International Journal of Scientific Research in Multidisciplinary Studies
Vol.8, Issue.6, pp.01-05, June (2022)

Research Paper
E-ISSN: 2454-9312
P-ISSN: 2454-6143

Consequences of Cement Industry Dust on Soil Microflora and fertility

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Available online at: www.isroset.org

Received: 16/May/2022, Accepted: 10/Jun/2022, Online: 30/Jun/2022

Abstract— The key source of soil pollution is the effect of dust and gaseous pollutants from cement industry. The dust mainly spread around the cement industry to a radius of 5,000 meters, causing the soils to become mostly polluted. In the morphological observation of the soil samples, it was found that there was change in colour of soil in the surface layer. The chemical and physical properties of the soil changes due to pollution. The pH of the soil changed alkalinity. In this probe, the bacterial population and diversity in soil around a cement plant were assessed at two different sites. Site A (test site) was covered with cement dust, while site B (control site) was free of cement dust. Four soil samples were collected from the surface and below the surface at both sites and their bacterial density and diversity was quantified. The bacteriological identification was carried out using standard methods of analysis. The highest bacterial count of 128.00 x 10^4 was observed in surface soil sample in control site B, while the least count of 52.00 x 10^4 was observed in soil sample obtained below the surface at site A. A total of 12 Gram negative bacterial isolates were characterized which include; *Citrobacter amalonaticus, Kleibsella. oxytoca, Klebsiella.terrigena, Proteus.mirabilis, Enterobacter.cloacae, Enterobacter.aerogenes, Pseudomonas.aeruginosa, Proteus.vulgaris, Proteus.mirabilis, Pantoea.agglomerans, Pseudomonas.alcaligenes, Serratia odorifera* and *Serratia fonticola.* While, five species of Gram positive bacterial isolates were observed. In this research work, scientific results showed that cement dust can reduce the richness and diversity of soil bacteria which will cause the changes in the agrochemical and other properties of the soil. As a result, the cement industry adversely affected the vegetative development of the agricultural plants grown on it, disrupting the growing season and photosynthesis processes and resulting in reduced yields. Therefore, there is a need to take appropriate action for pollution control and prevention strategies in the cement plant.

Keywords— Cement industry, bacterial, soil microorganisms, pollution, dust.

I. INTRODUCTION

Soil is the outer loose materials of the earth surface; it is made as a result of rock weathering. It is rich in organic matter and so it provides a tremendous food for the growth of many organisms including bacteria, algae, fungi, actinomycetes and protozoa. In ecology, soil is an active habitat especially for biological interactions [1]. It is composed of five major components: mineral matter, water, air, organic matter and living organisms. The amount of these ingredients is not the same in all soils, it varies from locality to locality. The soil is packed of microorganisms, but their abundance and diversity can be reduced by inorganic matter content. This is because inorganic matter impacts nutrient availability, aeration, and water retention [1]. Many microorganisms contribute to soil fertility and man depends on soil for cultivation. However, bacteria are the most profuse and beneficial when compared with other soil microorganisms [2]. The most common soil bacteria belong to the genera Pseudomonas, Arthrobacter, Clostridium, Achromobacter, Sarcina, Enterobacter. Another group of bacteria common in soils is the Myxobacteria belonging to the genera Micrococcus, Chondrococcus, Archangium, Polyangium, Cyptophaga [3]. Bacteria brings a number of changes and biochemical transformations in the soil and thereby directly or indirectly help in the nutrition of higher plants growing in the soil [1,4]. Soil bacteria play vital roles in some processes which include; decomposition of cellulose and other carbohydrates, ammonification (proteins ammonia), nitrification (ammonia-nitrites-nitrates), and denitrification (release of free elemental nitrogen), biological fixation of atmospheric nitrogen (symbiotic and non-symbiotic) oxidation and reduction of sulphur and iron compounds, all these processes play a substantial role in plant nutrition [3]. Soil microorganisms can rescind pollutants, but pollutants can also abolish the microbial succession or inhibit some varieties of microorganisms. Pollutants can also promote the growth of some destructive microorganisms, and these often lead to development of resistance of the soil ecosystem as a whole [5]. The production of cement is associated with the release of dust into the environment which subsequently settles on soils [6]. Today, the world's environment, especially soils, is becoming more and more polluted by various industries. In specific, during the process of industrial waste, the discovery of natural deposits, the production of construction materials and their use in the national economy, there is a deterioration of agricultural lands and changes in a number of soil properties [7,8]. Cement is the

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most widely used raw material in the construction industry worldwide [9]. Historically, the demand for cement in many countries has developed in direct relation to economic growth. As a result of the increase in the world's population, the construction of industries aimed at meeting the demand for housing and daily needs has developed rapidly. This led to the stepping up of cement production, which is the main material in construction. Today, many developing countries are concentrating on the rapid expansion of the cement industry in order to develop infrastructure [7,10]. Globally, various injurious elements are released as a result of industrial pollution. Gas and dust generated by the cement industry are the key environmental pollutants [11,12,13]. 87-91% of the substances released into the atmosphere during cement production are released into the environment in the form of 9-13% gas in the form of dust [14,15,11]. The direct effects of cement dust pollution are alkalization of the ecosystem and the amendment of the soil chemical composition and though some of the heavy metals in cement dust like copper, zinc, manganese and iron are important for the growth of microorganism, however when in excess they become lethal to the microorganism [16,17]. The key harmful effects on the environment as a result of the cement industry is the impact of cement dust, which emits high doses of fluorine, sulfuric acid, hydrochloric acid, lead, zinc, copper and manganese [9]. Dust generated during cement production is dispersed by wind for short and long distances, depending on its size [18].

II. RELATED WORK

Evaluation of brick kiln operation impact on soil microbial biomass and enzyme activity by Nasrin Chowdhury. Keeping in view, the pollution and Dust from cement industries causes the accumulation of emitted metals in soil which may have effects on composition and physiological processes of microbial properties leading to a reduction in microbial population and which leads to degradation of soil quality and fertility. With this view, our present investigation was initiated to evaluate the impact of cement dust pollution on the diversity of soil bacteria and fertility, around a cement plant. This research was carried out as an awareness to take, appropriate action for pollution control and prevention strategies in the cement plant.

III. METHODOLOGY

Collection of Samples

Soil samples were collected from two different locations around the cement plant of Ras Al Khaimah, United Arab Emirates in the month of January 2022. A sample was collected next to the cement industry's fence (Site A) which was covered with cement dust and the other was about 12 km away from the factory (Site B). At both locations, samples were collected from top soil and below the surface soil, about 10-20 cm. The samples were collected in clean polythene bags and then transported to the laboratory for analysis.

Soil Preparation and Inoculation for Bacteria by spread plate

The soil samples were sieved to remove large pieces of debris and particles. Serial dilutions were carried out by measuring 1g soil from each sample with a sterile spatula into a four 100 ml flask under normal atmospheric condition. Thereafter, 10 ml of sterile water was introduced into each flask and the soil suspension was stirred gently to obtain a homogenized solution. Nine millilitres (9 mL) of sterile distilled water was later measured into 10 labelled test tubes in a test tube rack. Afterward, 1ml was measured from the stock solution and dispensed into the first test tube labelled "1". From the first test tube, 1ml was introduced into the second test tube labelled "2", and continuously up to the last test tube label "10". The samples were cultured by using spread plate method. 100 µL of each dilution of the series was spread on petri-dishes containing Nutrient agar, pH 7.2. Then inoculated Petri plates were incubated at 37°C for 24-hrs. After the incubation, the average colony forming units (CFU) per gram of soil from three different plates were calculated.

Isolation and Identification of Bacteria

The visible colonies on the plates were counted and recorded. Number of organisms were determined using the following formula:

$$\text{Number of organisms} = \frac{\text{Number of colonies}}{0.1} \times \frac{\text{Dilution factor}}{1}$$

To obtain pure cultures, colonies of bacteria which varied in shaped and colour were picked up and purified by streaking on fresh nutrient agar and incubated at 37°C for 24 hrs. The bacterial isolates were identified by Gram staining and other characteristics on the basis of classification schemes published in Bergey's Manual of Systematic Bacteriology [19].

Biochemical Characterization of Microorganisms

Isolated Bacteria were characterized using Rapid biochemical identification test kit (Himedia, ltd) which included Citrate Utilization, Lysine, Ornithine, Urease, TDA, Nitrate reduction, H2S production, Glucose, Adonitol, Lactose, Arabinose, Sorbitol.

Statistical analysis

The tests were performed in triplicates. Data are expressed as mean. Pair wise comparisons were performed. Experimental error was determined for triplicate and expressed as standard deviation (SD).

IV. RESULTS AND DISCUSSION

Soil Physiochemical Properties

According to the present research findings, the collected soil samples showed pH changes at varying distances and at varying depths 10 – 20 cm is shown in Table 1. This is because of the effect of cement dust emitted from Cement Industry. The soil pH at varying distances and depths were mildly acidic with no statistical significance at ($P > 0.05$).

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Table 1: pH value of different locations from the cement factory. Sites A (Next to fence of cement factory), Site B- 12 km away from cement factory

SNo.	Sample	pH
1.	Site A (surface soil)	6.13±0.03
2.	Site A (10-20cm below surface soil)	6.33±0.02
3.	Site B (surface soil)	6.47±0.12
4.	Site B (10-20cm below surface soil)	6.62±0.03

Bacterial load in soil samples

As shown in Table 2, the highest bacterial load was observed in the Site B (Surface soil) with 128.00 x 104 while the least was observed in Site A (Site A 10-20cm below surface soil) with bacterial load of 52.00 x 104. The result showed significant difference among the means of all the isolates.

Table 2: Bacterial count in soil samples

SNo.	Sample	Mean CFU/gm (x 10^4)
1.	Site A (surface soil)	81±14.00
2.	Site A (10-20cm below surface soil)	52±3.24
3.	Site B (surface soil)	128±12.23
4.	Site B (10-20cm below surface soil)	109±14.05

Biochemical Characterization of Isolated Bacteria from Cement Dust Polluted Soil from Site A

Table 3 presents the result of biochemical characterization of isolated bacteria from cement dust polluted soil Site A. Citrobacter.amalonaticus, Kleibsella. oxytoca, Proteus. mirabilis, Enterobacter. cloacae, Pseudomonas. aeruginosa, were observed and characterized biochemically from surface soil of Site A while Proteus. vulgaris, Serratia. fonticola, Enterobacter. aerogenes and Pseudomonas. alcaligenes were isolated and biochemically characterized below 10-20cm surface soil of Site A.

Table 3: Results of Biochemical analysis of soil samples from Site A

Sample	Citrate Utilization	Lysine	Ornithine	Urease	TDA	Nitrate reduction	H2S production	Glucose	Adonitol	Lactose	Arabinose	Sorbitol	Identified Microorganism
A	v	-	+	v	-	+	-	+	-	v	+	+	*Citrobacter amalonaticus*
B	+	+	-	+	-	+	-	+	+	+	+	+	*Kleibsella. oxytoca*
C	v	-	+	+	+	+	+	+	-	-	-	-	*Proteus.mirabilis*
D	+	-	+	v	-	+	-	+	v	+	+	+	*Enterobacter.cloacae*
E	+	-	-	v	-	+	-	+	nd	-	-	-	*Pseudomonas.aeruginosa*
F	v	-	-	+	+	+	+	+	-	-	-	-	*Proteus.vulgaris*
G	+	+	+	v	-	+	-	+	+	+	+	+	*Serratia fonticola*
H	+	+	+	-	-	+	-	+	+	+	+	+	*Enterobacter.aerogenes*
I	+	-	-	-	+	+	-	+	+	-	-	-	*Pseudomonas.alcaligenes*

A- E Site A (Surface soil), F- I Site A (10-20cm below surface soil)
\+ = Positive (more than 90%), - = Negative (more than 90%), v =11-89% positive, nd =No data available

Biochemical Characterization of Isolated Bacteria from Cement Dust Polluted Soil from Site B

Table 4: Results of Biochemical analysis of soil samples from Site B

Sample	Citrate Utilization	Lysine	Ornithine	Urease	TDA	Nitrate reduction	H2S production	Glucose	Adonitol	Lactose	Arabinose	Sorbitol	Identified Microorganism
A	v	+	v	-	-	+	-	+	+	+	+	+	*Klebsiella.terrigena*
B	v	-	+	+	+	+	+	+	-	-	-	-	*Proteus.mirabilis*
C	+	-	v	-	+	+	-	+	-	-	+	-	*Pantoea.agglomerans*
D	+	+	+	-	-	+	-	+	v	v	+	+	*Serratia odorifera*
E	v	-	+	v	-	+	-	+	-	v	+	+	*Citrobacter amalonaticus*
F	+	+	+	-	-	+	-	+	+	+	+	+	*Enterobacter.aerogenes*
G	v	-	-	+	+	+	+	+	-	-	-	-	*Proteus.vulgaris*
H	+	-	-	v	-	+	-	+	nd	-	-	-	*Pseudomonas.aeruginosa*
I	+	-	+	v	-	+	-	+	v	+	+	+	*Enterobacter.cloacae*

A- E Site B (Surface soil) , F-I Site B (10-20cm below surface soil)
\+ = Positive (more than 90%), - = Negative (more than 90%), v =11-89% positive, nd =No data available

Table 4 presents the result of biochemical characterization of isolated bacteria from cement dust polluted soil Site B. Klebsiella. terrigena, Proteus. mirabilis, Pantoea. agglomerans, Serratia odorifera, Citrobacter amalonaticus were observed and characterized biochemically from surface soil of Site B while Enterobacter. aerogenes, Proteus. vulgaris, Pseudomonas. aeruginosa, Enterobacter. cloacae were isolated and biochemically characterized below 10-20cm surface soil of Site B.

Discussion

Pollution of the environment with cement dust causes all parts of the ecosystem to become alkaline [7]. In this probe, we have conducted research and proved that pollutants formed as a result of cement production increase the alkalinity of the soil ecosystem and affect the electronic conductivity, pH and physicochemical properties of soil [10]. Contaminants can cause adverse effects on all organisms and reduce their chances of survival or success. The low bacteria populations and diversity observed in the contaminated soils showed that cement dust is toxic to bacteria. Urmanova et al 2021 [20], have reported similar results that pollutants in the form of dust have adverse effect on the activity of soil microorganisms, affecting the biogeochemical cycle of nutrients in the soil. Cement industry pollutants reduce the microbial population and

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soil biomass in the soil composition [12]. Some earlier studies have also reported high mortality in both plants and animals exposed to cement dust. Toxic elements released by the burning process of cement have been implicated in a lot of health problems and deaths [21]. It was observed that the control soils (soils free of cement dust) have higher bacterial load than those from cement dust populated area, this finding is similar with Stanley et al, 2014 [22]; Kulandaivel et al, 2015 [23], who reported increase in microbial diversity and population as sample collections were moved away from the factory site. The high bacteria densities at the soil surface compared with soils below the surface is in agreement with the findings of Maier et al, 2004 [24]. This could be because more nutrients and favourable conditions are at the soil surface than beneath. It could also be explained that more bacteria would aggregate at the surface, close to plant roots where they would be involved in materials decomposition, aeration, and nutrients cycling, to improve soil fertility. Fierer at al, 2003 [25] stated that soil microorganism's densities reduce as they dug progressively deep in to the soil. They said this could be because the quality and quantity of carbon substrate (organic matter) reduces as we go deep in the soil. Surface soil is rich in carbon substrates from the input of root exudates, surface litters and root detritus. The bacterial isolates identified in this study were mostly Gram-negative bacteria which were often found in control soils, and our results are similar with Trojanovska et al,1997 [26] and Brim et al, 1999 [27]. The diversity of Enterobacter species in this study is high in non-contaminated soil compared with the contaminated soil. However, the diversity of Pseudomonas species, and Klebsiella oxytoca were high in the contaminated soil compared with the non-contaminated soil. Similar trend was also observed in the data obtained by Meitz et al, 1983 [28]. This observation is because species survival in the soil is control by many factors other than the presence of contaminants. Laukova et al, 2002 [29] and Malik et al, 2002 [30] reported that the effect of cement dust on the diversity of soil bacteria cannot be generalized, but instead is dependent on the bacterial genera, and the species. Microbial survival in polluted soils depends on intrinsic biochemical and structural properties, physiological, and genetic adaptation.

V. CONCLUSION AND FUTURE SCOPE

Dust and gases are the key sources of pollution of soil as a result of the production of cement products. The chemical and physical properties of the soil altered under the influence of pollution. Cement dust pollution caused the change in soil pH, fertility. This research has revealed that there are less bacteria in the soil contaminated with cement dust compared with noncontaminated soil. Bacterial populations were also found more abundant on the surface of non-contaminated soil. Cement dust may reduce soil fertility, antimicrobial activity which leading to poor agricultural outputs and loss of plants nutrients. Therefore, pollution prevention and control strategies must be laid in place of cement factories. Further research should be carried out by the use of molecular techniques to investigate the change in microbial diversity in contaminated soils.

VI. ACKNOWLEDGEMENTS

Author would like to thank all individuals who provided their efforts for this research.

A. Abbreviations

CFU, Colony forming units; nd, No data available; µL, Microlitre; SD, Standard Deviation

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