Effect of cement dust on soil physico-chemical properties around cement plants in Jaintia Hills, Meghalaya

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ABSTRACT

Investigation was carried out to assess the effect of cement dust deposition on the physico-chemical properties of soil near some cement plants in Jaintia Hills, Meghalaya. Soil samples were collected and analysed and compared with the control site. Comparison of various soil physico-chemical parameters revealed that cement dust emanating from cement plants has changed the soil quality in the surrounding areas of cement plants. The normal soil pH in the area is generally acidic. However, due to the continuous deposition of cement dust soil pH was found slightly alkaline near the cement plants. The higher values of soil parameters such as electrical conductivity and bulk density were also noticed near the cement plants. However, lower values of water holding capacity, soil moisture content, soil organic carbon and total nitrogen content were found compared to the control sites. The effect of cement dust deposition on soil is more in areas nearer to the cement plants. At present the changes may not be so serious but if this trend continues, soil properties of a vast area around the cement plants are likely to change leading to multiple effects on flora, fauna and socio-economy of the area.

Keywords: Cement dust, Change in soil quality, Jaintia hills, Meghalaya

1. Introduction

Cement manufacturing industries are considered as one of the major environmental polluting industries in the world. It ranks 17 in the directory of polluting industries listed by Central Pollution Control Board, India. At the factory site, activities such as heating of the raw material like limestone, gypsum, red alluvium in the kiln and the burning of coal in the factory release particulate matter into the surrounding areas. Handling of cement also releases cement dust in the air. Thus, the particulates and dust released during various stages of cement manufacturing are likely to have adverse impact on different component of the environment such as air, water, soil and flora and fauna [1].

Cement dust is considered as one of the major pollutant emitted from cement manufacturing plants [2]. Dusts generated from the plants are easily transported and disperse by wind and are then deposited widely into the nearby areas. The long term depositions of dust impart pollution on soil, plants and water bodies due to its constant spreading and falling on the ground [3]. The soil quality is adversely affected by continuous depositions of cement dust

and long term changes will subsequently have an adverse impact on the soil ecological communities and even might become unfavourable to plant growth [4, 5].

Cement dust are potentially harmful to the environment including soil. The cement dust has high calcium content in it; thus the dust tends to be highly alkaline in nature [2, 6]. The dust generated from cement plants is composed of calcium silicate and calcium aluminate. When the dust is deposited on the soil surface, it along with soil forms cement like material which is hard and crystalline. Such material ultimately forms a layer of hard crust on soil surface [3]. This inevitably has an impact on the soil properties. The direct effects of the cement dust pollution are alkalization of the soil ecosystem and the alteration of its chemical composition. The dust particles can enter the soil as dry, humid or occult deposits and then undermine its physico-chemical properties [7]. Similar studies that emphasised on adverse impact of cement dust pollution on soil quality have also been reported in Saudi Arabia [8], Iran [9] and Jamaica [10].

The Jaintia Hills region is one of the three hill regions of the state of Meghalaya, India. A large number of cement plants have

been established in Jaintia Hills for manufacturing of cement from locally available limestone. Some of these plants are operating for more than 15 y and have contributed significant amount of cement dust in the surrounding areas. Although, studies on impact of limestone mining on water and soil have been done [11-15], no information is available on the effect of cement dust on soil in and around the cement plants of Jaintia Hills, Meghalaya. The present study reports the changes in soil quality due to deposition of cement dust operating in Jaintia Hills.

2. Materials and Methods

2.1. Study Area

The study was conducted in Jaintia Hills district of Meghalaya, India. The area has the maximum limestone deposits in the state of Meghalaya followed by Khasi Hills and Garo Hills. Extensive exploitation of limestone in the area started in 2004 after establishment of several cement manufacturing plants. At present, there are eleven cement plants already established. Currently, these are predominantly the major consumers of limestone resource in Meghalaya. All these cement plants were found to be located within an area of less than 10 km radius. The location of the study area is shown in Fig 1.
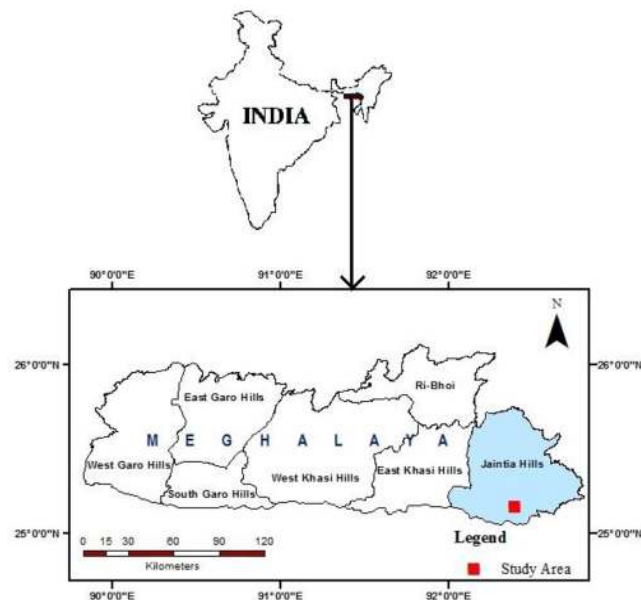

Fig. 1. Location map of the study area in Jaintia Hills Meghalaya.

2.1.1. Geology

The Jaintia Hills area is part of Meghalaya plateau which comprises of five different rock units namely: Pre-Cambrian gneissic complex with acid and basic intrusive, Shillong Group of rocks, Lower Gondwana rocks, Sylhet Traps and Cretaceous–Tertiary sedimentary rocks. Limestone is distributed predominantly in the southern fringe of Meghalaya plateau and falls under the rock formation units of Cretaceous–Tertiary sedimentary rock, which is then, div-

ided into three groups i.e. the Khasi group, the Jaintia Group and the Garo group. The Jaintia Group is further divided into three formations which include the Longpar (lower), the Shella (middle) and the Kopili (upper) formations. The Shella formation is further subdivided into six members: the upper Sylhet Limestone (Prang limestone), upper Sylhet sandstone (Narpuh Sandstone), middle Sylhet Limestone (Umlatdoh limestone), middle Sylhet sandstone (Lakadong sandstone), lower Sylhet Limestone (Lakadong limestone) and lower Sylhet sandstone. The limestone deposited in Jaintia Hills possesses all the above three members of Sylhet limestone with alternating bands of limestone and sandstone. Thus, the limestone rocks found in Meghalaya belong to the Shella formations of the Jaintia Group of Cretaceous–Tertiary sedimentary rocks of Eocene geological age [16, 17].

2.1.2. Soil

In Jaintia Hills, the major types of soil found are loamy soil, lateritic soil and alluvial soil. The texture of soil varies from sandy to clayey loam. In general, the soils of Meghalaya are acidic in nature, rich in organic carbon, low in phosphorus with available potassium ranging between low to medium [18, 19]. The acidity of soil is due to presence of low concentration of pyrite which on oxidation forms sulphuric acid and makes the soil acidic.

2.1.3. Climate

The climate of the study area is greatly influence by the Southwest Monsoon originating from Bay of Bengal. Altitudinal variation is the main reason for the area to experience temperate humid climate and tropical to sub-tropical humid climatic conditions. The elevation of the area varies from 498 m to 630 m above M.S.L. The average annual rainfall recorded in Jaintia Hills was 4,173 mm [18]. The mean annual temperature recorded in the area is 23.6ºC with minimum and maximum 14ºC and 35.0ºC, respectively [20].

2.2. Sampling

Keeping in view the altitudinal variations and feasibility of collection of samples, soil sampling was carried at different locations from the two randomly selected cement plants, at a distance of 200 m, 400 m and 600 m. The soil samples collected from a distance of about 4-5 km and 10-11 km away from selected cement plant-1 and 2, respectively were considered as control (SR). Long distance sampling was not possible due to the inaccessible topography of the area. The details of sampling sites near cement plants were displayed in Table 1. Sampling was done in winter, pre monsoon and post monsoon seasons of 2013. Soil samples were collected randomly from a depth of 0-20 cm. From each location, the bulk samples collected were passed through a 2 mm sieve to remove rocks and pebbles. The soils were then properly mixed by stirring with hands on a clean polythene sheet and ultimately a composite soil sample was prepared following coning and quartering method. Samples were packed in air tight polythene bags and then transported to the laboratory. The collected samples were air dried, grinded and then passed through the 0.2 cm sieve for further analysis of various physical and chemical parameters.

2.3. Analysis

Soil pH and electrical conductivity were determined in a soil and

Table 1. Soil Sampling Sites Near Cement Plants in Jaintia Hills Districts, Meghalaya

Sl. No	Location	Code	Distance (m)	Latitude Longitude	Elevation (m)
1	Undisturbed	SR	Reference / Control	25° 16'36.98" N 92° 22'45.22" E	792
2	Site 1	SC1_R1	200	25° 13'41.40" N 92° 23'2.76" E	764
		SC1_R2	400	25° 13'46.57" N 92° 23'6.05" E	699
		SC1_R3	600	25° 13'49.26" N 92° 23'10.76" E	636
3	Site 2	SC2_R1	200	25° 12'2.66" N 92° 22'51.19" E	708
		SC2_R2	400	25° 11'58.89" N 92° 22'53.28" E	681
		SC2_R3	600	25° 11'42.82" N 92° 22'57.66" E	668

NB: (SR - Soil from Control Site; SC1- Soil from cement plant site -1; SC2- Soil from cement plant site - 2).

distilled water suspension (1:2.5) using Deluxe pH-101 meter and Conductivity-601 meter, respectively. Parameters like moisture content, bulk density and water holding capacity (WHC) were estimated following gravimetric, laboratory and Keen Box-method, respectively [21, 22]. Walkley and Black rapid titration method was adopted for analysis of organic carbon in soil. Estimation of Total Nitrogen in soil was done following Kjeldahl method using Pelican Kelplus Model: Classic DX (VA). Molybdenum blue method was adopted for determination of available phosphorus (AP) using Systronics UV-VIS Spectrophotometer-118 [23]. 1N ammonium acetate extract solution was used for estimation of available potassium using Microprocessor Flame Photometer Model 1381. The three way analysis of variance (ANOVA, $p < 0.05$) was performed to determine whether there is any statistical significant differences or not between the means of different sites, seasons and years. Further, Dunnette's Multiple Comparison test was performed to find whether the sites at different distances affected with cement dust differ significantly or not from the control site (SR) at $p < 0.05$.

3. Results and Discussion

Field observation revealed that the vegetation of the surrounding areas of cement plants was covered with cement dust. During post-monsoon and winter seasons the cement dust deposition is more severe in absence of rain. This has adversely affected the growth plants in the area. Many sensitive species might have reduced in their population and abundance. Plants and leaves fully covered by cement dust are shown in Fig 2. The deposition of cement dust has also affected the soil of the area as the clumping of soil particles on mixing with cement dust and forming hard crust can be seen in the area. The soil forming hard crust after mixing with cement dust can be seen in photographs of Fig 3.

The results of analysis various physico-chemical parameters of soil are summarized in Table 2 and represented graphically

in Fig 4. The findings pertaining to various soil quality parameters are described and discussed in following sections.

3.1. Soil Texture

The texture of soil at all the sites was loamy sand in nature except at SC2_R1. The loamy sand characteristic of soil is generally due to natural geological features of the area itself. However, sandy texture at SC2_R1 could probably be due to the removal of vegetation cover in and around the area, contamination of sand, fine pieces of rocks from the creation of open space for storage of extracted limestone rocks and unpaved road used for transportations and parking spaces. Similar studies has been was reported with soils around the cement factory in Saudi Arabia having sandy loam to loamy sand [8]; sandy loam to loamy sand in North Ethiopia [24]; and sandy soils in Poland [25].

3.2. Bulk Density

The values of bulk density was found to vary from 1.38 g/mL to 1.49 g/mL at SC1_R1; 1.26 g/mL to 1.38 g/mL at SC1_R2 and 1.19g/mL to 1.33 g/ml at SC1_R3. The values of bulk density at was found to varied from 1.42 g/mL to 1.55 g/mL; 1.25 g/mL to 1.29 g/mL and 1.14 g/mL to 1.33 g/mL at SC2R1, SC2_R2 and SC2_R3, respectively. The results showed that BD in soils gradually decreases with increasing distance from the cement plants except during winter season at Site 2. The highest and lowest values of bulk density at both sites were observed in soil samples collected closest to and farthest from the cement factory, respectively. Throughout the study period, lowest bulk density was found in soil at SR. Soil near the cement plants tends to have higher values of bulk density due to low organic matter content in the soil [26]. Another finding reported that the marginal decrease in bulk density near the cement plants could be attributed to the change in percentage of sand, clay and content of organic matter in soil [27].

Fig. 2. Photographs showing plants fully covered with cement dust.

3.3. WHC

The percentage of WHC at Site 1 varied from 35.23% to 43.25% at SC1/1; 41.75% to 45.06% at SC1/2; and 44.05% to 48.52% at SC1/3. Its value at SC2/1, SC2/2 and SC2/3 located near Cement Plant-2 were 31.89% to 33.71%; 40.96% to 47.16%; and 44.39% to 56.73%, respectively. Throughout the study period different distances from the cement plants varie, WHC of soils from SR was found relatively high and varied from 50.04% to 60.30%. The highest percentage recorded was during pre-monsoon season and lowest during winter season. However, soils collected at different distances from the cement plants varied from 35.23% to 48.52%. Based on the results, WHC was found to increase significantly as we move away from the cement plants. The percentage of WHC was found lowest and highest at SC1_R1 and SC2_R1 and at SC1_R3 and SC2_R3, respectively. Soil at the contamination receiving sites particularly adjacent to cement factory retain least amount of water as compared to the soils at SR which bear maximum WHC [28]. Similarly, other findings also found that WHC of soils near cement plants in Himachal Pradesh decrease with increasing distance [26].

3.4. Soil Moisture Content (SMC)

SMC was found highest in soils collected from the SR when compared to soil samples collected from the vicinity of cement plants. The SMC values recorded at SR (control) site were found varying between 18.51% and 32.49%. The amount of moisture present around Site 1 was 9.79% to 16.96% at SC1_R1; 11.38% to 17.85% at SC1_R2 and 18.49% to 22.21% at SC1_R3. Similarly, amount of moisture present content at SC2_R1, SC2_R2 and SC2_R3 located around Site 2 were 2.55% to 10.69%; 7.05% to 21.32% and 7.14% to 27.64%, respectively. It was found that lowest SMC recorded was during winter and maximum during pre-monsoon season in most cases. The SMC was found to increase in its content with increasing distance from the cement plants. This indicates that soils at sites near the cement plants possessed low SMC whereas sites away possessed higher SMC in soil. The area away from the cement plants possesses good cover of vegetation. Thus, the fairly good SMC at these sites is attributed chiefly to presence of vegetation. However, minimal content of moisture at SC2_R1 is due to sandy texture of soil and area being devoid of plant growth. Similar study also found that amount of moisture content in soils increased progressively as distance from the factory site increased [29].

3.5. Soil pH

Soil pH at the SR varied from 4.4 to 5.5 indicating strongly acidic soil in the area. However, in the vicinity of the cement plants pH varied from neutral to slightly alkaline near the cement plants and slightly acidic away from the factory. pH of soil around site 1 was found to range from 6.7 to7.2 at SC1_R1; 6.1 to 6.8 at SC1_R2; and 5.8 to 6.5 at SC1_R3. Its values at SC2_R1, SC2_R2 and SC2_R3

Fig. 3. Photographs showing soil forming hard crust after mixing with cement dust.

located around Site 2 varied from 7.5 to 7.9; 6.9 to 7.3 and 5.5 to 6.6, respectively. It was observed that pH value of the soil was recorded highest at site closest to the cement plant i.e. at SC1_R1 and SC2_R1 and lowest at SC1_R3 and SC2_R3 indicating decrease in soil pH with increasing distance from the cement plants.

In general pH of soil in the area is acidic. However, due to deposition of cement dust on the soil near the cement plants, this caused a change in soil pH to the alkaline side. This change is probably due to liming effect of the dust [30]. Cement dust contains $CaCO_3$, resulting in alkalinity when it comes in contact with soil [31, 6]. Cement dust released from the industry when comes in contact with soil has indirect effect on soil quality [32, 33]. Another finding also confirmed that soil surrounding the cement plants was alkaline in nature, this is chiefly due to the influence of cement dust [34]. [35] and [36] also reported that soil pH varied from 7.06 to to 8.8 near the cement plants. In addition, the gradual decrease in soil pH with increasing distance from the cement plants was also reported [37, 3].

3.6. Soil Electrical Conductivity (SEC)

The comparison of SEC levels at SR with that of soils collected from varying distances around Site 1 and Site 2 showed that level of SEC decreases with increasing distances from the factory. The lowest SEC recorded was observed at SR which is located farthest from the cement plants. However, the highest level of SEC was observed in soil nearest to the factory site. Seasonally, the level of SEC was highest during winter seasons and lowest in post-monsoon season. The lesser levels of SEC during pre-monsoon and post-monsoon seasons may be chiefly due to the wash off of the cement dusts deposited on the top soil layer by rainfall.

The lowest SEC recorded was at SR and it varied from 0.028 dS/m to 0.031 dS/m. However, its value around Site 1 varied from 0.022 dS/m to 0.041 dS/m at SC1_R1; 0.02dS/m to 0.036 dS/m at SC1_R2; and 0.014 dS/m to 0.033 dS/m at SC1_R3. The recorded SEC values at SC2_R1, SC2_R2 and SC2_R3 located around Site 2 from 0.095 dS/m to 0.512 dS/m; 0.079 dS/m to 0.171 dS/m; 0.035 dS/m to 0.097 dS/m, respectively. The concentration of EC in soils near cement plants was higher as compared with that of the reference site. Overall, the level of SEC around Site 2 was found comparatively highest. This is due to the significant amount of cement dust added into the soil surface. Based on the results, level of soil conductivity was found to increase considerably under the influence of cement dust.

Variations of soil EC due to influence of cement dust was confirmed by [6]. Similar findings have also been reported by other researchers. Cement dust contaminated sites had significantly higher SEC than in the control soil [38]. Study also reported that EC in soil around cement plants in North Ethiopia varied from 0.047 dS/m to 0.432 dS/m indicating saline nature of soil [24]. Similarly, the effect cement dust on soil health in Raipur district, Chhattisgarh

Table 2. The Values of Various Physico-chemical Parameters of Soil Samples Collected from Control Site and Around the Cement Plants

Parameter	Seasons	Control	Site 1			Site 2		
		SR	SC1-R1	SC1-R2	SC1-R3	SC2-R1	SC2-R2	SC2-R3
SMC	WIN	18.51 ± 1.08	10.06 ± 0.11	11.38 ± 0.55	18.51 ± 1.08	2.55 ± 0.57	7.05 ± 0.29	7.14 ± 0.13
	PRM	32.49 ± 0.28	16.96 ± 0.15	17.85 ± 0.06	18.49 ± 0.18	10.69 ± 0.88	21.32 ± 0.38	27.64 ± 0.5
	POM	28.17 ± 0.69	9.79 ± 0.11	13.7 ± 0.02	22.21 ± 0.74	9.49 ± 0.09	17.89 ± 0.15	23.71 ± 0.24
pH	WIN	5.4 ± 0.15	7.2 ± 0.20	6.8 ± 0.15	6.5 ± 0.10	7.9 ± 0.06	7.0 ± 0.12	6.6 ± 0.10
	PRM	5.5 ± 0.12	6.9 ± 0.10	6.6 ± 0.15	6.5±0.17	7.6 ± 0.12	7.3 ± 0.06	6.1 ± 0.12
	POM	4.4 ± 0.06	6.7 ± 0.12	6.1 ± 0.06	5.8 ± 0.06	7.5 ± 0.06	6.9 ± 0.06	5.5 ± 0.06
EC	WIN	0.029 ± 0.001	0.041 ± 0.001	0.036 ± 0.001	0.033 ± 0.002	0.512 ± 0.004	0.171 ± 0.004	0.097 ± 0.008
	PRM	0.028 ± 0.001	0.036 ± 0.001	0.033 ± 0.003	0.022 ± 0.001	0.267 ± 0.003	0.145 ± 0.002	0.065 ± 0.001
	POM	0.031 ± 0.002	0.022 ± 0.0008	0.020±0.0005	0.014 ± 0.0004	0.095 ± 0.001	0.079 ± 0.0023	0.035 ± 0.0023
BD	WIN	1.17 ± 0.0057	1.38 ± 0.0156	1.26 ± 0.07	1.20 ± 0.0177	1.55 ± 0.17	1.29 ± 0.0046	1.33 ± 0.0002
	PRM	1.06 ± 0.0054	1.40 ± 0.0092	1.38 ± 0.226	1.33 ± 0.0033	1.52 ± 0.372	1.26 ± 0.0207	1.14 ± 0.0019
	POM	1.15 ± 0.0121	1.49 ± 0.0103	1.34 ± 0.0050	1.19 ± 0.0161	1.42 ± 0.0104	1.25 ± 0.0184	1.19 ± 0.0084
WHC	WIN	50.04 ± 0.290	40.35 ± 1.161	45.06 ± 1.697	48.52 ± 0.408	33.71 ± 1.980	40.96 ± 0.459	44.39 ± 0.447
	PRM	60.30 ± 0.273	43.25 ± 1.824	43.08 ± 1.996	44.05 ± 1.095	32.98 ± 1.325	47.16 ± 0.487	56.73 ± 2.79
	POM	55.09 ± 0.838	35.23 ± 0.850	41.75 ± 0.526	48.27 ± 1.82	31.89 ± 1.051	46.25 ± 1.234	51.73 ± 0.608
OC	WIN	2.58 ± 0.321	2.01 ± 0.034	2.30 ± 0.876	2.55 ± 0.121	0.50 ± 0.265	1.64 ± 0.266	1.66 ± 0.034
	PRM	2.59 ± 0.034	2.10 ± 0.059	2.20 ± 0.631	2.12 ± 0.068	0.57 ± 0.044	0.94 ± 0.034	2.02 ± 0.034
	POM	2.51 ± 0.090	1.31 ± 0.068	1.33 ± 0.090	1.82 ± 0.059	0.51 ± 0.034	1.78 ± 0.034	2.39 ± 0.068
TKN	WIN	0.286 ± 0.047	0.187 ± 0.008	0.224 ± 0.024	0.252 ± 0.014	0.098 ± 0.028	0.191 ± 0.008	0.205 ± 0.029
	PRM	0.369 ± 0.019	0.173 ± 0.021	0.168 ± 0.014	0.187 ± 0.008	0.103 ± 0.008	0.168 ± 0.014	0.243 ± 0.008
	POM	0.321 ± 0.023	0.154 ± 0.024	0.173 ± 0.021	0.205 ± 0.008	0.079 ± 0.016	0.224 ± 0.014	0.285 ± 0.021
AP	WIN	2.075 ± 0.158	1.792 ± 0.323	1.644 ± 0.169	1.597 ± 0.163	2.111 ± 0.075	1.956 ± 0.027	1.828 ± 0.15
	PRM	3.550 ± 0.160	2.789 ± 0.378	2.242 ± 0.115	3.100 ± 0.777	4.554 ± 0.402	4.128 ± 0.403	3.672 ± 0.027
	POM	8.044 ± 1.750	8.144 ± 2.261	6.383 ± 1.109	5.611 ± 3.213	10.556 ± 1.711	7.633 ± 0.863	4.794 ± 0.170
SEK	WIN	0.422 ± 0.031	0.708 ± 0.020	0.667 ± 0.034	0.603 ± 0.032	0.442 ± 0.035	1.435 ± 0.009	0.812 ± 0.008
	PRM	0.612 ± 0.023	0.668 ± 0.028	0.532 ± 0.028	0.423 ± 0.029	0.418 ± 0.032	0.955 ± 0.02	1.095 ± 0.031
	POM	0.427 ± 0.013	0.352 ± 0.003	0.587 ± 0.013	0.412 ± 0.006	0.475 ± 0.010	1.235 ± 0.035	0.608 ± 0.01

NB: WIN = winter; PRM = Pre Monsoon; POM = Post Monsoon

and found that SEC decreases with distance from the cement plant [39]. Another report was also confirmed that sites located nearest to the cement plants bear higher level of EC and lowest were observed at the SR [28].

3.7. Soil Organic Carbon (SOC)

Analytical results revealed that concentrations of SOC were found to gradually increase in percentage as distance from factory increases. Its concentration varied from 1.31% to 2.10%; 1.33% to 2.30%; and 1.82% to 2.55% at sampling site SC1_R1, SC1_R2 and SC1_R3, respectively. The amount of SOC at Site 1 was found to increase in its content with increasing distance from the factory in all seasons except during pre-monsoon. Whereas, the concentrations around Site 2 was found to vary from 0.50% to 0.57% at sampling site SC2_R1; 0.94% to 1.78% at SC2_R2; 1.66% to 2.39% at SC2_R3. At all sites, its content decrease significantly

near the factory site and increases with increasing distance. On the contrary, the maximum content of SOC was found at the SR and its values varied from 2.51% to 2.59%.

A similar finding in relation to SOC content around cement plant was also reported in Poland [20]. Cement dust is alkaline in nature and when it comes in contact with soil subsequently mediate both the synthesis and decomposition of soil organic matter [40]. Finding of the concluded that the concentration of SOC at contamination receiving sites particularly at sites nearest to the cement factory was always low [28]. In relation with distances, [39] found that SOC content in soil tends to increase with increasing distance from the factory site.

3.8. Total Kjeldahl Nitrogen

Concentration of total nitrogen in soil samples collected from SR was found highest in the range of 0.286% to 0.369%. However,

it concentration around Site 1 ranged from 0.154% to 0.187% at sampling site SC1_R1; 0.168% to 0.224% at SC1_R2; and 0.187% to 0.252% at SC1_R3. Concentration of total nitrogen was found to improve with increasing distance from the cement plants in all seasons except in pre-monsoon season. In Site 2, its values varied from 0.079% to 0.103% at SC2_R1; 0.168% to 0.224% at SC2_R2; and 0.205% to 0.285% at SC2_R3. In this site, the value of total nitrogen was also found to increase with increasing distance from the cement plant.

The concentration of nitrogen was also found increasing significantly with increasing distance from the factory [3, 39]. Soil around the cement plant was found to exhibit lower concentrations of total nitrogen when compared to those away from the factory site. Soil collected and analysed around Calabar Cement Company in Nigeria have low content of nitrogen with values ranging from 0.01 to 0.08% [41]. This decrease in content of nitrogen could be attributed to the burning of plant residues during farming operations or dry season, leaching, and the high rate of organic-matter

Fig. 4. Graphical representations of various soil physicochemical parameters collected from control (SR) and from sampling site 1 and 2.

decomposition [42] as well as continuous cropping, which promotes rapid mineralization and absorption of nitrogen. The process of mineralisation of nitrogen decreases as nitrogen content increases [3].

3.9. AP

There is not much variation in AP content between the soils samples collected from SR and that from around the cement plants. However, the concentration of AP was found to decrease as distance from the factory site increases in all seasons except during pre-monsoon season at Site 1. The highest concentration of AP was recorded during post-monsoon season while the lowest was in winter season.

Phosphorus is one of the vital components of cement and it is deposited along with cement dust [43]. The availability of phosphorous in soil is heavily dependent upon the soil pH and its form present in the soil. Cement dusts contain calcium and when it comes in contact with phosphorus forms chelate resulting in reduction of phosphorus availability in the soils [3]. In addition, the lower level of AP could be due to phosphorus fixation into unavailable forms, such as calcium phosphates [44] which could be attributed to large quantities of calcium deposited in the highly dusted areas. In the same context, [39] also found that availability of phosphorous in soil is lowest near the cement plants and highest away from the cement plants.

3.10. Soil Exchangeable Potassium (SEK)

SEK at the SR and at around the cement plants showed not much variation seasonally. Its content at all sites varied from 0.352 mg/g to 1.435 mg/g. It was observed that the concentration of potassium in soil gradually decrease with increasing distance from the factory in all seasons except during post-monsoon season at Site 1. However, maximum concentration throughout the study period was found at SC2_R2 at Site 2 in all seasons except during pre-monsoon season.

The concentration of SEK decreased with increasing distance from the factory. The higher concentration of SEK at sites located adjacent to the cement plants during winter season could be attributed to continuous deposition of cement dust in the soil. Cement dust tend to increase potassium content in soils [39]. The potassium content in soil near a cement factory in Madhya Pradesh was also found to increase significantly [3]. Similar findings were also reported by other researchers [6, 8, 28, 39]. This increase is attributed to cement dust pollution. Similar finding reported that cement dust improved potassium content in soil and tend to remain higher than other cations [45].

3.11. Statistical Analysis

The analytical data of various soil physicochemical parameters were subjected to three way analysis of variance (ANOVA, $p < 0.05$) and Dunnette's test. The results revealed that data of different sites selected near Cement Plant-1 was found to vary significantly between different years, seasons and sites except for SMC and Soil pH (between years); BD and TP (between seasons) and AP between sites where $p > 0.05$. The Dunnette's test showed that data of these different sites near the cement plants differ significantly when compared with SR except for SEC (showing no significant difference between SC1-R2 with SR) and AP (no difference between
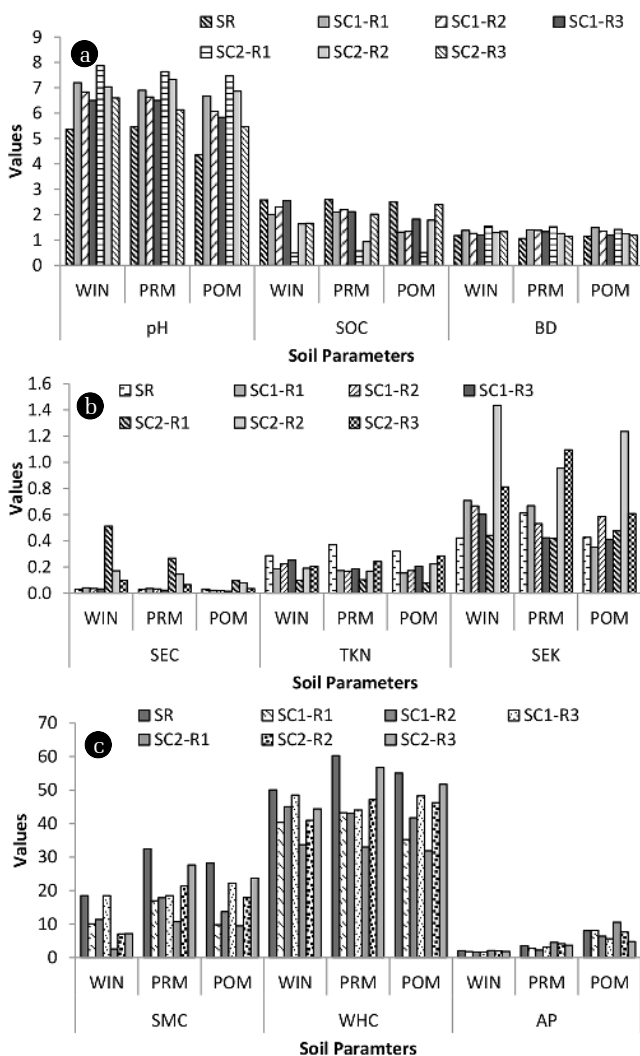
all sites and SR). Data of soils near Cement Plant-2 was found to vary significantly between different years, seasons and sites except for SOC between years. The Dunnette's test here also revealed that significant difference exist between soil samples near the cement plants compared to those of SR except in respect of BD and TP at SC2-R3 and AP where no variations ($p > 0.05$) was found when compared with that from SR.

4. Conclusions

The results of various soil physico-chemical parameters analysed revealed that the soil samples from the SR possess better soil quality compared to that collected from different sites around the cement plants. The normal soil pH in the area is generally acidic. However, due to the continuous deposition of cement dust soil pH was found slightly alkaline near the cement plants. So, in respect of pH, there is improvement in soil quality due to deposition of cement dust. The values of soil parameters such as WHC, soil moisture content, SOC and total nitrogen content were found to increase significantly with increasing distance from the factory sites whereas there was a decrease in pH, electrical conductivity and bulk density values with increasing distance from the factory. The effect of dust deposition on soil is more in the areas nearer to the cement plants. Based on our findings, it can be concluded that if such trend of dust deposition continues, soil properties of a vast area around the cement plants are likely to change in terms of its physico-chemical properties. These changes will in turn have multiple deleterious effects particularly on agriculture, flora, fauna and socio-economy of the area in the near future.

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