The Physiological and Microbiological Characteristics of Cement Dust Polluted Soil Around Lafarge Cement Industry

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Abstract

A study was conducted to investigate the impact of cement dust pollution from LARFAGE cement Industry, Ewekoro on physicochemical and microbiological properties of surrounding soil microbes. The physiochemical characteristics determined were soil pH using pH meter, moisture content was determined using oven drying method, electrical conductivity was determined on a 1:1(V/V) soil/water mixture. While heavy metals contents were determined using Atomic Absorption Spectrophotometer. Microbial species were examined using disc diffusion method. The results showed that, pH of the soil ranged from 6.27±0.03- 6.47±0.03. The areas closer to the factory site (500m) had highest pH values (6.47). The soil moisture content ranged from 15.78±2.52- 9.65±1.16, with values decreasing progressively away from the factory site. The levels of heavy metals except Mg, Zn and Na were higher within the factory than in the control. Cr, Fe, Pb, Fe, Cd, Ca and Cu were significantly higher at P<0.05 in all localities than in control. Isolated microbial flora consists of 5 bacteria genera belonging to, Corynebacterium, Clostridium, Bacillus, Flarobacterium and Micrococcus, and 8 fungal genera belonging to Aspergillus, Penicillium, Trichoderma, Mucor, Nocrolia, Geotrichum, Rhizopus and Fusarium. The bacteria and fungi was influenced by the cement dust deposition. The minimum counts of bacteria 1.89±0.34 and 1.99±0.09 X 108 in polluted soil and 1.85±0.51 X 104 control soil were lower than the fungal counts 10.33±2.33 X104 – 15.00±1.15 X 104 in both soils. The lower counts of bacteria compared to fungi may be as a result of nutrient status of the soil. Microbial population diversity increased steadily away from the factory. Thus, the variation is attributed to the impact of pH and heavy metals on microbial population.

Introduction

Soil is described as the outer loose material of the earth surface, formed as a result of rock weathering, rich in organic matter and providing an excellent media for the growth of many organisms including bacteria, fungi, actinomycetes, algae and protozoa. Ecologically, soil is an active habitat especially for biological interactions (Sundararaj. 2004, Obaroh et al., 2016).

Soil is composed of five major components such as mineral matter, water, air, organic matter and living organisms, constituents of which is not the same in all soils, as it varies from natural environment to another (Sundararaj, 2004). The soil is full of microorganisms, but their inhabitants and diversity may be decreased through inorganic content. This is because inorganic matter influences nutrient availability, aeration, and water retention (Sundararaj, 2004). Microorganisms play vital role in nutrient cycling of carbon, nitrogen, sulfur and phosphor elements in most terrestrial ecosystems. Thus, soil microbial biomass can regulate nutrient availability for terrestrial plants (Sharma et al., 2013, Gougouliaset al., 2014, Mooshammer et al., 2014).
Soil condition can directly and indirectly affect the response of soil microorganisms (Bardgett et al., 2008). Alterations in microbial populations or activity can lead to changes in physical and chemical properties of soil, thereby demonstrating an early indication of soil improvement or an early warning of soil degradation (Crisler et al., 2012). Microbial biomass ratio (Cmic/Corg), and soil respiration are common indicators soil quality monitoring (Jin and Bethke, 2003). The Cmic/Corg ratio demonstrates correlation between microbial biomass and soil organic matter (Li and Chen, 2004). Increasing or decreasing of organic matter stability can change established constant (Westerhoff et al., 2007). Usually, higher amounts of the Cmic/Corg ratio determine the equilibrium between microbial activity and the inputs of organic matter in the case of mineralization (Liu et al., 2012, Österreicher-Cunha et al., 2012). Fertility and quality of soil are related to a high amount of microbial biomass which has an impact on total organic matter content and resulting in the dynamics of organic matter content (Luo et al., 2016).

Cement production are great sources of environmental pollution with detrimental effects on plants and animals. It is predicted that 5-6% of carbon dioxide is generated from cement industries. Cement industries emit pollution in the form of dust and gases which locate their way into the soil and environment (Amani et al., 2018). Dust from cement industries leads to accumulation of emitted metals in soil which may have effects on both the composition and physiological processes of microbial properties leading to a reduction in microbial population and which leads to degradation of soil quality.

Materials And Methods

STUDY AREA

Lafarge cement WAPCO, Ewekoro is situated in Ewekoro Local Government Area of Ogun State of Nigeria. Ewekoro is bordered in the West and East by Papalanto and Abeokuta respectively. It lies between latitude 60° 53’ N and longitude 30° 14’ E. The climate of the area is tropical with guinea savannah features. The rural dwellers in this area are mainly farmers with cassava, rice and yam as major crops. Limestone quarrying and Cement production activities have been going on in this area since 1960. Lafarge of France operates the Ewekoro works as one of the mills of West African Portland Cement Company (WAPCO) (Stanley et al., 2014).

DETERMINATION OF MOISTURE

In a plot of land measuring 40m by 40m within the Lafarge cement industry, soil samples were taken at different points along a diagonal plane. Samples were collected inside the cement plant at varying depths of A1 (0 – 10 cm, 10 – 20 cm), A2 (0 – 10 cm, 10 – 20 cm) and A3 (0 – 10 cm, 10 – 20 cm) using soil Auger. The samples were collected in clean polythene bags and then transported to the laboratory for analysis. The soil samples were labeled according to the regions from which they were obtained. Similarly, another set of soil samples were collected from 500m and 1000m away from the cement plant and denoted as B and C respectively.
Moisture was determined by oven drying method. Well-mixed sample (1.5g) was accurately weighed in clean, dried crucible (W). The crucible was allowed in an oven at 100-105°C for 6-12 h until a constant weight was obtained. Then the crucible was placed in the desiccator for 30 min to cool. After cooling, it was weighed again (W₂). The percent moisture was calculated by following formula:

\[
\text{% Moisture} = \frac{W - W₂}{W₂} \times 100
\]

Where

\( W = \) Initial weight of crucible + Sample

\( W₂ = \) Final weight of crucible + Sample

**pH AND ELECTRICAL CONDUCTIVITY**

Soil pH/Electrical conductivity was determined on a 1:1 (V/V) soil/water mixture composed of a 10 gram soil scoop and 10 mL double-deionized water. Samples were stirred both before and after a 15 minute equilibration period. pH was measured on a Mettler Toledo Seven-Multi pH meter calibrated to pH buffers 4, 7, and 10.

**DIGESTION ANALYSIS**

According to Majolagbe et al. (2013), 0.5g of the soil was weighed into a quartz beaker with 10mls of HNO₃ added and gently heated on a hot plate. Heating was continued until the brown fumes turned white. The mixture was allowed to cool and rinsed with 20mls of deionised water and filtered into a standard 25mls volumetric flask and made up to mark in readiness for AAS.

**MICROBIAL ANALYSIS**

Following the procedure described by Biyik et al. (2005), 0.5g soil sample was added to 50ml of agar and was mixed vigorously for one minute. Soil suspension (0.5ml) was pipetted and collected into a vial containing 4.5ml of 0.1% agar and shaken for one minute. From the serial dilution, 1ml was pipette into two PDA petri plates and spread. The petri plates were sealed with the Parafilm and incubated at room temperature. Microbial growth was observed at 24h, 48h and 72h.

**ISOLATION OF MICROORGANISMS**

A 0.1ml aliquot of ten-fold serial dilution of the sample was inoculated onto the plates, with pour plate method. The plates were incubated at room temperature for 18-24 hours. Observations were made for development of colonies. The visible colonies on the plates were counted and recorded.

Number of organisms were determined using the following formula:
The observed growths were sub-cultured to obtain pure isolates. This was achieved by inoculating the individual colonies in a nutrient agar slant and incubated between 35-37°C for 24 hours. The isolates were subsequently stored at 4°C in the refrigerator.

IDENTIFICATION AND CHARACTERIZATION OF MICROORGANISMS

The different isolates were identified on the basis of their morphological, microbiological and biochemical characteristics as outlined in Aneja (2003).

STATISTICAL ANALYSIS

Statistical analysis was performed using the Analysis of Variance (ANOVA). The data were presented means determined from three replicates. Means of values determined from each point were evaluated using Tukey multiple comparison test and values at P <0.05 were considered to be statistically significant.

Results And Discussion

SOIL PHYSIOCHEMICAL PROPERTIES

The effect of cement dust emitted from Lafarge Cement Industry, on the soil pH collected at varying distances (0m, 500m and 1000m) around Lafarge cement industry and at varying depths 0 – 10 cm and 10 – 20 cm is shown in Figure 1. The soil pH at varying distances and depths were mildly acidic with no statistical significance at (P > 0.05). The electrical conductivity of the soil at varying depths of 0-10 cm and 10-20cm at all sampling locations shows no significant difference at (P >0.05). However, moisture content of the sampled soil matter from the three locations shows statistical difference at (P <0.05), such that the depths of 0-10cm and 10-20cm recorded moisture content ranging from 11.67 to 15.78% and 9.48 to 15.15% respectively (Table 1)

Table 1 pH value, electrical conductivity and water content of different locations from the cement factory. Sites A (inside the factory), B (500 m away from the factory), C (1000 m away from the factory used as control) around cement factory.
Heavy Metals Concentration

Levels of magnesium in the soil at soil depth of 0 to 10 cm and at different distances (0 m, 500 m, and 1000 m), ranged from 140.23 ± 8.80 to 192.56 ± 23.33 with significant difference at (P < 0.05) when compared to the control. Similarly, the level of Ni and Pb at depth of 0-10 cm at distances 0 m, 500 m and 1000 m were significantly different at (P < 0.05). However, the levels Cr, Fe, Cu, Na, Zn, Ca and Zn were not significantly different at (P>0.05) in all localities when compared to the control as shown in Table 4. Also, the levels of Pb, Fe, Cu, Zn, Ni and Ca at soil depth of 10-20 cm at varying distances show significant different at (P < 0.05) when compared to the control. Mg and Cd levels were found to have no statistical significance between locations A, B and C respectively as shown in Figure 2.

Table 2: Effect of cement dust on concentration of metals. A (0 m from cement industry), B (500 m from cement plant), C (1000 m from cement plant). *P < 0.05

| Parameters | A(0-10) | A(10-20) | B(0-10) | B(10-20) | Control | Control |
|------------|---------|----------|---------|----------|---------|---------|
| Pb mg/kg   | 2.05±0.76* | 1.93±0.34 | 2.18±0.23* | 1.76±010 | 1.36±0.68 | 1.68±0.13 |
| Ni mg/kg   | 4.39±0.61* | 3.83±0.56 | 2.90±0.35* | 2.58±0.23 | 3.52±0.21 | 2.73±0.44 |
| Cd mg/kg   | 0.87±0.53 | 1.49±0.41* | 0.95±0.16 | 0.51±0.30* | 0.41±0.21 | 0.49±0.29 |
| Fe mg/kg   | 4.04±0.65 | 21.46±1.69* | 16.72±1.22 | 15.88±1.23* | 16.82±0.46 | 16.54±0.69 |
| Cr mg/kg   | 21.94±1.78 | 3.39±0.38 | 3.55±0.29 | 3.24±0.49 | 3.49±0.05 | 2.93±0.25 |
| Cu mg/kg   | 4.04±0.65 | 17.06±2.05 | 13.75±1.29 | 11.73±2.07 | 12.86±2.01 | 11.45±2.15 |
| Zn mg/kg   | 18.30±2.56 | 107.32±24.06 | 84.22±5.43 | 73.31±3.68 | 81.47±4.54 | 65.96±10.42 |
| Na mg/kg   | 106.04±2.28 | 52.32±7.65 | 38.46±1.21 | 35.18±3.45 | 49.12±6.87 | 35.06±1.78 |
| Ca mg/kg   | 46.74±2.94 | 156.96±22.89 | 130.05±5.81 | 116.21±11.59 | 147.35±20.61 | 105.18±5.35 |
| Mg mg/kg   | 140.23±8.80* | 295.76±40.53* | 176.78±6.35* | 131.94±5.10* | 192.56±23.33 | 128.50±7.50 |

Values expressed as Mean ± SEM, *P<0.05 significantly different from control (Mean’s t-test)
**MICROBIAL ANALYSIS**

**Table 3:** Shows the microbial counts in the soil from the sampling areas. The isolated microbes were characterized and identified as heterotrophic bacteria and fungi. Total fecal coliforms, hydrocarbon utilizing bacteria and fungi. The total heterotrophic bacterial count at 10cm and 20cm at varying distances ranged from $1.85 \pm 0.51$ - $2.42 \pm 0.23 \times 10^8$ while the heterotrophic fungal count ranged from $10.33 \pm 2.33$ - $15.00 \pm 1.15 \times 10^4$ from the cement industry shows statistical difference at $(P<0.05)^*$ significant level. Similarly, the total fecal coliforms in all the depths and at all distances were found not statistically significant at $(P>0.05)$. The hydrocarbon utilizing bacteria count at varying depths at varying distances ranged from $0.0026 \pm 0.001$ - $0.0032 \pm 0.003 \times 10^3$ shows statistical difference at $(P<0.05)^*$ significant level.

**Table 3** Effect of cement dust on microbial counts. A (0m from cement industry), B (500m from cement plant), C (1000m from cement plant). $^*P < 0.05$

| Parameters     | A(0-10)        | A(10-20)       | B(0-10)        | B(10-20)       | Control         | Control         |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| THB ($\times 10^8$) | $1.89 \pm 0.34^*$ | $1.99 \pm 0.09^*$ | $2.42 \pm 0.23^*$ | $2.16 \pm 0.40^*$ | $2.22 \pm 0.08$ | $1.85 \pm 0.51$ |
| THF ($\times 10^4$) | $10.33 \pm 2.33^*$ | $8.33 \pm 1.86^*$ | $11.67 \pm 2.03^*$ | $6.00 \pm 4.26^*$ | $15.00 \pm 1.15$ | $8.67 \pm 1.86$ |
| TFC ($\times 10^2$) | $0.37 \pm 0.37$ | $0.00 \pm 0.00$ | $0.00 \pm 0.00$ | $0.00 \pm 0.00$ | $0.37 \pm 0.37$ | $0.00 \pm 0.00$ |
| THUB ($\times 10^3$) | $1701.0 \pm 1649.51$ | $59.00 \pm 2.31^*$ | $65.00 \pm 5.86$ | $71.67 \pm 16.60^*$ | $67.33 \pm 5.89$ | $54.33 \pm 8.35$ |
| THUF ($\times 10^2$) | $4.00 \pm 1.15^*$ | $3.00 \pm 0.00^*$ | $6.00 \pm 0.58$ | $5.00 \pm 2.52^*$ | $7.33 \pm 1.86$ | $2.33 \pm 0.67$ |
| 0/0 HUB | $0.0028 \pm 0.0015^*$ | $0.0030 \pm 0.0018^*$ | $0.0026 \pm 0.001$ | $0.0032 \pm 0.001^*$ | $0.0030 \pm 0.001$ | $0.0032 \pm 0.003$ |

Values expressed as Mean ± SEM, $^*P<0.05$ significantly different from control (Mean’s t-test). THB=total heterotrophic bacteria; THF=total heterotrophic fungi; TFC=total fecal coliforms; THUB=total heterotrophic utilizing bacteria; THUF=total heterotrophic utilizing fungi; HUB=hydrocarbon utilizing bacteria

**Table 4:** Microbial biomass identified 0m from the cement factory.
### Table 5: Microbial biomass identified at 500m from the cement factory.

|          | A (0-10m) | A (10-20m) |
|----------|-----------|------------|
| Bacillus spp | Bacillus spp |
| Flarobacterium spp | Pseudomonas aeruginosa |
| Aspergillus florus | Rhizopus stolonifera |
| Mucor spp | Penicillium spp |
| Penicillium spp | Fusarium spp |
| Corynebacterium spp | Corynebacterium spp |
| Aspergillus niger | Aspergillus niger |
| Trichoderma spp | Trichoderma spp |
| Fusarium spp | Bacillus spp |
| Bacillus spp | Clostridium spp |
| Micrococcus spp | Rhizopus stolonifera |

### Table 6: Microbial biomass identified at 1000m from the cement factory.

|          | B (0-10m) | B (10-20m) |
|----------|-----------|------------|
| Bacillus spp | Bacillus spp |
| Clostridium spp | Pseudomonas spp |
| Aspergillus florus | Florabacterium spp |
| Mucor spp | Narcoedia spp |
| Rhizopus stolonifera | Rhizopus stolonifer |
| Micrococcus spp | Aspergillus niger spp |
| Aspergillus wentti | Rhizopus spp |
| Penicillium spp | Fusarium spp |
| Pseudomonas aurigunosa | Aspergillus fumigates |
| Trichoderma spp | Micrococcus spp |
| Geotrichum spp | Penicillium spp |
|              | C (0-10m)        | C (10-20m)        |
|--------------|------------------|-------------------|
| Bacillus spp | Bacillus spp     |                   |
| Clostridium spp | Clostridium spp |                   |
| Microoccus spp | Mucor spp       |                   |
| Trichoderma spp | Aspergillus florus |               |
| Penicillium spp | Flarobacterium spp |             |
| Bacillus spp | Penicillium spp  |                   |
| Corynebacterium spp | Bacillus spp |             |
| Aspergillus wentii | Microccus spp  |                   |
| Trichoderma spp | Aspergillus niger |               |
| Mucor spp | Trichoderma spp  |                   |
| Nocrolia spp | Pseudomonas aeruginosa |   |
| Rhizopus stolonifera |             |                   |
| Aspergillus wentu |             |                   |
| Geotrichum spp |                  |                   |

**Discussion**

The study of physicochemical and microbiological properties of soil around LaFarge Cement Industry, Ewekoro revealed a strong influence by the particulate pollutants that settled on the soil from the cement factory. It can be seen that the effect of the dust on soil heavy metal content, moisture content and the pH of soil depended on the distance from the factory. There was alteration in the soil properties arising from the cement dust. The cement dust particles entering the soil decreased the pH of the soil, making it slightly acidic. The highest pH observed in this study was 6.47 and this was from soil collected at 500m away from the factory. This finding is so due to increased degradation of particulates by microorganism in the soil, resulting in accumulation of acidic metabolites. Bilen (2010) reported that changes in soil pH is connected with content of the cement dust in the soil, affecting soil pH directly, and affecting soil alkaline phosphatase enzyme activity indirectly. However, the moisture content of cement polluted soil was lower than that of unpolluted soil. This may be due to the fact that cement dust can coat the soil and consequently prevent the penetration of water (Frederick *et al.*, 2014).

The levels of all the metals except Pb, Mg and Ni were higher within the factory than in the control. The result revealed that the level of Cr, Fe, Zn, Na, Ca and Ni were significantly lower ($p \leq 0.05$) in the control (1000m from factory site) than in the other sites of sampling, with values increasing steadily from inside the factory. These findings agree with the report of Majolagbe *et al.* (2013) in their study of environmental media in the study area, but it differs from the findings of Frederick *et al.* (2014) who reported higher values in the control than at other sampling sites close to Nigerchem cement factory in South-Eastern Nigeria. The level of Mg was significantly higher in control than at other points of sampling, similar to the findings of Frederick *et al.* (2014). Ni maintained almost the same concentration at all the distances and in the control. The concentrations of all the metals analyzed in the environment samples are within
permissible limits for soil (Iqbal, 2011) but their accumulation over time can adversely affect the type and number of the soil microorganisms.

The present study indicated that the heterotrophic bacteria (THB) counts varied in all sampling points. The difference in counts may be due to changes in the physiochemical properties of the soil. However, the difference in the counts of heterotrophic bacteria (THB) and fungi (THB) between the polluted soils compared to the control probably is due to the rapid biodegradation of the cement dust in the soil (Ijah and Abioye, 2003). The counts of HUB in polluted soils were lower when compared to the control. The reason for lower count in polluted soils may be due to the presence of residual cement dust in the soils which reduced carbon supply in the soil, hence favours the growth of fungi as compared to the control (Ijah and Antai, 2003). The bacterial counts in both polluted and control soils were lower than the fungal counts in the both soils. The lower counts of bacteria compared to fungi may be as a results of nutrient status of the soil and the presence of some toxic compound which do not favour bacteria growth (Asadu and Agada, 2008).

Isolated microbial flora from cement impacted soil consists of 5 bacteria genera belonging to, *Corynebacterium*, *Clostridium*, *Bacillus*, *Flarobacterium* and *Micrococcus*, and 8 fungal genera belonging to, *Aspergillus*, *Penicillium*, *Trichoderma*, *Mucor*, *Nocrolia*, *Geotrichum*, *Rhizopus* and *Fusarium*. Fungal species belonging to four genera reported in this study have been isolated from cement polluted soil (Mlitan et al., 2013a, Mlitan et al., 2013b). The microbial diversity from soil samples from inside the factory and adjoining areas were scanty. Two *Bacillus* sp., were able to grow in soil from inside the factory which is in concordance with the studies of Desai et al., 2004; Ali et al., 2009 who reported that isolated obligate neutrophiles are belonging to the genera *Bacillus*, *Micrococcus*, *Aspergillus* and *Micrococcus*. The fungal isolates found in the cement impacted soils were more in number and in types than the bacterial isolates. Microbial diversity and population increased steadily as you move away from the factory. Our findings show that soils impacted by the cement dust hindered neutrophile organisms compared to the control. This is in concordance with the works of Bilen (2010), Frederick et al. (2014) who reported that the soil pH is affected by the heavy metals and the hydrogen concentration. The mild soil pH is as a result of the negative impacts of the cement dust on the soil microbial populations (slowed) and the metabolic activities.

**Conclusion**

This study shows that the levels of heavy metals and the pH inside the cement factory and the adjoining areas were high. The adverse effect of this is noticeable by the population and diversity of the soil bacteria, which were generally low. An indicator of the soil health is the soil pH, which was impacted by the cement dust. Considering that agricultural activities are occurring in this vicinity, crop yields could be substantially affected. Although the present levels of the heavy metals pollutants do not pose immediate threat to animal lives, accumulation over time can lead to great danger. Further studies on the effect of the cement dust on the rhizosphere microorganisms need to be conducted.
Declarations

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Kehinde Sowunmi conceptualized and designed the study and also drafted the first manuscript. Shoga designed and reviewed the final manuscript for intellectual content, Oriyomi, Adewunmi and Lukman Sowunmi participated in the study, designed and reviewed for intellectual content. All authors’ responsible for the integrity of the data.

CONFLICT OF INTEREST

The authors declare no competing interest.

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**Figures**

![Location of the cement company in Ewekoro Local Government Area (Stanley et al., 2014)](image)

**Legend**
- **Lafarge Cement Factory**

**Figure 1**

Location of the cement company in Ewekoro Local Government Area (Stanley et al., 2014)
Figure 2

Physiochemical properties of soil around Larfarge Cement Industry at Ewekoro (C= control)
Figure 3

Effect of cement dust on concentration of metals. A (0m from cement industry), B (500m away from cement plant), C (1000m away from cement plant). *P < 0.05.
Figure 4

Microbial counts and diversity in soil around Lafarge Cement Industry, Ewekoro