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Full Length Research Paper

Impact of Emissions of Gagal Cement Works on Soil Quality, at Barmana, District Bilaspur, Himachal Pradesh (India)

Amisha Sharma and Dr. Pankaj Gupta
Department of Environment Science, Himachal Pradesh University, Summer Hill, Shimla-171005, India.

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Corresponding Author:
Pankaj Gupta

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ABSTRACT

Among all industries, cement industry is one of the important industries whose emissions impact the environment and human life. Cement factories release cement dust into the environment leading to potential water, air and soil pollution. Cement dust particles initially settle on soil surface and later enter into deeper layers of soil, where they have the greater likelihood to alter with the physico-chemical properties of soil. The dust is usually carried by wind and water, contributing to pollution. Present paper is based on the study carried out to analyze the impact of emissions of Gagal Cement Works on soil quality, at Barmana, District Bilaspur, Himachal Pradesh. The samples were collected in the month of June 2023 and analyzed for Organic Carbon, pH, Electrical Conductivity, Nitrogen, Phosphorus, Potassium, Zinc, Iron, Manganese and Copper. All the parameters were within normal range except for available Nitrogen (low), available Phosphorus (high) and Copper (low). The results obtained from soil analysis indicate that deposition of cement dust in the soil may have shifted soil pH towards alkaline range. Soil is more alkaline at 0 mts distance in all directions. Available potassium, usually prominent in cement dust thus showed excessive toxicity near the cement plant in north, south and east directions which is definitely harmful for the environment

Introduction

Increasing demands of population has led to the growth of industrialization. Industrialization has drawn attention of many researchers because of its impacts on environment and on human life. Among all industries, cement industry is one of the important industries. Cement is used as a construction material. Increased population has increased its demand. Cement is made up of different oxides namely CaO, SiO_2, Al_2O_3, and Fe_2O_3. Raw materials used for the manufacturing mainly consists of limestone, clay and small amount of iron ore, bauxite and sand. Cement industries cause different types of pollution directly and indirectly during manufacturing, storage, transportation processes. Cement factories release cement dust into the environment leading to potential water, air and soil contamination. The dust can be carried by wind and water, contributing to pollution.

Soil pollution is a state when soil loses its structure, biological and physico-chemical properties due to the increased concentration of contaminants. Soil pollution is caused due to the contaminants released from various sources, viz. industries, residential areas or any other anthropogenic & natural sources. Soil pollution is a major threat to living organisms because it affects the soil texture making it less fertile thereby affecting the yield. Soil pollution in industrial areas is a major cause of carcinogenic and non-carcinogenic problems. Air carries significant amount of dust and deposits this on soil, plant leaves, etc. Further these toxins are inhaled or consumed by organisms (Devarajan, 2015). Bermudez *et al*. (2010) studied heavy metal pollution in topsoil near a cement plant in Yocsina, Cordoba province of Argentina. Wang (2013) studied magnetic properties and heavy metal pollution of soils in the vicinity of a cement plant in Xuzhou, China and established a link between magnetic parameters and heavy metal concentrations. Farzadkia *et al*. (2016) carried out a case study on the impact of cement plant on the soil and leaves of tree species in Golestan Province. Samples were collected from four different locations within 500 mts and 21 packages were analyzed. The study concluded presence of significant amount of dust on leaves of Oak, Black Tello and Reed which contain Cesium, Barium, Bismuth, Silver, Chromium, Cobalt, Cadmium and Arsenic. Higher concentrations were present near the factory. Thus, there is need of determining the impacts of pollutants of cement plant on soil and its impact on farming activities.

Materials and methods

Study area

The study was conducted near Gagal Cement Works, Barmana. This plant is located in district Bilaspur of Himachal Pradesh. Bilaspur constitute 1167 km^2 area. Bilaspur lies between North Latitude 31.30 and 31.916667 and East Longitude 75.916667 and 76.466667. It is bound by Mandi district on the East, Hamirpur district on the North. Climate is characterized as sub- tropical. District experiences cool winters from November to March and summers are invariably hot in the month of May and June. Maximum temperature may reach up to 34.7°C and minimum temperature may go up to 9°C. The annual rainfall in the area is about 1106.28 mm. Majorly Alluvial soils and non-calcic brown soils are observed in this region. These soils are fertile. Agriculture is the main occupation of the people and more than 70 percent population is engaged in Agriculture. Major crops grown in the area are Wheat, Maize, Pulses, Sugarcane, and Rice apart from vegetables. Forests majorly constitute Northern Tropical Dry Mixed Deciduous types. Major species present in the forests are *Pinus roxburghii* (Chir Pine), *Acacia catechu* (Khair), *Tectona grandis* (Teak), *Melia azedarach* (Darek), *Bauhinia variegata* (Kachnar), *Bombax ceiba* (Simul), *Quercus leucotricophora* (kharsu oak), *Cycas revolute* (Sago palm), etc. Barmana is about 20km from Bilaspur on National Highway (NH 21) connecting Chandigarh to Manali, passes through Gagal Cement Works. Barmana is situated at Latitude 31.41509 and Longitude 76.83470 while Gagal Cement Works is situated at Latitude 31.41316 and Longitude 76.83678. This plant constitutes two production units namely Gagal I and Gagal II with a total capacity of 4.4 million tonnes per annum. This plant is surrounded by villages namely Langat, Nalag, Uuparli, Chadool, Bhated, Khataed, Harkhar, Judaani and Baeri.

Soil Sample Collection:

Soil samples were collected in the month of June 2023 from selected sites located at the distance of 0 mts to 500 mts adjacent to the Gagal Cement Works industrial area from four different directions namely North, South, East, and West. One sample was collected randomly from some kilometers to the plant and one control sample was also collected which was supposed to be free from emission. Before sample collection, area around Gagal Cement Works was analyzed using standardized methods listed in table 3 and two different sites were selected in each direction at different distances, which acted as control. At first, surface litter was removed thoroughly with hand and then soil was dug at the depth of 0-15 cm and 500 gms soil sample was collected in cotton bag and labeled with information like sample number, distance from plant, direction with latitude and longitude. Foreign materials like plant roots, stones, debris were removed thoroughly with hands. Then all the samples were passed through sieve to remove small stones and other small foreign materials.

Table 1: List of different soil samples at various distances from Gagal Cement Works with their directions

Sr. No.	Soil Samples	Direction in respect to Gagal Cement Works	Distance from Gagal Cement Works (in meters)	Latitude	Longitude
1.	S- 1	North	0	31.415719	76.834483
2.	S- 2	South	0	31.414391	76.831747
3.	S- 3	East	0	31.414257	76.838871
4.	S- 4	West	0	31.415873	76.830402
5.	S- 5	North	500	31.417610	76.832890
6.	S- 6	South	500	31.408520	76.843415
7.	S- 7	East	500	31.413579	76.840275
8.	S- 8	West	500	31.416307	76.828797
9.	S- 9	---------	4000	31.411695	76.862827
10.	S- Control	---------	20000	31.432594	76.713788

With the help of sieve, soil was separated to remove stones and debris which can even damage instruments. Shade drying of samples was done prior to laboratory analysis. Properly labeled samples were taken to the laboratory for further analysis. Table 2 and 3 lists the parameters studies for different soil samples and the methods employed for analyzing the physic-chemical properties of soil.

Results and discussion

This study was conducted at ten marked sites at different distances from Gagal Cement Works. Eight samples were collected from four directions namely North, South, East and West at 0 mts and 500 mts respectively. One sample was collected from 4000 mts and one was collected from 20000 mts for reference. All these samples were collected in the month of June 2023 and analyzed for Organic Carbon, pH, Electrical Conductivity, Nitrogen, Phosphorus, Potassium, Zinc, Iron, Manganese and Copper. Data of different analysis were recorded and analyzed to draw inferences.

Table 2: List of various parameters studied for different soil samples

Sr. No.	Physico-chemical properties	Primary nutrients	Micronutrients
1.	pH	Nitrogen	Zinc
2.	Electrical Conductivity	Phosphorus	Iron
3.	Organic Carbon	Potassium	Manganese
4.			Copper

Table 3: Methods for the analysis of different soil quality parameters

Sr. No.	Soil Parameters	Methods for Analysis
1.	Hydrogen Ion Concentration (pH)	Potentiometric Method
2.	Electrical Conductivity (dSm^{-1})	Conductivity Meter
3.	Organic Carbon (%)	Black and Walkley method or Wet digestion or Rapid Titration Method
4.	Nitrogen (kg ha^{-1})	Kjeldahl Distillation Method
5.	Phosphorus (kg ha^{-1})	Olsen's method or Alkali Extraction Method
6.	Potassium (kg ha^{-1})	Flame photometer
7.	Micronutients (Zinc, Iron, Manganese, Copper) (mg/kg)	DTPA extraction method by using AAS

Table 4: Analysis of soil quality parameters for reference site (soil sample collected at 20 km away from Gagal Cement Works)

Sr. No.	Soil quality parameters	Results
1.	Hydrogen ion concentration (pH)	6.83
2.	Electrical Conductivity (dSm^{-1})	0.066
3.	Soil Organic Carbon (%)	0.30
4.	Available Nitrogen (kg ha^{-1})	25.088
5.	Available Phosphorus (kg ha^{-1})	45.472
6.	Available Potassium (kg ha^{-1})	112
7.	Zinc (mg kg^{-1})	0.664
8.	Iron (mg kg^{-1})	5.498
9.	Manganese (mg kg^{-1})	2.654
10.	Copper (mg kg^{-1})	0.190

Deficiency and excess availability of one nutrient is inter-related with the presence of other nutrient. In reference soil sample (table 4), all the parameters were within normal range except for available Nitrogen (low), available Phosphorus (high) and Copper (low). The reason for low Nitrogen may be due to reduced use of fertilizer for long time. And if Phosphorus is high then it can alters the availability of Nitrogen to plants. Soils rich with organic matter may alter with the availability of copper. High levels of organic matter alters with Copper extraction because of high solubilization of organic matter, it causes high mobility of Copper and vice-versa. And high organic carbon in soil is contributed by higher deposition of dead leaves, plant parts and dead insects for longer time (Palma *et al*. 2007).

Table 5: Results obtained by analyzing various soil quality parameters from different samples collected at various distances

Sr. No.	Name of Field	pH	EC	OC	N	P	K	Zn	Fe	Mn	Cu
	Normal level/Range	**6.5-7.5**	**0-0.8**	**0.51-0.75 (%)**	**280-560 kg/ha**	**10-25 kg/ha**	**112-280 kg/ha**	**>6 mg/kg**	**>4.5mg /kg**	**>2 mg/kg**	**>0.2mg /kg**
1.	S-1	7.53	0.114	2.70	12.544	45.248	828.8	1.128	9.826	1.322	1.068
2.	S-2	7.73	0.133	2.70	12.544	45.920	1478.4	0.772	3.888	0.756	0.784
3.	S-3	7.46	0.134	1.95	37.632	49.950	1948.8	1.462	2.358	2.322	1.686
4.	S-4	7.55	0.060	2.10	12.544	47.040	358.4	2.914	15.12	3.270	0.602
5.	S-5	7.41	0.073	1.50	25.088	46.368	246.4	1.190	2.984	0.922	0.454
6.	S-6	7.51	0.082	1.65	25.088	52.190	246.4	0.382	0.288	1.188	0.436
7.	S-7	7.42	0.111	2.70	25.088	45.248	806.4	1.200	9.254	0.690	0.884
8.	S-8	7.45	0.068	1.65	37.632	45.696	425.6	0.834	1.390	0.290	0.222
9.	S-9	7.54	0.059	1.05	25.088	46.816	313.6	0.556	8.114	1.006	0.108
10.	S-Control	6.83	0.066	0.30	25.088	45.472	112	0.664	5.498	2.654	0.190

Physico- chemical Properties of Different Soil Samples

Cement dust particles firstly settle on soil surface and later enter into deeper layers of soil, where they have the greater probability to alter with the physico-chemical properties of soil. During manufacturing of cement, the main components used are limestone and clay- which supplies calcium for the cement production. Apart from this, emissions from cement industry include huge amount of CO_2, CO, H_2S, VOCs, NOx, SOx, dioxins, furans, $PM_{2.5}$ and PM_{10} (Bilen et al. 2019).

pH: Soil pH is important for the normal growth of the plants. Cement dust is alkaline in nature and alters the soil pH levels. Generally, for normal growth of plants, they need slightly acidic soils, but deposition of cement dust make the soil pH to shift towards alkaline side. The shift of soil pH affects various enzyme activities and biological processes (Mishra and Siddiqui, 2014). In the present study, pH of the soil samples was observed 7.73 which is high. At 0 mts distance in all directions, pH was slightly alkaline than compared to 500mts distance. pH decreases gradually from the nearest site to most far (table 5). The high pH near the cement plant has a direct connection with the presence of cement dust. The highest pH was observed in the south direction to Gagal Cement Works at 0 mts distance. A similar study by Kholdorov, 2021, Dheeba and Sampathkumar, 2012, Shabir and Sharma, 2021, Lamare and Singh, 2020 and Ashraf et al. 2022 showed alkaline pH near the cement plant due to the deposition of Calcium Silicates.

Electrical Conductivity: It measures the ions present in the soil suspension. When the concentration of ions is high then Electrical Conductivity of soil increases, soil Electrical Conductivity has a direct influence on crop production. It results in salinity and affects water system if dissolved salt concentration is high (Corwin and Lesch, 2003).

In present study, the Electrical Conductivity of 0.134 dSm^{-1} was observed which was highest at 0 mts distance to Gagal Cement Works in East direction (table 5). The Electrical Conductivity values were within permissible limits in all the directions. Study performed by Shabir and Sharma, (2021) showed that conductivity was higher near the cement plant.

Soil Organic Carbon Content: It is an important parameter of soil, constitute all plants and animals residues. Normally soils contain 2-10 percent of Organic Carbon content and the optimum range for the growth of plants is 0.51-0.75 percent. Organic Carbon provides suitable habitat and needed nutrients to the soil organisms and also helps to improve water holding capacity by forming aggregates of soil particles. Soil Organic Carbon increases soil ability to retain water during dry periods and absorbs water during wet periods. It means decrease in Soil Organic Carbon content causes soil erosion.

It also helps in reducing water pollution by increasing filtering and adsorbing non-point source pollutants (Canqui et al., 2013). In the present study, Soil Organic Carbon content varies from 2.70 to 0.30%. In North, South and West direction, Organic Carbon content was higher at 0 mts distance while in East direction, content is higher at 500 mts distance. Organic Carbon content decreases with the distance except for the East direction (table 5). While similar study performed by Lamare and Singh, (2019) and Shabir and Sharma, (2021) showed that Organic Carbon content increases with the increase in the distance from the cement plant.

Primary nutrients in different soil samples

Cement dust released from industries constitute hazardous pollutants which affect nearby environment. A study reported that cement dust has direct correlation with the availability of primary nutrients. It shows that the availability of primary nutrients increases with the increase in distance (Ramesh et al., 2014).

Nitrogen: It is the primary nutrient because it is necessary for the growth and development of plants. Plants utilize Nitrogen in the form of NO_3^- and NH_4^+. In the present study, results showed that Nitrogen content ranges from 37.632 kg/ha to 12.544kg/ha. In the collected samples, Nitrogen content was 12.544kg/ha in North, South and West direction at 0 mts distance, 25.088kg/ha in North, South and East direction at 500 mts distance and 37.632kg/ha in East and West direction at 0 mts and 500 mts distance respectively. North, South and West directions shows gradual increase with the distance in East direction, Nitrogen content was higher at 0 mts as compared to 500 mts distance (table 5). Study conducted by Shabir and Sharma, (2021) and Lamare and Singh, (2020) showed increasing trend in Nitrogen concentration with increasing distance while results presented by Devarajan et al. (2015) showed that higher concentration was at the nearest distance to the cement plant.

Phosphorus: It is an important component of cement dust and deposits on the soil surface. Phosphorus balance in soil is important in relation to nitrogen, potassium and with micronutrient availability to plants. Soil pH plays a significant role in the phosphorus availability. 6.5 pH is the optimum pH for phosphorus availability and at high or neutral pH; phosphorus reacts with Calcium to form minerals. Higher levels of Phosphorus may not affect much but causes Zinc, Iron, Manganese deficiencies to plants in soil and eutrophication in water. Lower amount of phosphorus, causes plants to utilize phosphorus in their early growth stages and in their later stages of growth, plants may face issues like older leaves start to curl, distorted leaves, leaves remain small, purpling of leaf undersides and tip dieback (Mathew et al. 2018). In the present study, phosphorus showed positive correlation in north and south direction with distance and negative correlation in east and west direction (table 5).

The normal range needed for the plant growth is 10-25 kg/ha. In this study, all samples showed an elevated level of Phosphorus when compared to normal range. Study conducted by Lamare and Singh, (2020) and Shabir and Sharma, (2021) showed that available

Phosphorus was lowest near the plant while Krishnaveni et al. (2015) showed low levels of available Phosphorus irrespective of the distance.

Potassium: It is an important nutrient for increasing the productivity of plants. Two important functions of potassium in plants include modulation of plant stomata aperture and improvement of nitrogen use efficiency. If potassium levels start decreasing in soil then it activates the translocation of mobile K^+ ions from old leaves to new leaves to support stomata aperture osmo-modulation. At the worst, plants responds to low potassium levels in a certain way, i.e. leaf may start falling, crop grow slowly and have poorly developed root system, premature defoliation in broadleaf species, seeds become more prone to diseases & damage and there occurs chlorosis along the leaf margins. Excess of potassium reduces enzymatic activity and alters the infiltering process as result of which, clay particles disperse and start clogging pore space (Prajapati and Modi, 2012). The normal range of potassium for the plant growth is 112-280 kg/ha. In this study, potassium levels ranged from 112 to 1948.8 kg/ha. From all tested samples, most showed potassium levels quite higher than normal level. In the East direction, at 0 mts distance soil possess excessive potassium toxicity. This excess toxicity is not good for the normal plant growth. A normal pattern is seen in North, South and East direction that soil potassium levels decreasing with the increase in the distance while in West direction, Potassium increases with the increase in the distance (table 5). Similar study performed by Devarajan et al. (2015) showed that highest concentration of available potassium is at the farthest point and the lowest concentration was recorded near the cement plant while Lamare and Singh, (2020) and Shabir and Sharma, (2021) showed higher concentration was at the nearest point to the plant and study by Dar *et al*. (2015) showed higher potassium levels in all directions to the cement plant and concluded that soils are infertile in nature.

Micronutrient in different soil samples

A micronutrient is an important element usually required in trace amount. The requirement of micronutrient to plant is met from sources, viz. the soil or through chemical fertilizer. Quantity and quality of the agricultural products depends on micronutrient. Presence of one element is totally related to the other element's presence. If not present in required manner, it can affect intake of other element (Sherefu and Zewide, 2021).

Zinc: It is an important micronutrient as it performs various functions. It activates number of enzymes, production of auxines, helps in photosynthesis and sugar formation, synthesis of IAA, formation of chlorophyll, and seed production and fertility. It is an essential component of many enzymes and helps in growth regulation and disease resistance. Zinc and its availability in soil can be decreased by alkaline pH, lower level of available Nitrogen, higher level of available phosphorus and arsenic, excess moisture. In calcareous soils, zinc deficiency can be seen easily and is accompanied with iron deficiency. Zinc deficiency symptoms can be seen in plants as-chlorosis and necrosis, stunted growth of plants, rosetting and bronzing of leaves and retarded growth and yield of plants.

Zinc deficiency also affects human beings by causing nutritional disorder, when they consume food having grown in Zinc deficit soils. While excess Zinc can affect enzyme activity and seep into groundwater (Rudani et al. 2018). In the present study, the impact of cement dust pollution on Zinc level showed decreasing trend with increasing distance from the cement plant in all directions except North direction, where Zinc was slightly lower in concentration at 0 mts than 500 mts distance. The highest amount of Zinc was detected in the west direction at 0 mts distance is 2.914 mg/kg while lowest amount was detected in the South direction at 500 mts distance is 0.382 mg/kg (table 5). A similar study performed by Devarajan et al. 2015, Krishna and Govil, 2007, Gupta and Sharma, 2012 and Dheeba and Sampathkumar, 2012 showed higher concentration of Zinc near the cement plant.

Iron: It is the 3rd most limiting nutrient for plant growth and metabolism. It performs number of functions in all living organisms like DNA synthesis, photosynthesis, synthesis of chlorophyll and its development, respiration, energy transfer, nitrogen fixation and is an important constituent of enzymes and proteins. In many places of world, iron uptake by plants is difficult despite its abundance on earth. This happens mostly in alkaline soils, neutral soils and in aerobic soils. In neutral pH soil, and in aerobic environment, bioavailability of iron decreases as it forms highly insoluble ferric compounds. In alkaline soil uptake by plants is difficult and plants shows symptoms like yellowing of leaves, poor growth and reduced yield. General deficiency symptoms include- iron chlorosis, stunted root growth, young leaves appear greener in color, purpling of stem and older leaves, wilting of shoot, blackening of leaf tips and stem bases and lack of root branching.

In present study, results showed that the concentration of Iron ranges from 0.288 mg/kg to 15.12 mg/kg. The maximum value 15.12 mg/kg was found in the west direction at 0 mts distance while minimum value 0.288 mg/kg was found in the South direction at 500 mts. In North direction, the concentration of iron at 0 mts and 500 mts was 9.826 mg/kg and 2.984 mg/kg. In South direction, the concentration of iron at 0 mts and 500 mts was 3.888 mg/kg and 0.288 mg/kg. In East direction, the concentration of iron at 0 mts and 500 mts was 2.358 mg/kg and 9.254 mg/kg. In West direction, the concentration of iron at 0 mts and 500 mts was 15.12 mg/kg and 1.390 mg/kg. Iron concentration showed a decreasing trend with increasing distance in all the directions except for East direction (table 5).

Firstly, symptoms are seen in older and mature leaves and later on progress to younger leaves. As we all know excess of anything is as dangerous as its deficiency. When waterlogged conditions appear iron may occur in excess in soil and is taken in excess by plants. Its excessive nature promotes toxicity and form reactive oxygen radicals. Symptoms like bronzing, blackening of roots, and damaged cell membranes by lipid peroxidation may appear (Rout and Sahoo, 2015).

Manganese: It is one of the main micronutrient and is the 11th most abundant element on earth crust. Young organs of plants are generally rich in Manganese. It is taken up by plants in divalent ion form, i.e. Mn^{2+}. Its uptake decreases in the presence of high concentration of Magnesium, lime, Iron, Calcium and in alkaline pH. Manganese performs various functions in plants as chlorophyll production, essential for photosystem II, plays important role in oxidation and reduction processes in plants, helps in cell division, and acts as a activating factor for more than 35 different enzymes and activates RNA polymerase.

In soil surface erosion, excess leaching, alkaline pH soils (solubility decreases 100 times by increasing 1 unit of pH) and in calcareous soil like conditions manganese deficiency may occur. Its deficiency symptoms first appear on young leaves then on older leaves. These include- small yellow spots on leaves in dicot plants, grey-green spots on leaves in monocot plants and decrease in dry matter and yield. If soil has excessive manganese, it harms the plants and shows symptoms like- necrosis in leaves, accumulation of granules starch in chloroplasts, reduced photosynthesis, brown spots on leaves.

Excess toxicity can be removed by adding high amount of magnesium because magnesium has antagonistic effect on manganese (Mousavi et al., 2011). In the present study, manganese showed decreasing trend with increasing distance from the cement plant in all directions except for the South direction. In South direction concentration at 0 mts was 0.756 mg/kg while 1.188 mg/kg at 500 mts. The highest and lowest concentrations were recorded in West direction at 0 mts and 500 mts distance, i.e., 3.270 mg/kg and 0.290 mg/kg respectively (table 5). A similar study by Gupta and Sharma, (2012) showed that with increasing distance from the site, the availability of manganese decreases.

Copper: It is an essential micronutrient, traditionally used as an antifungal agent in agriculture. Copper availability is higher in acidic soils. If Nitrogen is high in soil then plants need more Copper. Copper holds its importance due to various functions, It helps in cell wall formation, is required in Photosystem II, acts as a cofactor by helping to bind small molecules, e.g. binds Oxygen as ligands, is required for respiration, protein synthesis, ethylene sensing. Deficiency symptoms include- twisted or malformed growth of leaves, necrosis and chlorosis, delayed maturity, melanosis (brown discoloration) and deficient crops are more prone to diseases specifically ergot (a fungal infection).

Excess of Copper is as harmful as any other malformation. Excess availability of Copper causes phyto-toxicity by forming reactive oxygen radicals, damaging cellular processes, inactivating enzyme mechanism and destroying protein structure (Yruela, 2009). In the present study, copper availability showed a decreasing trend with increasing distance from the cement plant. In north direction, the concentration of copper at 0 mts and 500 mt was 1.068 mg/kg and 0.454 mg/kg. In south direction, the concentration of copper at 0 mts and 500 mts was 0.784 mg/kg and 0.436 mg/kg. In east direction, the concentration of copper at 0 mts and 500 mts was 1.686 mg/kg and 0.884 mg/kg. In west direction, the concentration of copper at 0 mts and 500 mts was 0.602 mg/kg and 0.222 mg/kg (table 5). The highest concentration was recorded in the east direction at 0 mts distance while lowest was recorded in sample-9 which is collected at 4000 mts from the plant. A similar study by Devarajan *et al*. 2015, Gupta and Sharma, 2012 and Krishna and Govil, 2007) showed higher concentration of copper near the cement plant.

According to Kholdorov, (2021) dust emissions from the cement plant travels and affects up to 5000 mts radius causing changes in the various parameters of soil. Ashraf *et al*., 2022 reported that deposition of cement dust make the soil calcareous due to higher concentration of calcium carbonate and this ultimately alter the soil pH, making nutrient availability less and most soils lose holding capacity towards nutrients and become infertile in nature (Dar *et al*., 2015). All these changes lead to disruption in natural nutrient cycling and affecting the natural environment.

Conclusion

Cement industries contribute to environmental pollution by releasing sulfur oxides (SO_x), nitrogen oxides (NO_x), particulate matter (PM), carbon dioxide (CO_2), kiln dust, dioxins & furans, polycyclic aromatic hydrocarbons (PAHs), heavy metals and acids. These pollutants can have detrimental effects on various aspects of the environment including contributing to ozone layer depletion, causing acidification & eutrophication, increasing global warming potential, etc. It is important for industries to adopt more sustainable practices to minimize their impact on the environment. Thus, it can be concluded that the Gagal Cement Works is causing soil pollution in the nearby areas due to deposition of dust. Various soil quality parameters from Gagal Cement Works were studied and compared with the normal soil. The results obtained from soil analysis indicate that deposition of cement dust in the soil may have shifted soil pH towards alkaline range. Soil is more alkaline at 0 mts distance in all directions. High pH soils makes environment unfavorable for the growth of soil microorganisms which are important for the growth of plants, ultimately affecting growth of the plants. Alkaline pH soil decreases availability of nitrogen, phosphorus, potassium & micronutrients and due to this uptake by plants decreases. Available potassium, usually prominent in cement dust thus showed excessive toxicity near the cement plant in north, south and east directions which is definitely harmful for the environment. In soil samples collected near the cement plant in north, south and west directions showed decreased concentrations of available nitrogen and in north and south directions showed decreased concentration of available phosphorus, when compared to those collected at 500 mts. The impacts of cement dust on soil micronutrients namely copper, manganese, zinc & iron showed decreasing trend with increasing distance except in the north direction for zinc, east direction for iron and south direction for manganese. By analyzing the surrounding area, it can be concluded that cement dust has adversely affected the agricultural patterns and health of people & cattle in the nearby area. Therefore, it is recommended that time to time quality analysis of the environment with respect to air, water, noise and soil is required and must be done. Besides this, proper environment management plan need to be implemented and modified timely. Nearby people must be informed about the negative impacts of cement dust. Agricultural practices must be avoided up to 1-1.5 km because of high load of dust. Phytoremediation plants can be planted to reduce the hazardous substance concentration from the soil and green belt must be developed around the area and plants such as *Eucalyptus globulus* and *Madhuca indica* can be planted because these possess high dust-holding capacity. In nutshell, the government should take appropriate measures to check prone causes of harm and thereby protecting community from polluted environment.

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