International Journal of Chemical Science
Online ISSN: 2523-2843, Print ISSN: 2523-6075
Impact Factor: RJIF 5.22
www.chemicaljournals.com
Volume 2; Issue 4; July 2018; Page No. 24-30

A review on impact of cement dust on soil health with special reference to Kashmir, India

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Abstract
Each major technological advance over the last few decades has introduced a new hazard to man and environment, either directly or indirectly. Industrialization, urbanization, economic growth and associated increase in energy demands have resulted in a profound deterioration of air quality in developing countries like India. The pattern of economic growth is becoming increasingly associated with environmental pollution. Pollution of the environment is thus one of the major effects of human technological advancement. Environmental contamination due to dust particle coming from Cement Industries, Coal Mining, Quarrying, Stone Crushing, Thermal power Plant etc., has drawn much attention of the environmental scientists today as they create serious pollution problems and pose threat to the ecosystems. The cement industry has been recognized to be playing a vital role in the imbalances of the environment and producing air pollution hazards. Cement dust is a potential phytotoxic pollutant in the vicinity of a cement producing plants and creates serious pollution problems causing enormous damage to the ecosystem. These pollutants emanating from the kiln, spread over a large area and affect the vegetation, soil and other natural resources. Thus an attempt to summarize the ill effects of cement dust on ecosystem, soil and vegetation was made in the present study.

Keywords: cement dust, soil, economic growth, coal mining

Introduction

Environmental stress, such as air pollution, is among the factors most limiting plant productivity and survivorship (Woo *et al*., 2007). The fast industrial growth is causing enormous environmental pollution problems and affecting distribution of plants and soil characteristics of the area. Industrial pollution is caused by the discharges of varieties of industrial pollutants in the forms of gases, liquids and solids which affect the physical, chemical and biological conditions of the environment and are detrimental to human health, fauna, flora and soil properties (Dueck and Endenijk, 1987). Environmental contamination due to dust particle coming from Cement Industries, Coal Mining, Quarrying, Stone Crushing, Thermal power Plant etc., has drawn much attention of the environmental scientists today as they create serious pollution problems and pose threat to the ecosystems. The cement industry has been recognized to be playing a vital role in the imbalances of the environment and producing air pollution hazards. Cement dust is a potential phytotoxic pollutant in the vicinity of a cement producing plants and creates serious pollution problems causing enormous damage to the ecosystem. These pollutants emanating from the kiln, spread over a large area and affect the vegetation, soil and other natural resources. These dust particulates get deposited on various parts of plants especially on leaf surfaces as well as on ground soil and affect growth and yield of crop plants through biological changes (Stern, 1976) [39].

The typical gaseous emissions to air from cement manufacturing plants include nitrogen oxide (NOx), sulphur dioxide (SO_2), carbon oxides (CO and CO_2) and dust (Pregger and Friedrich, 2009). The dust escaping from cement factories is often transported by wind and deposited in areas close and far away from the factory. These include agricultural lands, natural vegetation, towns and villages, such depositions of particulate matter and other pollutants interfere with normal metabolic activities of plants, causing direct injury and impairment of growth and quality and may ultimately lead to decrease in plant yield (Ediagbonya *et al*., 2013) [17]. Dust deposition affects photosynthesis, stomatal functioning and productivity (Santosh and Tripathi, 2008) [33]. Besides causing suppression of plant growth, cement dust induces the change in the physico-chemical properties of soil, which are generally unfavorable to plant growth (Singh and Rao, 1978) [38].

The main impacts of the cement activity to the environment are the broadcasts of dusts and gases. Air pollutants generated by the cement manufacturing process consist primarily of alkaline particulates from the raw and finished materials. The soil no longer has its natural cover of vegetation and the natural exchange of gases between soil and air is greatly reduced because they are no longer replenished by vegetation growth, these soils lose organic matter and soil organisms die from the lack of food and oxygen. The direct effects of cement dust pollution are the alkalization of the ecosystem and the changing of the chemical composition of soils (Mandre, 1995) [27]. Alkaline cement dusts (pH≥9) may cause direct injury to leaf tissues (Vardaka *et al*. 1995) [40] or indirect injury through alteration of soil pH (Auerbach *et al*. 1997) [10]. The pollutant particles can enter into soil as dry, humid or occult deposits and can undermine its physicochemical properties (Laj and Sellegri, 2003) [23]. Thus, cement dust pollution has a negative effect on the physico-chemical properties and the biological activity of the soil. Soil microbial activity is important for the nutrient biogeochemical cycling and it is negatively affected by the cement dust pollution (Ocak *et al*., 2004; Arul &

Nelson, 2015) [28, 8]. Dust pollution has also been found to be problematic around cement factories (Semhi *et al*. 2010) [35]. Cement dust contains heavy metals like nickel, cobalt, lead, chromium, mercury pollutants hazardous to the biotic environment, with adverse impact for vegetation, human and animal health and ecosystems (Baby *et al*., 2008) [11].

Research work has been carried out on the impact of cement dust on human and livestock health where air quality analysis in the Khrew industrial area of Kashmir has revealed that the concentration of average ambient air concentrations of Suspended Particulate Matter, Sulphur dioxide (SO_2) and Nitrogen oxides (NO_x) were found above the permissible limits as given by CPCB (Mehraj and Bhat, 2012). Owing to the fact that comparatively, not many studies have been performed to investigate the influence of cement dust pollution in the Kashmir valley and due to essential role of vegetation in both natural and managed ecosystems, the changes caused by the atmospheric pollution are not restricted to the vegetation only, but also extend to the detrimental effects on biodiversity, ecosystem dynamics and human welfare, the present investigation was attempted to summarize the detrimental effects of cement dust on environment, plant and soil health.

Production process of cement

India is the second largest producer of cement after China. The production process for cement consists of drying, grinding and mixing limestone and additives like bauxite and iron ore into a powder known as "raw meal". The raw meal is then heated and burned in a pre-heater and kiln and then cooled in an air cooling system to form a semi-finished product, known as a clinker. Clinker (95%) is cooled by air and subsequently ground with gypsum (5%) to form Ordinary Portland Cement (OPC). Other forms of cement require increased blending with other raw materials. Blending of clinker with other materials helps to impart key characteristics to cement, which eventually govern its end use. There are two general processes for producing clinker i.e. a dry process and a wet process. The basic differences between these processes are the form in which the raw meal is fed into the kiln, and the amount of energy consumed in each of the processes. In the dry process, the raw meal is fed into the kiln in the form of a dry powder resulting in energy saving, whereas in the wet process the raw meal is fed into the kiln in the form of slurry.

There is a semi-dry processing, which consumes more energy than the dry process but lesser than the wet process. Majority of cement plants are dry process plants. Limestone is crushed to a uniform and usable size, blended with certain additives (such as iron ore and bauxite) and discharged on a vertical roller mill, where the raw materials are ground to fine powder. An electrostatic precipitator de-dusts the raw mill gases and collects the raw meal for a series of further stages of blending. The homogenized raw meal thus extracted is pumped to the top of a pre-heater by air lift pumps. In the pre-heaters the material is heated to 750°C. Subsequently, the raw meal undergoes a process of calcination in a pre-calcinator (in which the carbonates present are reduced to oxides) and is then fed to the kiln. The remaining calcination and clinkerization reactions are completed in the kiln where the temperature is raised to between 1,450°C and 1,500°C. The clinker formed is cooled and conveyed to the clinker silo from where it is extracted and transported to the cement mills for producing cement. For producing OPC, clinker and gypsum are used and for producing Portland Pozzolana Cement (PPC), clinker, gypsum and fly ash are used. In the production of Portland Blast Furnace Stag Cement (PSC), granulated blast furnace slag from steel plants is added to clinker. The main raw material used over here for cement industry includes limestone ($CaCO_3$), clay, sandstone (SiO_2), bauxite (N_2O_3) and gypsum ($Ca_2SO_4.2H_2O$) and involves the release of various particulates, dust, gases and heavy metals. The whole process can be summarized in the following flowchart:

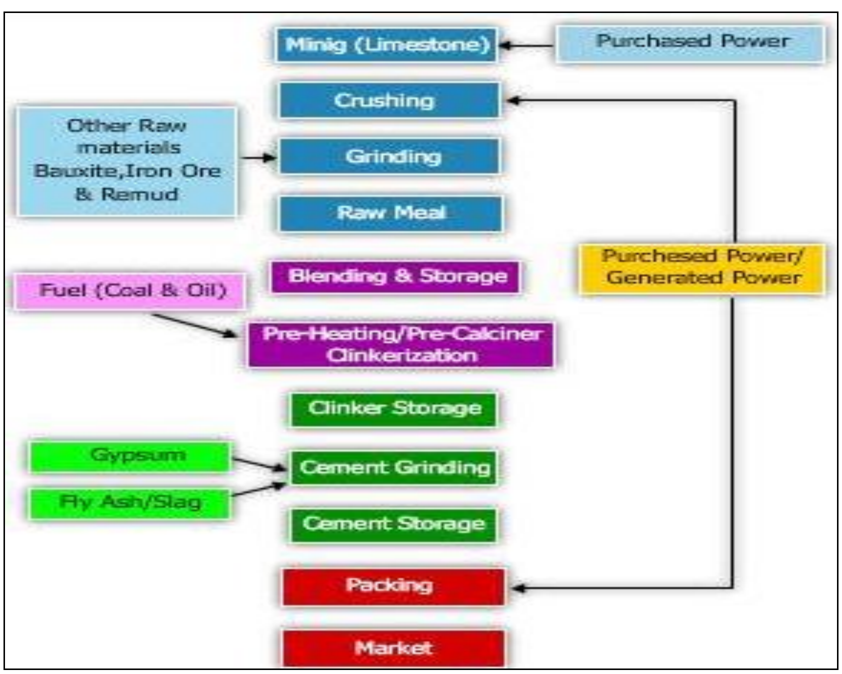

Fig 1

Scenario of cement industries in Kashmir

Major sources of air pollution in Kashmir valley are cement factories, brick kilns, stone crushers and automobile exhaust. In the agro-climatic Kashmir region of Jammu and Kashmir State, there has been an expansion of some industries particularly cement industry in some agriculturally and biodiversity rich areas. In 1979, a cement factory under the banner of Jammu and Kashmir Cements Ltd., with daily production of 600 tons and now 1200 tons, was set up at Khrew. The increasing number of cement factories in Kashmir because of government promotion and local demand led to the blooming of major industry which is mainly operational near Khrew area when in the month of March more cement factories, J&K cements additional line of 600 TPD, TCI, Dawar, Cemtac, Green valley and Itifaq started in this area.

The cement had generated good employment in the area but at the same time due to the air pollution caused by the dust coming out of the chimney of this factory releasing an enormous amount of cement dust into the atmosphere, there has been a considerable effect on the flora and fauna. Cement dust from the cement plants forming a thin layer is deposited over the adjacent agricultural fields. The adverse effects of cement pollution are well demonstrated in Khrew area which has been experiencing such effects for the last three decades. With no fixed ideas and discrimination, a personal awareness to the deteriorating condition prevailing could be acquired within a single visit to the area.

As State Pollution Control Board has permitted construction of 15 cement factories (Red Category Industry) and extraction of limestone within and in close proximity of Dachigam National Park, Khonmoh–Khrew wildlife Conservation reserves. The cement factories have been set up in violation of Environment (Protection) Act, Wildlife (Protection) Act. The population of Red Deer has come down to 137 from around 5000 due to destruction of its habitat-Dachigam National Park and Khrew- Khonmoh Reserves. The illegal mining in the wildlife area by cement factories has destroyed the habitat of Porcupines who are now migrating to the fields and destroying the saffron bulbs and other agricultural products.

Impact of cement dust on environmental quality

Environmental contamination due to dust particle coming from Cement Industries, Coal Mining, Quarrying, Stone Crushing, Thermal power Plant etc., has drawn much attention of the environmental scientists today as they create serious pollution problems and pose threat to the ecosystems. The cement industry has been recognized to be playing a vital role in the imbalances of the environment and producing air pollution hazards. Cement dust is a potential phytotoxic pollutant in the vicinity of a cement producing plants and creates serious pollution problems causing enormous damage to the ecosystem. These pollutants emanating from the kiln, spread over a large area and affect the vegetation, soil and other natural resources. These dust particulates get deposited on various parts of plants especially on leaf surfaces as well as on ground soil and affect growth and yield of crop plants through biological changes (Stern, 1976) [39].

As listed by the Central Pollution Control Board, Cement industry is one of the 17 most polluting industries and is one of the most basic industries involved in the development of a country. Cement is the most widely used building material throughout the world. With the increase in demand for cement in India too, the number of factories is increasing each year and both consumption and production of cement has increased greatly in recent years.

During the last decades, the emission of dust from cement factories has increased alarmingly due to expansion of more cement plants to meet the requirement of cement materials for construction of building. The construction of many business and production infrastructures paved the way for the boom of the cement industry. Nonetheless, despite the value of cement and other related materials, it also has met environmental criticisms as the dust emanating from the cement factories adversely affects visibility, reduces growth of vegetation and hampers aesthetic sight of the area.

The pollutants generated by the cement manufacturing process consist primarily of alkaline particulates. The main impacts of the cement activity on the environment are the broadcasts of dusts and gases. The industry releases huge amounts of cement dust into the atmosphere which settle on the surrounding areas forming a hard crust and causes various adverse impacts. The largest volume substances emitted during the production of cement are carbon dioxide, particulate matter (dust), oxides of nitrogen, and sulphur dioxide. Cement dust contains heavy metals like nickel, cobalt, lead, chromium, mercury pollutants hazardous to the biotic environment, with adverse impact for vegetation, human and animal health and ecosystems (Baby *et al*., 2008) [11].

Dust is a collection of the solid particles of natural or industrial origin, generally formed by disintegration processes and is considered as one of the most widespread air pollutants (Arslan and Boybay 1990) [7]. In India, the dust pollutants contribute around 40% of total air pollution problems (Chauhan and Sanjeev 2008) [14]. Various studies have reported a serious setback in plant physiology due to the effect of dust (Anda 1986) [6]. Dust particulates are reported to be absorbed through the outer surface of the plants showing some common effects such as chlorophyll degradation, necrosis, and reduction in photosynthesis and decline in growth. Dust deposition reduces diffusive resistance and increases temperature of leaf making the tree more likely to be susceptible to drought (Farmer 1993) [18].

Impact of cement dust on plant physiology

The cement kiln dust, containing oxides of calcium, potassium and sodium is a common air pollutant affecting plants in various ways i.e. cement dust and cement crust on leaves plug stomata and interrupt absorption of light and diffusion of gases, lowering starch formation, reducing fruit setting (Lerman, 1972) [25], inducing premature leaf fall (Czaja, 1962) [15] and leading to stunted growth (Darley, 1966) [16]. Cement-Kiln dust affects plant growth mostly by the formation of crusts on leaves, twigs and flowers. The crust is formed because some portion of the settling dust consists of the calcium silicates, which are typical of the clinker (burned limestone) from which cement is made. When this dust is hydrated on the leaf surfaces, a gelatinous calcium silicate hydrate is formed, which later crystallizes and solidifies to a hard crust.

Physiological disorders such as reduced growth is ultimately due to the cumulative effects of the causal factors on the physiological processes necessary for plant growth and its development (Schutzki and Cregg, 2007) [34]. Air pollution has become a major threat to the survival of plants in the industrial areas (Gupta and Mishra, 1994). Injury to the plants ranges from visible markings on the foliage, reduced growth and yield to premature death of the plant. The pollutants can cause a serious threat to the overall physiology of plants (Anda, 1986) [6]. Leaf is the most sensitive part to the air pollutants (Singh, 1981) [37]. Plants demonstrate a wide array of responses when exposed to pollutants in the form photosynthesis, respiration, enzymatic reactions, stomatal behavior, membrane disruption, senescence and ultimately death.

Impact of cement dust on soil health

Bayhan *et al.* (2002) [12] investigated the changes in some characteristics of the soil due to dust emitted from the cement plant. The comparative examination showed that the pollution caused an increase of 22.00% in lime, 15.93% in exchangeable cations, 2.66% in pH and 7.86% in electrical conductivity. These changes resulted in decrease in organic matter content, decrease in field capacity and decrease in wilting point in polluted region. Ali *et al.* (2003) [2] studied the impact of ceramic dust on the soil properties before and after the cultivation by soybean (*Glycine max* L. CV. Crawford) and rosemary (*Rosemarinus officinalis* L.) singly or in competition. It was found that ceramic dust may mediate both the synthesis and decomposition of soil organic matter and therefore influence cation exchange capacity; the soil N, S, and P reserve; soil acidity and toxicity; and soil water-holding capacity, then improve its characteristics.

Shanthi *et al.* (2004) [36] assessed the impact of cement dust pollution on nitrogen status of soils near a cement industry and compared with unpolluted soil. In order to understand the influence of cement dust pollution on the nitrogen status, soil nitrogen, inorganic fractions and soil biochemical processes were assayed. A significant decrease in total nitrogen content, nitrogen fractions like nitrate and nitrite with significant increase in soil ammonia content were observed in polluted soil. Further, the mineralization of peptone nitrogen and oxidation of ammonia nitrogen were significantly decreased in two polluted soils, indicating decreased carbon and nitrogen source for the microbial and plant growth. Soils around cement factories showed high concentrations of heavy metals especially Pb, Zn and Cd on top soils of 0-10 cm deep (Al Khashman *et al.* 2006) [3].

In a study by Khashman and Shawabkeh (2006) [3], soils around cement factories showed high concentrations of heavy metals especially Pb, Zn and Cd on top soils of 0-10 cm deep. The effect of alkaline dust pollution emitted from a cement plant on the soil microbial biomass carbon was investigated by Kara and Bolat (2006) using the chloroform fumigation-extraction (CFE) method. Microbial biomass C (Cmic) values ranged from 157.82 to 1201.51 $\mu g\ g^{-1}$ soils in the polluted area and from 726.70 to 1529.14 $\mu g\ g^{-1}$ soils in the control area. Soils polluted with alkaline cement dust resulted in significant reductions in C mic levels compared to control soils. Microbial biomass C correlated negatively with CaCO3 content ($r = -0.52$, $P < 0.05$) and positively with soil organic C ($r = 0.67$, $P < 0.01$). Mean C mic: C org ratio was 2.55 and 3.09 in the polluted soils and control soils, respectively. The decrease in this ratio was an indication of soil degradation in the polluted soils. A significant decline in the C mic: C org ratio in cement dust-polluted soils also indicated that this parameter could serve as a good indicator of soil health.

Asadu *et al*. (2008) [9] studied the effects of cement kiln dust on selected soil physico-chemical properties by comparing the cement affected soils with the non-affected soils which showed that at both soil depths of 0-20 and 20-40 cm, Exchangeable calcium, sodium, hydrogen, magnesium and soil organic matter were significantly higher in the affected soils than the non-affected soils. The relatively high soils content Fe, Al, Zn, Cu, Pb, Cr and Cd were related to anthropogenic sources of cement industry. The soil pH was moderately to slightly acid (mean 5.8%), organic matter content was moderate (mean 2.54%), total Nitrogen content was low (mean 0.04), and available phosphorus (P) was high (mean 87.43 mg/Kg), exchangeable calcium content was moderate to high (3.02 - 7.44 cmol/kg) in the surface soil; most samples had low magnesium content (mean 0.25 cmol/kg), medium concentration of exchangeable potassium (mean 0.27 - 1.38 cmol/kg) and effective cation exchange capacity (ECEC) had low to medium (2.50 – 15.17 cmol/kg) values around Calabar cement company (Ioniobong, 2008) [20]

Belan (2010) [13] determined the effects of cement dust pollution generated by cement plant on the soil microbial population, microbial respiration and some enzyme activities in cultivated wheat (CT) and no-till (NT) soils at distances of 1, 3, 5, 7, 10 and 15 km away from the cement plant. The samples were analyzed for chemical, physical and microbiological properties of the samples. Significant ($p < 0.055$) positive correlation in CT and NT soils was found between soil microbial population and CO2-C production. The highest microbial population and CO2-C production was observed at 15 km away from the cement plant in CT and NT soils. Semhi *et al.* 2010 in their study on dust emitted from cement industries in Oman has shown high concentrations of REE and heavy metals in soils within a radius of 0.5 to 2 km around the cement factory.

Mandal and Voutchkov (2011) [26] studied the heavy metals in soils around the cement factory in Rockfort, Kingston, Jamaica in close vicinity of the Rockfort and the Harbour view area and analysed by INAA, AAS, XRF for major, minor and trace elements and observed that the top soils of the study area are enriched in Pb, Zn, Cr, Cd, V, Pb, and Hg which are released into the air from the cement kilns. Results show that the soils are enriched in Ca with a maximum value of 18% followed by Al, Fe and Na. Heavy metals in the soils of the study area shows relatively high concentrations of zinc with a maximum of 132 ppm followed by Cr (57) ppm and Pb (32) ppm. Al-Omran *et al.* (2011) collected soil samples at two depths (0-5 and 20-30 cm) in the vicinity of cement factory and analyzed chemical properties as well as their heavy metal content and indicated that the soil samples were calcareous in nature with 22.1 to 35.5% $CaCO_3$ with higher percentages in the surface soil samples taken near the cement factory, sandy loam to loamy sand in texture and moderately to slightly alkaline. Exchangeable calcium contents ranged from 1.4 to

5.44 c.mol.kgG1 while the mean values of exchangeable potassium reached 0.32 cmol.kgG1.The cation exchange capacity (CEC) was low to medium (1.94 to 8.14 cmol.kgG1) and the soils of the study area were moderately to heavily contaminated with (As, Cd, Pb and Ni) and heavily contaminated with Cr, the most contaminated sites area was found within the 0 to 2 km of the cement factory. Concentration of Cd, Cr and Zn metals were higher in soil surface than sub surface soil samples while, Cu, Pb and Fe concentrations in subsurface soil were higher around the cement factory (Al-Oud *et al*. 2011) [5].

Rajasubramanian *et al.* (2011) carried out a study particularly to discriminate the effect of cement dust deposition on soil and over the vegetation and its consequent effects on groundnut crop. Iron, calcium, magnesium, phosphorus, potassium that are prominent in cement dust were found to be higher in concentration in the polluted soil. Also pH of the soil increased due to the effect of cement dust when compared to control soil.

Khamparia *et al*. (2012) [22] carried out an investigation to study the assessment on effect of cement dust on soil health and reported that due to effect of cement dust pollution the soil properties like pH, electrical conductivity, and calcium carbonate content increased significantly. Similarly the content of potassium, calcium and magnesium increased in the vicinity of the cement plant. The cation exchange capacity of the soil also increased from 40.5 to 50.2 meq 100 g^{-1} soil at 5000 m and 50 m distance respectively. The content of heavy metal like lead and cadmium increased from 2.08 and 0.030 mg kg^{-1} at 5000 m to 3.63 and 0.055 mg kg^{-1} soil at 50 m distance respectively. On the other hand the phosphorus content significantly decreases from 17.1 kg ha^{-1} at 5000 m to 11.3 kg ha-1 at 50 m distance. Whereas the content of other major and micronutrients like itrogen, copper, zinc, iron, manganese and boron observed decreasing trend but the results were statistically non-significant. Paal *et al.* (2012) [30] studied the vegetation responses to long-term alkaline cement dust pollution in *Pinus sylvestris*-dominated boreal forests and found that the impact of alkaline dust accumulated over a century persisted despite resolute reductions of pollution. Forest soil conditions changed 10 km leeward and 5 km windward from the source: the litter pH level changed from 3.6 to 4.5 in unpolluted forests to 7.1–7.4 in the heavily polluted forests, and soil Ca content increased ten-fold. Soil alkalization had induced a remarkable succession from typical boreal vegetation toward vegetation of boreo-nemoral or calcareous habitats.

An Investigation on environmental risk assessment of cement dust on soils and vegetables in an urban city of South Western Nigeria was carried out by Laniyan *et al*. (2014) [24] and the geochemical result of soils showed that most of the metals have values above the USEPA standard except Ni, V, Cr, and Ba, due to the effect of cement factory. Contamination factor and degree (Cdeg) revealed extreme contamination of Zn and Mn. Inter elemental analysis showed a strong correlation between Cr-As ('r' = 0.872) and Ga-v ('r' = 0.936), which reflects the same anthropogenic source. Mean concentrations of 215.30 g Kg^{-1} Fe, 7.96 g Kg^{-1}, Zn, 0.33 g Kg^{-1} Cu, 80.79 g Kg^{-1} Mn, 2.05 g Kg^{-1} Ni, and 26.91 g Kg^{-1} Co was found around Ashaka cement factory, Nigeria (Wufem *et al*. 2014) [14].

Adejoh (2016) [15] studied the assessment of heavy metal contamination of soil and cassava plants within the vicinity of a cement factory in north central, Nigeria and the results indicated that mean Cd contents in the soil and control soil samples were 1.22 ± 0.34 and 0.78 ± 0.16 µg/ g respectively, the mean values for Cu, Ni, Pb and Zn concentrations in the soil samples were 3.42 ± 0.70, 0.07 ± 0.02, 8.40 ± 2.48 and 0.04 ± 0.01µg/ g, respectively while for the control sites, the mean values were 0.72 ± 0.09, 0.02 ± 0.07, 0.91 ± 0.04 and 0.02 ± 0.01, respectively.

Oludoye & Ogunyebi (2017) [29] carried out an experiment to study the nutrients assessment of tropical soils around a mega cement factory in southwest Nigeria and indicated total organic nitrogen, total organic carbon and heavy metals decreased with increasing distance from the cement factory while there was increase in the amount of soil potassium and soil phosphorous, the results also showed inverse correlation between most of these heavy metals, the pH, and the activities of the soil nutrients are indicative that pollution caused by cement production exhibit a significant effect on soil nutrients and this may invariably affect the quality and condition of the soil of the area.

Conclusion

Cement factory dust is responsible for the substantial amount of dust in the atmosphere resulting in damage not only to the air quality but also to soil and vegetation. Therefore, appropriate mitigation measures are required to be taken in order to control the pollution in the area which includes:

a. Development of a thick green belt around the periphery of each cement factory.
b. Provision of macadamization /development of better roads within and around the premises of cement factories.
c. Appropriate air pollution control devices to be installed and regularly checked.
d. Observance of standards of permissible limits for various constituents as prescribed by SPCB and CPCB.

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