0.08	6.84	0.10	6.94	12.50
4	Very shallow Soil									
0-20	7.5	6.5	4.0	1.2	0.47	0.04	5.71	0.05	5.76	6.10
5	Within the plant 500m South of the factory									
0-30	7.5	6.6	5.6	2.4	0.79	0.07	8.86	0.05	8.91	7.00
30-50	7.6	6.7	4.2	1.6	0.79	0.05	6.64	0.05	6.69	7.40
6	Gongila river bank by the bridge									
0-45	7.4	6.3	5.6	3.4	0.17	0.12	9.28	0.05	9.33	15.30
45-85	7.1	5.7	4.0	1.0	0.15	0.05	5.20	0.05	5.25	10.00
85-105	6.7	5.7	10.2	3.4	0.46	0.13	14.19	0.05	14.24	18.40
7	Lat 10^0 52'658N Long $11^0$28'350E									
0-30	7.2	6.5	5.6	3.2	0.38	0.01	9.19	0.10	9.29	12.80
30-50S	7.3	6.4	8.8	3.0	0.44	0.01	12.25	0.01	12.35	13.40
8	Quarrying pit (profile)									
0-35	6.6	5.4	4.4	1.6	0.22	0.05	6.27	0.10	6.37	11.80
35-75	7.2	6.4	9.0	4.3	0.23	0.04	13.57	0.10	13.67	22.30
75-200	6.9	5.8	6.4	2.6	0.21	0.10	9.31	0.10	9.41	22.50
200-280	6.2	5.4	9.0	3.8	0.16	0.05	13.08	0.10	13.19	17.00
9	Lat. 10^o 57' 013N Long. 11^o 25' 289'E									
0-30	6.8	6.0	3.2	1.2	0.28	0.05	4.73	0.10	4.83	4.40
30-50	6.6	5.8	2.4	1.0	0.21	0.05	3.66	0.10	3.76	3.60
10	Lat. 10^o 57' 101N Long. 11^o 26' 246'E									
0-30	6.4	5.7	2.5	1.0	0.25	0.07	3.82	0.10	3.92	8.70
30-50	5.5	5.0	2.8	1.0	0.14	0.05	3.19	0.10	3.92	7.80
11	Lat. 10 57' 90 7N Long. 11^o 28' 009'E									
0-30	6.5	5.8	3.2	0.8	0.39	0.10	4.49	0.10	4.59	7.10
30-50	6.5	5.8	3.69	0.8	0.16	0.14	4.79	0.10	4.89	5.70
12	Lat. 10 56' 681N Long. 11^o 26' 179'E									
0-30	5.8	4.9	4.2	1.2	0.20	0.22	5.82	0.10	5.92	15.70
30-50	6.0	4.8	4.4	1.2	0.14	0.13	5.87	0.10	5.97	19.00

13	Lat. 10 52’ 940N Long. 11^{o} 26’ 179’E									
0-30	6.0	5.1	1.6	1.0	0.140	0.08	2.85	0.05	2.87	3.00
30-50	5.7	5.2	3.8	1.6	0.16	0.10	5.66	0.05	5.71	3.70
14	Lat. 10 52’ 263N Long. 11^{o} 27’ 664’E									
0-30	6.1	5.5	6.60	2.8	0.12	0.17	9.69	0.05	9.74	10.30
30-50	5.2	4.0	3.4	0.80	0.11	0.44	4.75	0.40	5.15	13.00
15	Lat 10^{0} 55’ 195N Long 11^{0} 28’ 634E									
0-30	7.1	6.1	4.0	1.0	0.17	0.13	5.30	0.10	5.40	3.50
30-50	7.0	6.2	3.6	1.2	0.14	0.18	5.12	0.05	5.17	20.90
16	Lat 10^{0} 54’ 659N Long 11^{0} 29’ 152E									
0-30	7.1	6.3	3.4	0.80	0.64	0.12	4.96	0.05	5.01	6.30
30-50	7.0	6.2	3.6	1.2	0.14	0.18	5.12	0.05	5.17	20.90
17	2km from workers village to Ashaka Gari									
0-30	6.6	5.1	2.80	1.20	0.09	0.31	4.40	0.10	4.50	11.60
30-50	6.5	5.6	4.6	1.4	0.1	0.41	6.51	0.10	6.61	10.70
18	Lat. 10^{0} 54’225N Long. 11^{0} 31’130’E									
0-30	5.8	4.8	4.0	1.0	0.1	0.19	5.29	0.10	5.39	24.90
30-50	5.5	4.2	2.3	1.0	0.17	0.23	3.70	0.10	3.80	4.80
19	Lat.10^{0} 53’ 924N Long. 11^{0}31’145E									
0-30	6.3	5.2	2.4	1.0	0.17	0.12	3.69	0.05	3.74	4.81
30-50	6.0	4.8	1.6	0.8	0.15	0.13	2.68	0.05	2.73	5.40
20	Lake Northwest of Plant (Shallow soil)									
0-30	6.7	0.5	9.8	3.0	0.88	0.38	14.06	0.05	14.11	16.30
21	Lat. 10^{0} 56’ 980N Long. 11^{0} 28’ 345E									
0-30	7.3	6.8	7.2	3.6	1.52	0.16	12.48	0.05	12.53	14.10
22	Lat. 10^{0} 56’ 982N Long. 11^{0} 28’ 643E									
0-30	7.5	6.8	6.2	2.8	0.38	0.14	9.52	0.05	9.57	12.90
30-50	7.4	6.7	3.4	1.8	0.23	0.14	5.57	0.05	5.62	14.10
23	Lat. 10^{0} 51’ 681’N Long. 10^{0} 51’ 681N									
0-30	6.1	5.5	2.4	1.0	0.13	0.05	3.58	0.05	3.63	6.20
30-50	5.7	4.7	2.2	1.2	0.22	0.13	3.75	0.10	3.85	6.10

Source: Field Analysis, 2013

The results of the analysis revealed that the highly impacted areas fall within 500m radius from the plant and moderately impacted fall between 500m to 1km radius from the plant. Slightly impacted areas found within 1km to 5km radius from the plant, whereas very slightly to non-impacted areas fall between 5km to 10km radius from the plant.

The pH of the soils range from 6.8 to 7.6, 6.7 to 7.5, 6.7 to 7.2, and 5.5 to 6.8 in Zones 1 to 4 respectively. From the plant pH decreases radially from zone 1 to 4. The high pH in zones 1 and 2 has a direct bearing to the high dust received from the plant. The cement dust has high Ca content and has made the soils in zones 1 and 2 slightly alkaline. Further accumulation will lead to strongly alkaline unless the Ca is leached out of the plant root zone. Under strong alkaline condition, the availability of certain plant nutrients such as phosphorus and boron can be reduced to deficiency level. It can also result in low levels of micronutrients (Fe, Mn, Zn, Cu and Co) that can affect plant growth and overall performance is constrained under high pH. The activities of soil micro-organism will also be curtailed and soil structural deterioration increased.

The principal saturating cation in the cement dust and all the soils was Ca in the soils. In the soil, it ranged from zones 1 to 4 from 3.4 to 7.2, 3.0 to 9.8, 1.6 to 9.0 and 1.6 to 4.4 cmol(+)kg^{-1}. The calcium content is highest around the plant in zones 1 and 2. There is however high calcium content in soils of zones 3 and 4 which are far away from the plant. This is partly because of high Ca content of the soils developed from shale. There is clear incidence of Ca addition from the dust generated from the plant, which is reflected on the pH of the soils of the different zones. The next saturating cations are Mg and K respectively. The Mg and K contents of the soils follow the same trend to that of Ca. Zones 1 and 2 are highly impacted and decreases in zones 3 and 4 respectively. The exchangeable Na contents of the soils do not clearly indicate the impact arising from the dust.

Exchangeable acidity of all the soils of the four zones are low ranging between 0.5 to 0.10 cmol(+)kg^{-1}. This is expected as the pH of the soils do not indicate high levels of exchange acidity. High Ca content leads to surface crusting which increase bulk density, reduced infiltration at the expense of runoff resulting in increased erosion and loss of topsoil.

The total exchangeable bases in zones 1 and 2 are generally high. The values also represent the effective cation exchange capacity (ECEC) which seems to be influenced by the cement dust from the plant. In zones 1 and 2, they ranged from 0.57 to 12.48 and 4.20 to 14.06 cmol(+)kg^{-1}. In zones 3 and 4 they ranged from 2.68 to 13.57 and 2.82 to 5.82 cmol(+)kg^{-1} respectively. There is a clear decreasing trend from the plant outwards, which can be inferred to reflect the diminishing distribution of the cement dust with distance.

Soils of the highly and moderately impacted zones have higher base saturation. In zones 3 and 4, they have lower base saturation. The high base saturation of zones 1 and 2 are related to the higher pH and Ca content received from the cement dust. There is no clear impact of the availability of phosphorus due to the cement dust. Organic carbon, total, carbonate and bicarbonate, chloride and electrical conductivity do not show apparent relationship with the cement dust. There is a slight relationship of the sites close to the plant with HCO_3 and electrical conductivity.

5. Summary and Conclusion

The impact of the cement dust falling on the soils within and around Ashaka area has been evaluated. The impact is glaring on the soils within the radius of 0-5km. This has affected the physical and chemical properties of the soil. Among the physical properties is the surface soil structural deterioration leading to surface crust. The surface crust leads to increased bulk density which can limit seedling emergence and early root development. The chemical impacts on the soils are evidenced in increased soil pH, and exchangeable cations especially Ca and Mg. The high pH has not reached the critical level. However, it is approaching the zone.

There is need to put into practice mitigation measures to check the influx of the cement dust in the soils. This calls for reduction in the amount of cement dust into the air. There is also need for the company to embark on extension programme to the farmers within the vicinity of the plant. This will go a long way in reducing the impact of cement dust on their farms for increase crop yield through better land management practices.

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