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ASSESSMENT OF PHYSICOCHEMICAL PARAMETERS OF ROAD DUST POLLUTION: A COMPREHENSIVE STUDY

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Abstract
The present study focuses on the assessment of physicochemical parameters of road dust pollution in the Siltara-II industrial area. Ten sampling sites were selected to analyze the concentrations of key ions and metals, including sulfate (SO_4^{2-}), sodium (Na^+), chloride (Cl^-), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), and iron (Fe). Descriptive statistics was employed for data analysis. The results reveal significant variations across the sites, reflecting the influence of industrial activities on road dust composition. Sulfate concentrations ranged from 4.88 to 6.34 mg/g, while sodium levels varied between 3.52 and 4.66 mg/g. Chloride was the most abundant ion, with concentrations ranging from 95.13 to 104.02 mg/g. Potassium, calcium, and magnesium concentrations were comparatively lower but showed site-specific trends. Iron content was notably higher at certain sites, particularly site 6 (39.82 mg/g) and site 8 (33.8 mg/g), indicating localized pollution sources. The comprehensive analysis highlights the necessity for targeted environmental management strategies to mitigate road dust pollution in industrial regions.

Keyword:
Road Dust Pollution, Physicochemical Parameters, Industrial Area, Ion Concentration

1. Introduction

Road dust pollution is an increasingly pressing environmental issue, especially in urban and industrial areas where human activities contribute to the accumulation of pollutants on road surfaces. This dust, which is frequently loaded with a range of hazardous substances, not only degrades the quality of the air but also puts human health at serious risk and can contaminate nearby ecosystems (1, 2). Road dust's physicochemical properties are influenced by a number of variables, such as its proximity to industrial areas, traffic volume, and the local climate. Understanding these attributes is imperative when developing effective approaches to monitor and relieve road dust pollution (3, 4).

In industrial regions, road dust is a complex mixture of particles derived from multiple sources, including soil, vehicle emissions, tire and brake wear, construction activities, and industrial discharges (5). Heavy metals, polycyclic aromatic hydrocarbons (PAHs), and other hazardous compounds that are known to have negative impacts on human health and the environment are all present in these particles. (6). The inhalation of fine particles, for instance, has been linked to respiratory and cardiovascular diseases, while the deposition of dust can lead to the contamination of soil and water bodies, thereby affecting the local biodiversity and agricultural productivity (7).

The assessment of physicochemical parameters in road dust involves analyzing various ions and metals that are indicative of pollution sources and levels. Key parameters often studied include sulfate (SO_4^{2-}), sodium (Na^+), chloride (Cl^-), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), and iron (Fe). These components are typically chosen because they are either major constituents of road dust or serve as tracers for specific pollution sources. For instance, high levels of sulfate and chloride can indicate the

influence of industrial emissions, while elevated sodium and magnesium levels may suggest the contribution of road salt used for de-icing (8).
The area under study, Siltara-II industrial zone, is a crucial industrial center in the region, known for its high concentration of manufacturing and processing facilities. The substantial industrial operations in this zone, along with heavy vehicular movement, result in considerable pollution due to road dust. Research conducted in comparable industrial environments has emphasized the significance of comprehending the dispersion and density of contaminants in road dust to evaluate the environmental repercussions of industrial operations. (9). This study aims to build on these findings by providing a comprehensive analysis of the physicochemical parameters of road dust in the Siltara-II area, with the goal of identifying the primary sources of pollution and assessing the potential risks to human health and the environment.

2. Material and Methods

2.1 Study Area and Sampling

The study was conducted in the Siltara-II industrial area, where ten distinct sampling sites were selected based on their proximity to industrial activities and traffic density. Each site was chosen to represent a variety of environmental conditions within the area. Road dust samples were collected using a stainless steel brush and pan, ensuring that approximately 100 grams of dust was gathered from each site.

2.2 Sample Preparation

The collected dust samples were air-dried at room temperature for 48 hours to remove moisture. After drying, the samples were sieved through a 2 mm mesh to remove larger debris and homogenize the particle size. The sieved samples were then stored in airtight containers until further analysis.

2.3 Determination of Physicochemical parameters

The physicochemical analysis of road dust from the Siltara-II industrial area, colour and pH were evaluated using standard methods. Colour was assessed visually and quantified using a colorimeter, which measures the intensity of the dust's colour in comparison to standard solutions. pH was determined by dissolving a sample of road dust in distilled water and measuring the pH using a calibrated pH meter. These methods provided essential information on the visual and chemical properties of the road dust, contributing to the overall understanding of its pollution characteristics. Different ions present in road dust from the Siltara-II industrial area was conducted using conventional methods. For sulfate (SO_4^{2-}) determination, the gravimetric method was employed, where the sulfate ions were precipitated as barium sulfate and weighed. Sodium (Na^+) and potassium (K^+) concentrations were measured using a flame photometer, which quantifies these ions based on their emission spectra. Chloride (Cl^-) levels were assessed through the Mohr's titration method, utilizing silver nitrate as the titrant. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were analyzed using a colorimetric method involving complexation reactions with specific reagents, followed by measurement of absorbance. Iron (Fe) content was determined using a colorimetric method, where iron ions form a colored complex with a reagent and the intensity of the colour, measured by a spectrophotometer, indicates the concentration.

2.4 Statistical analysis

Descriptive statistics was applied to calculate the average value of recorded all ions [such as sulfate (SO_4^{2-}), sodium (Na^+), chloride (Cl^-), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), and iron (Fe)] in studied road dust sample. SPSS (version 20) was used for correlation analysis.

3. Results and Discussion

3.1. Dust Characteristics

The physical characteristics of the dusts are shown in Table 1. The colour of dusts was varied from yellow toblack. The urban dusts were blackish to black in color. The pH value of dust was ranged from 7.5–8.4. The dust of coal burning site was foundto be slightly acidic due to the relatively higher content of ions i.e. Cl^- and SO_4^{2-} .

Table 1. Characteristics of road dust of India.

S. No.	Location (Siltara-II)	Color	pH
1	Sample site-1	DB	8.2

2	Sample site-2	Bl	6.8
3	Sample site-3	Bl	7.9
4	Sample site-4	DB	8.4
5	Sample site-5	DB	8.3
6	Sample site-6	LB	7.9
7	Sample site-7	LB	7.7
8	Sample site-8	B	7.4
9	Sample site-9	G	8.1
10	Sample site-10	B	7.5

B = Brown, Bl = Black, DB = Dark brown, LB = Light brown, G = Grey.

3.2. Ions in Road Dust

The contents of water-soluble ions in the road dusts is summarized in Table 2. The concentration ofions *i.e.* Cl^-, SO_4^{2-}, Na^+, K^+, Mg^{2+} and Ca^{2+} was ranged from 95.13-104.02, 4.88-6.34, 3.52-4.66, 0.83-1.21, 0.71-0.94, and 3.42-5.05 mg/l respectively.Ions *i.e.* Ca^{2+}, Na^+, $Cl^-$and SO_4^{2-}were found to be major contributing species in the road dusts.

A temporal increase in the concentration of all ions was observed due to increasein the frequency of the vehicles at rate of ≥2% - 8% in the Raipur region of the country. The concentration ofions in the dust was observed in following increasing order: $Cl^- < SO_4^{2-} < Ca^{2+} < Na^+ < K^+ < Mg^{2+}$.

3.3 Metal in Road Dust

The concentration of the metal *i.e.* Fe, in the road dusts of Raipur city isshown in **Table 2**. The content of Fein the road dusts wasranged from 14.45–39.82 mg/l. Among all sampling site, Fe exhibited extremely high concentrationin all locations becauseferro-alloy Industries runs more in these locations.

Table 2. Concentration of ions in road dust, mg/l.

S. No.	Location (Siltara-II)	SO_4^{--}	Na^+	Cl^-	K^+	Ca^{++}	Mg^{++}	Fe
1	Sample site-1	5.52	4.66	101.21	1.10	3.95	0.94	16.97
2	Sample site-2	6.19	3.68	104.02	1.14	3.42	0.91	14.45
3	Sample site-3	4.88	4.26	98.22	1.00	5.05	0.77	15.4
4	Sample site-4	6.22	4.16	102.42	1.03	3.75	0.83	14.8
5	Sample site-5	5.19	3.96	96.11	0.90	4.12	0.71	19.17
6	Sample site-6	6.34	3.52	95.13	0.83	4.02	0.88	39.82
7	Sample site-7	5.71	4.14	102.41	1.21	5.04	0.91	30.78
8	Sample site-8	4.92	4.55	103.84	1.05	3.65	0.89	33.8
9	Sample site-9	5.59	4.02	102.98	1.17	4.43	0.81	33.1
10	Sample site-10	5.93	3.87	98.42	1.21	3.83	0.74	16.97

The results of the physicochemical analysis of road dust samples from the Siltara-II industrial area are summarized in the following table:

Table 3. Range, Mean and Standard Deviation of ions in road dust, mg/g.

Parameter	Range (mg/g)	Mean (mg/g)	Std. Deviation (mg/g)
SO_4^{2-}	4.88 - 6.34	5.79	0.58
Na^+	3.52 - 4.66	4.08	0.41
Cl^-	95.13 - 104.02	100.07	2.87
K^+	0.83 - 1.21	1.06	0.13
Ca^{2+}	3.42 - 5.05	4.12	0.62
Mg^{2+}	0.71 - 0.94	0.85	0.08
Fe	14.45 - 39.82	23.63	9.37

Table 4. Correlation among all the studied ions of road dust

	SO_4^{--}	*Na+*	*Cl -*	*K+*	*Ca^{++}*	*Mg++*	*Fe*
SO_4^{--}	1						

Na+	-0.65	1					
Cl -	-0.01	0.41	1				
K+	0.06	0.22	0.68	1			
Ca++	-0.40	0.14	-0.20	0.08	1		
Mg++	0.27	0.24	0.54	0.19	-0.18	1	
Fe	0.02	-0.16	-0.06	-0.20	0.17	0.29	1

Result of correlation analysis showed positive correlation of K^+ with $SO4^{--}$, Na^+ and Cl^-. Similarly, Ca++ showed positive correlation with Na^+ and Cl^-. Mg++ showed positive correlation with $SO4^{--}$, Na^+ , Cl^- and K^+, Fe showed positive correlation with $SO4^{--}$, K^+ , Ca++ and Mg++ ions. Further, Na^+, Cl^- and Ca++ showed negative correlation with $SO4^{--}$. Also, Ca++ reported negative correlation with Cl^-. Mg++ reported negative correlation with Ca++. Also, Fe showed negative correlation with Na^+ , Cl^-, and K^+ (Table 4).

3.4 Discussion

The results of this study indicate that the physicochemical composition of road dust in the Siltara-II industrial area is influenced by a combination of industrial emissions, vehicular traffic, and local environmental factors. The high levels of chloride, sulfate, and iron across several sites suggest significant contributions from industrial activities, while the presence of calcium and magnesium indicates the impact of soil dust and construction materials. The variability in the concentration of these parameters across the different sampling sites underscores the complex nature of road dust pollution in industrial areas, where multiple sources contribute to the overall contamination levels.
Understanding the distribution and sources of these pollutants is critical for developing targeted strategies to manage and mitigate road dust pollution. Measures such as improving industrial emission controls, managing traffic density, and minimizing dust resuspension from unpaved areas could help reduce the environmental and health impacts of road dust in industrial regions.

4. Conclusion

Road dust pollution is a complex issue that intersects with various urban processes, including transportation, industrial activities, and environmental management. The main dominating species in the road dust is the Fedue to huge coal burning and running of Industries.The road dust is acidic in nature at hazardous levels.The motor vehicle exhaust emissions are expected to be main sources for contaminating the road dust with Cl^-, SO_4^{2-}, nearby highways. Moreover, the findings of this study are intended to inform the development of targeted environmental management strategies. By identifying the most polluted areas and the primary sources of road dust pollution, local authorities and industrial operators can implement measures to reduce emissions, improve dust control practices, and enhance air quality monitoring.

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