

Effect of cement dust on soil chemical properties in the vicinity of a Cement Factory, Ramnagar Chandauli, India

ABSTRACT

The present study was carried out to assess the effect of cement dust deposition on the chemical properties of soil in the vicinity of Jai Laxmi cement factory, Ramnagar, Chandauli. Soil samples were collected and analyzed and compared with control site and standard soil classification. Comparison of soil chemical parameters revealed that cement dust from factory effect the soil quality surrounding cement factory. pH was found to be neutral to slightly alkaline near cement factory. EC (Electrical Conductivity) was in non-saline range. Soil organic carbon and SOM (Soil Organic Matter) was in medium range. NPK (Nitrogen, Phosphorus, Potassium) was also high in affected range than the control site. At present it may not be that serious but if this trend continues soil properties of a vast area is likely to be change indirectly affecting flora, fauna, and human being.

The present study was conducted to assess the soil chemical properties and effect of cement dust on the soil quality in the surroundings area of the Jai Laxmi Cement factory, situated at the industrial region of Ramnagar, Chandauli. Assessment of chemical properties of soil leads to the managing of resources while working with soil of a region. The specific analysis of this factor and different parameters testing related to this study is much needed to check the effects of cement dust from factory on soil because soil is our life-supporting system and plays a vital role in the earth's ecosystem. Besides all the goodness, the soil quality is degrading day-by-day due to rapid urban-industrial growth and improper use and management of soil.

The objective of study attempts to analyse the impact of these industrial activities and its interferences on the soil quality present in the vicinity of Jai Laxmi cement factory, Ramnagar Chandauli. It was done so to study the chemical parameters of soil in the vicinity of the Jai Laxmi cement factory, Ramnagar Chandauli and to Compare the affected soil sample with the standard soil classification.

Keywords: Chemical properties, soil quality, cement dust, modernization, NPK, SOM

1. INTRODUCTION

In today's world, day by day, many small-scale and large-scale industries are setting up and affecting and degrading different environmental components such as air, soil, water, vegetation, and human health [1]. The word soil is derived from the Latin word 'solum' which means 'floor' or 'ground'. Soil provides numerous regulatory services, since it is the second global carbon sink, and nutrient cycling [2].

Soils contain 3.5% of the earth's carbon reserves, compared with 1.7% in the atmosphere, 8.9% in fossil fuels, 1.0% in biota, and 84.9% in oceans [3]. It is the interface at which all forces acting on the Earth's crust meet to produce a

medium of unconsolidated material, acting as an environment for further changes and developments, keeping pace with the evolution of the global Earth system as a whole [4].

Cement is the most widely used concrete material throughout the world. The cement industry is one of the 17 most polluting industries listed by the CPCB of India [5]. Despite its profitability, the cement industry faces many challenges due to environmental pollution and health issues as a result of the effluent that enter the environment as a by-product.

These include emissions of airborne pollution in the form of dust, and gases; soil pollution by settling of dust and effluents discharge from the industry; noise and vibration when operating machinery and during blasting in quarries; and cement dust when inhaled can potentially contribute to different breathing and Interstitial lung diseases [6].

Cement dust deposition on the soil surface changes the Physico-chemical properties of soil as it causes a shift of pH towards the alkaline range, which generally reduces the absorption of mineral substances from the soils. Interference of alkaline cement dust with soil may mediate both the synthesis and decomposition of soil organic matter and therefore influences the soil N, P, and K, and soil water-holding capacity. It also affects the microbial activity of soil [7].

Cement dust is a localized air pollution problem in the vicinity of a cement factory. Dust particles from the limestone mines, coal yards, and cement clinkers are emitted into the air, together with dust from various processes such as crushing and clinkerisation. The heavy encrustation of cement dust is formed on the plants growing in cement polluted areas [8].

2. MATERIALS AND METHOD

2.1 Study Area:

The study was carried out in the month of January-April the study was conducted for the chemical properties of soil quality assessment near *Jai Laxmi Cement Co. (Pvt) Ltd*, Ramnagar Chandauli. The study area has been taken within a 1 km radius of Jai Laxmi Cement factory Ramnagar Chandauli, to assess the soil's chemical parameters analysis.

Based on the distance from the cement factory and the predominant wind direction. Five locations were selected from the center of the cement factory.

Sampling Sites:

For affected soil samples, 4 sites were selected from each direction of the Jai Laxmi Cement factory i.e., *Puraini* (site-1) from the North, *Jiwanathpur* (site-2) from the East, *Katariya* (site-3) from the West, and *Sengar* (site-4) from the Southeast direction of cement factory under the vicinity of 1km radius. The control soil sample is unaffected by cement dust and effluents from where a single field is chosen from *BHU* (site-5).

2.2 Methodology for Soil Collection:

Soil samples were collected from the mentioned experimental site from January to April month, using clean trowels in clean plastic bags, sealed tightly as well as labeled properly after the collection of the soil samples.

From each field three spots were dug till approx 0-15 cm of topsoil, and the soil from all three places was mixed thoroughly to represent the heterogeneity of soil as soil is frequently ploughed for Agri-purposes, and one sample was taken from each field randomly by trowel. For the control soil sample that is unaffected by cement dust and effluents, a single field is chosen, and a single sample from that field is acquired by the same methodology for testing the respective parameters.

2.3 Technique Used for Analysis:

Soil pH and Electrical Conductivity were determined in the soil and were measured by the pH meter and Digital Conductivity Meter given by Jackson and Wilcox, respectively [9], [10]. Parameters like Soil Organic Matter and Soil Organic Carbon, the technique used for the analysis was done by Rapid Titration Method given by Walkey and Black [11]. For Soil Total Nitrogen, Phosphorus, and Potassium Content the technique used for analysis was Available Nitrogen by Subbiah and Asija, for nitrogen analysis [12]. The calorimetric method by Olsen for Phosphorus Content and the Flame Photometric Method by Toth and Prince for the test of Potassium [13], [14].

3. RESULT AND DISCUSSION

3.1 pH:

The table 1 and figure 1 given below depicts the data accumulation of the pH of soil sample taken from the study area. The lowest value recorded was 6.24 in the month of April, at Katariya i.e., site-3 and the highest value recorded was 7.81 in the month of April, at Puraini i.e., site-1.

In the surface soil of affected sites, at the site-1 the pH range interpretation is of slightly alkaline, for site-2, range interpretation is of slightly acidic, for site-3 the interpretation of range is slightly acidic to neutral, for site-4 the range interpretation of pH is slightly alkaline. The soil range interpretation for the control site, i.e., site-5 is in a neutral range generally because the respective land is an organic farm.

The variations in the range of pH can be because of the deposition of chemicals from various different industries located in the area. The pH of the alkaline range can be due to liming effect of the cement dust as it contains CaCO_3 resulting in the alkalinity of soil [15]. While the field is commercial Agri field addition of fertilizers can also be a reason for varied pH. The pH of soil samples varied from neutral to slightly alkaline in the sites near the cement plant and slightly acidic away from the factory. A similar result was found by [16].

STUDY AREA	MONTH				MEAN
	JANUARY	FEBRUARY	MARCH	APRIL	
Puraini (Site-1)	7.59	7.71	7.76	7.81	7.71
Jiwanathpur (Site-2)	6.37	6.84	6.32	6.57	6.52
Katariya (Site-3)	6.81	6.73	6.95	6.24	6.68
Sengar (Site-4)	7.36	7.31	7.35	7.34	7.34
BHU (Site-5)	7.07	7.05	7.24	7.09	7.11

Table 1: Soil pH results in the study area in different months

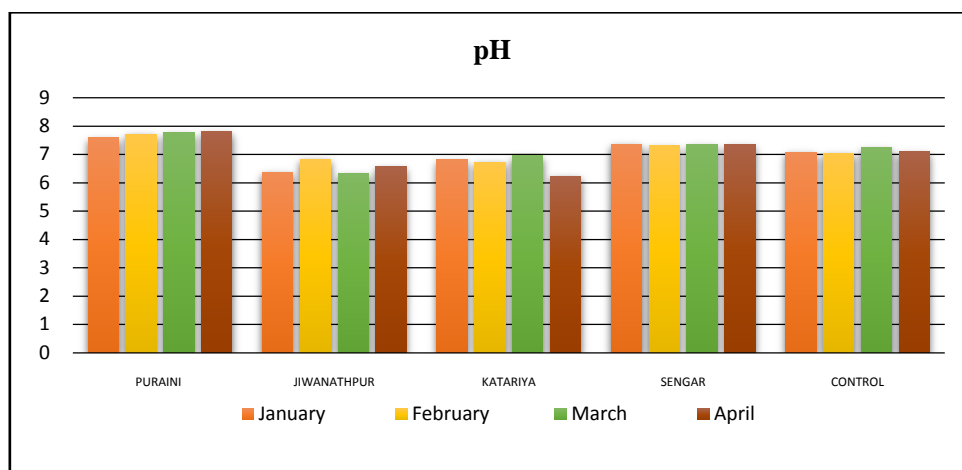


Figure 1: Graph representing the results of Soil pH in the study area

3.2 Electrical Conductivity:

Table 2 and figure 2 given below depicts the data accumulation of the electrical conductivity of soil sample taken from the vicinity of the study area of Jai Laxmi Cement Factory, Chandauli. The lowest value recorded was 0.32 dSm^{-1} in the month of March at the control site i.e., site-5 and the highest value recorded was 0.99 dSm^{-1} in the month of March, at the affected site i.e., site-1.

In the surface soil of affected sites, at the site-1 the EC range is from 0.48-0.88, for site-2, the range is 0.45-0.54, for site-3 the range is from 0.51-0.84, for site-4 the range of EC is 0.46-0.79. The soil EC range for the control site, i.e., site-5 is from 0.32-0.56.

The study of electrical conductivity of soil sample stated that the soil type of the affected area and the unaffected area is non-saline soil as the value is below 1.0 dSm^{-1} with the salt percentage of approx 0-0.1 % as per the limits suggested by [17]. It shows that the soil contains soluble salts in a very minute amount.

STUDY AREA	MONTH				MEAN
	JANUARY	FEBRUARY	MARCH	APRIL	
Puraini (Site-1)	0.88	0.48	0.99	0.69	0.76
Jivanathpur (Site-2)	0.45	0.49	0.54	0.43	0.47
Katariya (Site-3)	0.84	0.51	0.89	0.76	0.75
Sengar (Site-4)	0.79	0.46	0.58	0.68	0.62
BHU (Site-5)	0.52	0.41	0.32	0.56	0.45

Table 2: Soil EC (dSm^{-1}) results in the study area in different months

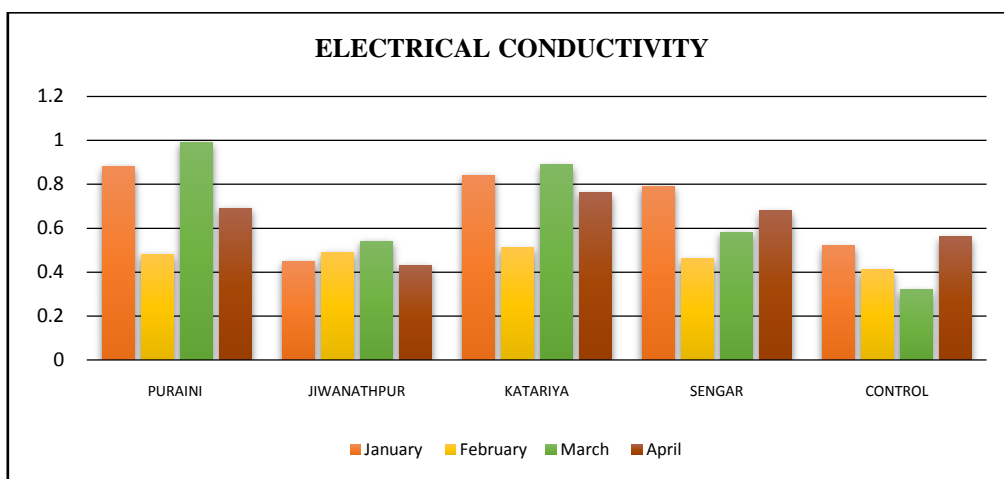


Figure 2: Graph representing the results of Soil EC (dSm⁻¹) in the study area

Soil Organic Carbon:

Table 3 and figure 3 given below depict the data accumulation of the percent organic carbon of soil samples taken from the vicinity of the study area of Jai Laxmi Cement Factory, Chandauli. The lowest value recorded was 0.28 % in the month of March, site-4 i.e., Sengar and the highest value recorded was 0.69 % in the month of March, site-2, i.e., Jivanathpur.

The concentration of soil organic carbon is greater in the surface soil of the affected soil site i.e., site-2, the value ranges from 0.39-0.69 which is in the medium range according to the range limits given by [17]. Most of the affected soil sample is in the medium range of percent organic carbon limit. The control site i.e., site-5 is also in the medium range being an organic Agri farm.

The high to medium range of organic carbon content in the soils is due to the luxuriant availability of organic matter like litter, and grasses along with long-term deposition of organic matter [18]. High temperature and good aeration in the soil increase the rate of oxidation of organic matter resulting reduction of organic carbon content [19].

STUDY AREA	MONTH				MEAN
	JANUARY	FEBRUARY	MARCH	APRIL	
Puraini (Site-1)	0.55	0.54	0.52	0.46	0.51
Jivanathpur (Site-2)	0.39	0.67	0.69	0.51	0.56
Katariya (Site-3)	0.48	0.31	0.57	0.34	0.42
Sengar (Site-4)	0.37	0.48	0.28	0.33	0.36
BHU (Site-5)	0.44	0.34	0.49	0.42	0.43

Table 3: Soil Percent Organic Carbon results in the study area in different months

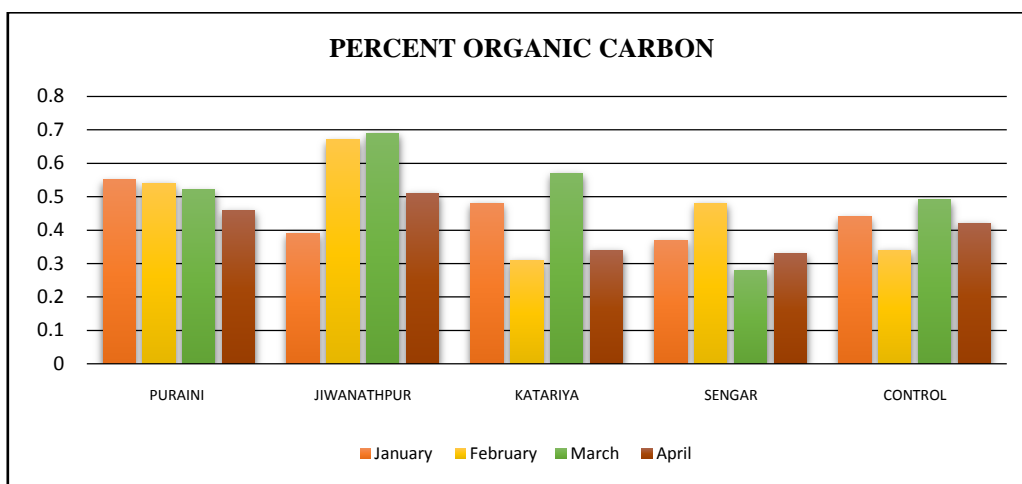


Figure 3: Graph representing the results of Soil Percent Organic Carbon in the study area

Soil Organic Matter:

The table 4 and figure 4 given below depicts the data accumulation of the percent organic matter of soil sample taken from the vicinity of the study area of Jai Laxmi Cement Factory, Chandauli. The lowest value recorded was 0.41 % in the month of January, site-5 i.e., BHU and the highest value recorded was 1.18 % in the month of march, site-2, i.e., Jiwathpur.

Soil organic matter showed a similar trend to that of soil organic carbon. The concentration of soil organic matter is greater in the surface soil of affected soil site i.e., site-2, the value ranges from 0.62-1.18. Most of the affected soil sample is in the medium range of percent organic matter limit. The control site i.e., site-5 is also in medium range being an organic agri farm. Value range of control site-5 is from 0.41-0.84. Soil organic matter typically comprises just 1% -5% of soil mass and the data range is approx in this value range.

More organic matter is present near the surface of soil on the topsoils. It is one of the main reasons that topsoils are more productive than subsoils. The amount of organic matter in soil is the result of all the additions and losses of organic materials that have occurred over years. Anything that adds large number of organic residues to a soil may increase SOM, on the other hand anything that decomposes organic matter rapidly or to be lost through erosion may deplete organic matter [20].

STUDY AREA	MONTH				MEAN
	JANUARY	FEBRAURY	MARCH	APRIL	
Puraini (Site-1)	0.94	0.93	0.89	0.79	0.88
Jiwathpur (Site-2)	0.62	1.15	1.18	0.87	0.95
Katariya (Site-3)	0.82	0.53	0.91	0.58	0.71
Sengar (Site-4)	0.63	0.82	0.48	0.56	0.62
BHU (Site-5)	0.41	0.58	0.84	0.72	0.72

Table 4: Soil Organic Matter results in the study area in different months

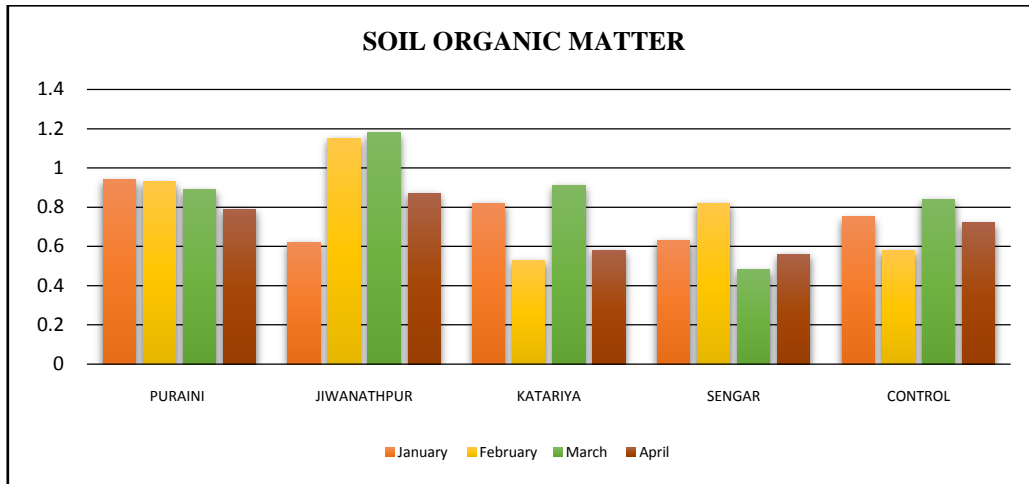


Figure 4: Graph representing the results of Soil Organic Matter in the study area

Total Nitrogen:

The table 5 and figure 5 given below depicts the data accumulation of the nitrogen content of soil sample taken from the vicinity of the study area of Jai Laxmi Cement Factory, Chandauli. The lowest value recorded was 22.5 kg/ha in the month of March, site-5 i.e., BHU and the highest value recorded was 213 kg/ha in the month of March, site-4, i.e., Sengar.

The concentration of soil nitrogen content is highest in the surface soil of affected soil site i.e., site-4, the value ranges from 147.7-213.7 which is in the low range according to the range limits given by Subbiah and Asija [12]. All the soil samples of the affected sites are in the low range of nitrogen content limit i.e., < 250. The control site i.e., site-5 is in the lowest range of nitrogen content.

The high range of nitrogen can be seen in the site-4 and site-2, of the affected site and other affected sites are in the 50-90 range values of nitrogen. Site-5 consist of the least amount of nitrogen because of the general practice of monoculture patterns which leads to decrease in fertility of soil thus decreasing the components necessary in the soil. Whereas the affected soils are in the industrial area and those being the commercial agri fields therefore, there's great possibility of least amount of addition of nitrogen rich chemical fertilizers.

STUDY AREA	MONTH				MEAN
	JANUARY	FEBRUARY	MARCH	APRIL	
Puraini (Site-1)	56.5	81.7	66.1	72.3	77.4
Jiwathpur (Site-2)	191.7	135.1	198.4	163.4	172.1
Katariya (Site-3)	84.8	72.3	50.2	78.7	71.5
Sengar (Site-4)	197.4	147.7	213.7	185.4	186.3
BHU (Site-5)	28.2	40.8	22.5	28.2	29.9

Table 5: Soil Nitrogen Content (kg/ha) results in the study area in different months

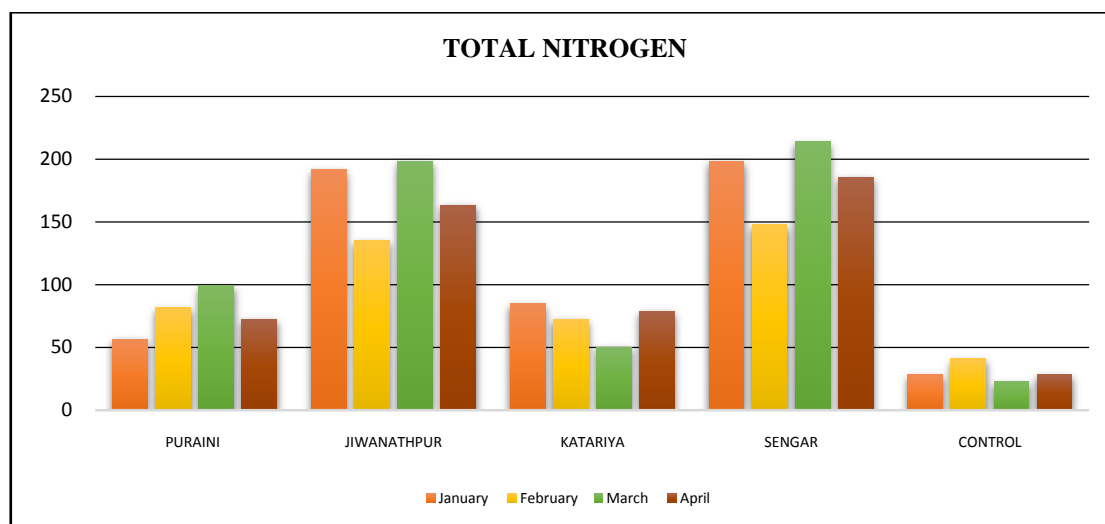


Figure 5: Graph representing the results of Soil Nitrogen Content (kg/ha) in the study area

3.3 Potassium Content:

The Table 6 and figure 6 given below depicts the data accumulation of the potassium content of soil sample taken from the vicinity of the study area of Jai Laxmi Cement Factory, Chandauli. The lowest value recorded was 22.9 kg/ha in the month of February, site-5 i.e., BHU and the highest value recorded was 231.2 kg/ha in the month of March, site-3, i.e., Katariya.

The concentration of soil potassium content is highest in the surface soil of the affected soil site i.e., site-3, the value ranges from 180.6-231.2 kg/ha which is in the medium range according to the range limits given by Jaiswal [17]. All the soil samples of the affected sites are in the medium range of potassium content limit i.e., from 101-250. The control site i.e., site-5 is in the lowest range of potassium content which is from 0-50.

The medium range of potassium can be seen in the highest range in site-3 and site-2, of the affected site and other affected sites are also in the medium range. Site-5 consist of the least amount of potassium because of the general practice of monoculture patterns which results in continuous drain of nutrients from soil reserve over the years without replenishments causing deficiency of potassium in the control site. Whereas the affected soils are in the industrial area and those being the commercial agri fields therefore, there's great possibility of addition of potassium content in the form of different chemical fertilizers.

STUDY AREA	MONTH				MEAN
	JANUARY	FEBRUARY	MARCH	APRIL	
Puraini (Site-1)	101.4	129.1	168.4	89.8	122.1
Jivanathpur (Site-2)	123.5	172.9	218.9	151.5	166.1
Katariya (Site-3)	231.2	180.6	188.5	196.4	199.1
Sengar (Site-4)	168.4	179.6	196.4	134.7	169.1
BHU (Site-5)	31.8	22.9	36.2	35.7	47.2

Table 6: Soil Potassium Content (kg/ha) results in the study area in different months

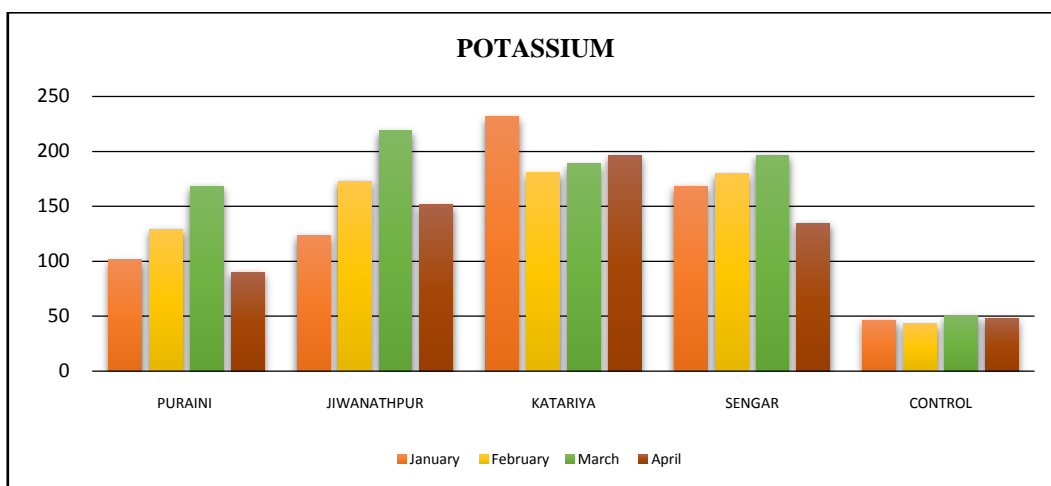


Figure 6: Graph representing the results of Soil Potassium Content (kg/ha) in the study area

3.4 Phosphorus Content:

The table 7 and figure 7 given below depicts the data accumulation of the phosphorus content of soil sample taken from the vicinity of the study area of Jai Laxmi Cement Factory, Chandauli. The lowest value recorded was 10.06 kg/ha in the month of January, site-2 i.e., Jiwathpur and the highest value recorded was 109.6 kg/ha in the month of March, site-3, i.e., Katariya.

The concentration of soil phosphorus content is highest in the surface soil of affected soil site i.e., site-3 and site-1, the value ranges from 40.44-109.6 kg/ha and 39.94-69.09 kg/ha respectively which is in the high range of phosphorus i.e., >40 according to the range limits given by Jaiswal [17]. Rest all the soil samples of the affected sites are in the medium range of potassium content limit i.e., from 26-40. The control site i.e., site-5 is in the lowest range of 12.26-25.11 of phosphorus content which is from 11-25.

The highest range of phosphorus can be seen site-3 and site-1, of the affected site and other affected sites which are site-2 and site-4 are in the medium range. Site-5 consist of the lowest amount of phosphorus because of the general practice of monoculture patterns which results in continuous drain of nutrients from soil reserve over the years without replenishments causing deficiency of phosphorus in the control site. Whereas the affected soils are in the industrial area and those being the commercial agri fields therefore, there's great possibility of addition of potassium content in the form of different chemical fertilizers.

STUDY AREA	MONTH				MEAN
	JANUARY	FEBRAURY	MARCH	APRIL	
Puraini (Site-1)	69.09	48.87	39.94	57.34	53.81
Jiwathpur (Site-2)	10.06	12.59	49.46	26.41	24.63
Katariya (Site-3)	40.44	71.38	109.6	97.07	79.62
Sengar (Site-4)	25.07	39.02	14.05	37.02	28.90
BHU (Site-5)	12.26	25.11	15.78	21.97	18.78

Table 7: Soil Phosphorus Content (kg/ha) results in the study area in different months

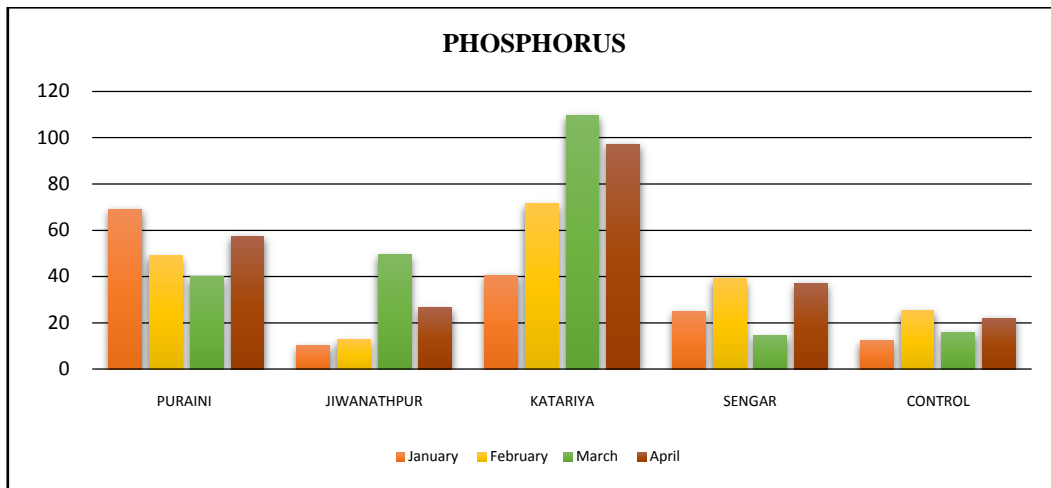


Figure 7: Graph representing the results of Soil Phosphorus Content (kg/ha) in the study area

3.5 Summary

Based on the result of the study, the affected area site-1 (Puraini) records the highest pH, with a mean value of 7.71 and EC with a mean value of 0.76 dSm^{-1} . Site-2 (Jiwanathpur) is highest in percent organic carbon and soil organic matter with the mean value of 0.56%, 0.95%, respectively and the lowest value records for soil pH with value of 6.52. Site-3 (Katariya) records the highest value for soil potassium content and soil phosphorus content with the mean value of 199.7 kg/ha and 79.6 kg/ha , respectively. Site-4 (Sengar) records highest value for total nitrogen content with mean value of 186.3 kg/ha . and the lowest value records for soil organic carbon and SOM with value of 0.42%. and 0.62% respectively. Site-5 (BHU) records lowest value for soil EC, total Nitrogen content, potassium content and phosphorus content with the value of 0.45 dSm^{-1} , 29.92 kg/ha , 47.02 kg/ha and 18.7 kg/ha ., respectively.

The soil samples were compared with standards of soil classification and based on the present study, The reason mainly can be the wind direction which results in settling dust and effluents discharged from the cement industry on sites over the years.

4. CONCLUSION

The result of various chemical parameters analyzed revealed that the soil sample from the Control site records lowest value for soil EC, total Nitrogen content, potassium content and phosphorus content with the value of 0.45 dSm^{-1} , 29.92 kg/ha , 47.02 kg/ha and 18.7 kg/ha ., respectively the soil quality is in good condition as compared to the soil collected from the different affected soil sites located in the vicinity of the cement factory. The normal soil pH is generally acidic but due to continuous deposition of cement dust on soil the pH of soil tends to be from neutral to slightly alkaline range. At different affected sites the highest value is recorded for different parameters as per the distance from the cement factory and the direction of the wind due to which cement dust is deposited on soil surface.

The effect of dust deposition on soil is more in the areas nearer to the cement plants. It is thus concluded that if such trend of dust deposition continues, soil properties of a vast area around the cement plants are likely to change in terms of its chemical properties. These changes will in turn have multiple deleterious effects particularly on agriculture, flora, and fauna of the area in the near future.

CONFERENCE DISCLAIMER:

Some part of this manuscript was previously presented in the conference: 6th International Conference on Strategies and Challenges in Agricultural and Life Science for Food Security and Sustainable Environment (SCALFE-2023) on April 28-30, 2023 in Himachal Pradesh University, Summer Hill, Shimla, HP, India.

Web Link of the proceeding: <https://www.shobhituniversity.ac.in/pdf/Souvenir-Abstract%20Book-Shimla-HPU-SCALFE-2023.pdf>

REFERENCES

1. **Vimlesh Rawat and Ratna Katiyar (2015)**. A review: on the effects of cement dust on vegetation. *International Journal of Scientific & Innovative Research Studies*. Vol (3), Issue-4.
2. **Rakshit A., Meena V.S., and Meena S.K., (2016)**. Effect of seed bio-priming and N doses under varied soil type on nitrogen use efficiency (NUE) of wheat (*Triticum aestivum* L.) under greenhouse conditions. *Biocatalysis and Agricultural Biotechnology*. Vol. 6, 68-75.
3. **Lal R., (2004)**. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science Journal Publications* vol. 304, 1623-1627.
4. **Ibrahim and Mirsal A., (2004)**. Soil pollution- origin, remediation, and monitoring. ISBN: 978-3-540-70775-2, 1st Edition 2004.
5. **Kumar S.S., Singh N.A., Kumar V., Sunisha B., Preeti S., Deepali S., Nath S.R., (2008)**. Impact of dust emission on plant vegetation in the vicinity of cement plant. *Environ. Eng. Manage. J.* 7(1):31-35.
6. **Syed Sana Mehraj, G. A. Bhat, Henah Mehraj Balkhi and Taseen Gul, (2013)**. Health risks for the population living in the neighborhood of a cement factory. *African Journal of Environmental Science and Technology*, Vol. 7(12), pp. 1044-1052.
7. **Vimlesh Rawat, Tandon P.K. and Ratna Katiyar, (2018)**. Hazardous effects of different regimens of cement dust on mung bean (*Vigna radiata*). *Journal of biological and chemical research. J. Biol. Chem. Research* volume 35(2).
8. **Narahari Chapagain and Min Raj Dhakal, (2011)**. Vegetation record around a cement factory and the impact of dust pollution on crop productivity. *Nepalese Journal of Biosciences* 1: 55-62.
9. **Jackson M.L. (1958)**. Soil Chemical Analysis, Prentice-Hall, Inc. Englewood.cliffe.n.j.
10. **Wilcox L.V. (1950)**. Electrical conductivity. *Am. Water works Assoc. J.*42,775-776.
11. **Walkey A. and Black, I.A. (1947)**. Critical Examination of rapid method for determining organic carbon in soils, effect of variance in digestion conditions and of inorganic soil constituents. *Soil sci pp.* 632:251.
12. **Subbiah B.V. and Asija C.L. (1956)**. A rapid procedure for the estimation of available nitrogen in the soil. *Current Science.* 25:259-260.
13. **Olsen S.R., Cole C.V., Watanbe F.S., and Dean L.A., (1954)**. Estimation of Available Phosphorus in soils by extraction with sodium bicarbonate. *USDA Circular* No. 939.

14. **Toth S.J. and Prince A.L., (1949).** Estimation of cation exchange capacity and exchangeable Ca, K and Na content of soil by flame photometer technique. *Soil Sci.*, 67:439-445.
15. **Oludoye O.O., Ogunyebi L.A., (2017).** Nutrients assessment of tropical soils around a mega cement factory in Southwest Nigeria. *J. Ecol. Eng.*;18:21-28. 31.
16. **Lamare R.E. and Singh O.P. (2020).** Effect of cement dust on soil Physico-chemical properties around cement plants in Jaintia Hills, Meghalaya. *International conference on chemistry and environmental sustainability (ICCES)*, vol. 25 issue 3, ISSN: 1226-1025.
17. **Jaiswal P. (2011).** Soil, plant and water analysis. Third Revised Edition, New Delhi – 110 002; *Kalyani Publications*.
18. **Kavitha C., and Sujatha M.P. (2015).** Evaluation of soil fertility status in various agro ecosystems of Thrissur district, Kerala. *International journal of agriculture and crop sciences (IJACS)*, 8(3): 328-338.
19. **Meena H.B., Sharma R.P., and Rawat U.S., (2006).** Status of macro and micronutrient in some soil of Tonk district of Rajasthan. *Journal of the Indian Society of Soil Science*, 54 (4): 508-512.
20. **Fred Magdoff and Harold Van Es, (2021).** *Building soils for better crop- Ch. 3, Amount of Organic Matter in Soils. Sustainable Agriculture Research and Education (SARE).*