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Effectiveness of chemical road dust suppressants on paved roads of Pimpri Chinchwad

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ABSTRACT

Introduction: Currently, reducing road dust emissions is a serious problem for safe and environment-protective transportation, leading to Particulate Matter (PM) limit violations and high population exposures to dust containing poisonous metals and mineral particles. Nowadays chemical road dust suppressants are being employed more frequently as a viable remedy to reduce roadside dust emissions.

Materials and methods: Two seasons winter and summer were selected for the study and during which, typically 3 types of roads as per average traffic density and land-use category identified in the city of Pimpri-Chinchwad were sprayed. Dry samples were taken on day one from a 1 m^2 area using a portable vacuum cleaner that was run for 8 to 10 min each. Similarly, samples were collected in the same area after 5-10 min after spraying with Calcium Chloride ($CaCl_2$) and Magnesium Chloride ($MgCl_2$). Also, the second set of samples was collected after 24 h of chemical applied.

Results: Maximum reduction in silt loading occurred i.e., 99.73% on the application of 30 g/m^2 of $CaCl_2$. Reduction observed in emission factor of $PM_{2.5}$ was 97.78% and in the case of PM_{10} it was 97.59%. While increase in average particle size was observed up to 27.88 µm.

Conclusion: Both the suppressant efficient in suppressing the road dust but the day 1 result shows more dust suppression as compared to the day 2 dust suppression also as per the dust loading $CaCl_2$ is a better dust suppressant than $MgCl_2$.

Introduction

The air quality, human health, and road safety can all be significantly impacted by the road dust that is produced by paved roads. Chemical road dust suppressants have come to light as a potential remedy to solve these issues. To reduce dust emissions and the difficulties they cause, paved road surfaces are treated with chemicals called chemical road dust suppressants. Dust suppressants less effective in reducing road dust pollution, but they reduced Particulate Matter (PM)-related life loss and increased willingness to pay values, emphasizing the need for practical indicators [1]. A literature on urban

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road sediment contamination, emphasized standardized sampling, analysis methods, and underrepresented regions' research gaps [2]. A study of PM_{10} variability in Andean cities, analysing samples for ions, minerals, and trace elements, identifying factors influencing Road Dust (RD_{10}) levels and identifying elements associated with traffic emissions [3]. Dust suppression effectiveness on dirt and gravel road materials, finding higher total dissolved solids and lower sodium adsorption ratios as good predictors [4]. Atmospheric temperatures affect chemical suppressant effectiveness in controlling mine haul road dust, with chemical suppressants showing higher efficiencies than water [5]. High concentrations of organic pollutants in wash water, highlighting the need for treatment before disposal and focusing on street sweeping [6]. Calcium Chloride ($CaCl_2$) and Magnesium Chloride ($MgCl_2$) effective dust suppressants on Wyoming gravel roads, reducing emissions by 87% [7]. Dust suppressants' effectiveness in Beijing, finding limited efficiency and proposing preventive and mitigation strategies [8]. A study of road dust at Venice airport, focusing on inorganic composition and sources without organic compound characterization [9]. An empirical model for predicting road dust emissions using pavement and traffic characteristics, improving inventories and air quality management [10]. The study found sifter and sieve simpler, less expensive dust application methods [11]. A need for increased research in Middle East and Africa [12]. Development of real-time method for measuring re-suspended particulate emissions from paved roads [13]. A discussion on urban road dust's impact on aquatic organisms, suggesting mitigation through regulatory policies and efficient Best Management Practices (BMPs) [14]. A study on seasonal variations and lateral differences in Stockholm road dust loads, highlighting the influence of surface properties and street repaving. They found road dust, a significant source of air pollution, even with electrification [15]. A review of methodologies for collecting road dust, discussing sources, particle size distribution, chemical composition, and indexes for accurate emission inventories and health protection programs [16]. A comparison on FORE (Forecasting of Road dust Emissions) and OSPM (Operational Street Pollution Model) air pollution dispersion models, focusing on salting, street cleaning, and dust binding [17]. A study on Bogota road dust physicochemical, sources, and PM_{10} fraction [18]. Study found no significant effectiveness of dust suppressants in reducing road dust emissions in a Mediterranean city, suggesting higher road dust loading may improve effectiveness [19].

As per study and researches carried out in India, found no soil acidification danger in Delhi's soil systems, but future assessments are crucial [20]. Heavy metal concentrations in road dust from Tiruchirappalli city, South India, with higher levels in outer city due to industrial activities [21].Taj Mahal showed higher $PM_{2.5}$ and PM_{10}, revealing non-carcinogenic risks and metals of concern for children and adults [22]. Fe and Pb hazards in road dust in Vellore, India, affecting children [23]. Heavy metal contamination in Delhi road dust from industrial sources [24].

Air pollution is a major issue in cities, especially in developing countries, and has adverse effects on human health and the environment. Particulate Matter (PM) emitted by road transport is a significant contributor to air pollution, which can come from both exhaust and non-exhaust processes. Non-exhaust emissions, such as road dust, are recognized as one of the largest sources of air pollution in urban environments. Road dust is a major source of Particulate Matter (PM) air pollution, which is associated with various health impacts such as respiratory and cardiovascular diseases. Chemical road dust suppressants, such as magnesium chloride ($MgCl_2$) and calcium chloride ($CaCl_2$), have been widely used to mitigate the adverse effects of road dust. Chemical road dust suppressants have proved useful in lowering dust emissions and enhancing air quality.

The present study assesses chemical suppressants effectiveness in reducing $PM_{2.5}$ and PM_{10} levels, identifying the most effective ones for mitigating road dust as the most dangerous source of air pollution. The study evaluates chemical suppressant effectiveness across various road types, considering factors like traffic volume, pavement material, and land use to determine the most suitable suppressants for specific road environments. The study also evaluates chemical suppressant effectiveness in summer and winter, focusing on seasonal variations in road dust generation and dispersion. The research aims to develop effective strategies for managing and reducing pollution.

Materials and methods

Study area

The second-biggest industrial location in Maharashtra is Pimpri Chinchwad Municipal Corporation (PCMC), one of India's main industrial hubs. The fifth-most populous city in Maharashtra is this one. More than 2900 industries are located in this industrial region, which is mostly home to the automotive and engineering industries. The PCMC area enjoys a year-round energising climate thanks to its high altitude, moderate rainfall, and lush vegetation. The annual rainfall at PCMC ranges from 700 to 800 mm. On warm afternoons, relative humidity can be as low as 30% and reaches a maximum of 70–80% during the rainy season. 1729359 people were counted in the population of PCMC in 2011. The current population is at 2000000. PCMC's geographic area is 181 square kilometres. There are 633 km of roads in all [25].

Site selection

Three sites were selected as sampling sites, starting with, the land-use category identified as "Industrial," situated in Jagtap Dairy, Pimple Saudagar. The activities surrounding this site include industrial operations, high-way traffic, and dusty roads. The Global Positioning System (GPS) coordinates for this location are Latitude: 18.5753 and Longitude: 73.7923. Moving on to site 2, the land-use category listed as "Residential," located in Kaspate Wasti, Wakad. The activities observed around this residential site comprise heavy traffic flow, the presence of hotels and restaurants, as well as small eateries. The GPS coordinates for this location are Latitude: 18.5967 and Longitude: 73.7654. Lastly, site 3 represents the land-use category as "Commercial," situated at Fab India Chowk, Hinjewadi. The activities encompassing this commercial site include heavy traffic, industrial establishments, dusty roads, open burning, as well as the presence of restaurants, dhabas, and small eateries. The GPS coordinates for this location are Latitude: 18.5956 and Longitude: 73.7682.

Chemical dust suppressants

Dust binders are substances that are added to materials or applied to surfaces in order to bind dust particles collectively, resulting in larger and heavier aggregates. These binders frequently include resins or polymers that coat the dust particles and form a cohesive coating. The possibility of the particles getting airborne is decreased by this layer, reducing dust production. On roads, mine tailings, or other loose materials prone to producing dust, dust binders are frequently utilised.

Calcium Chloride ($CaCl_2$) and Magnesium Chloride ($MgCl_2$) are effective dust suppressants for paved roads due to their moisture retention, binding effect, road surface penetration, cost-effectiveness, and environmental considerations. They attract and retain moisture, preventing the road material from drying out and generating dust. These salts also bind dust particles together, reducing their airborne dispersion and inhalation risks. Furthermore, they penetrate the road surface, strengthening it and minimizing dust production. In terms of cost and environmental impact, $CaCl_2$ and $MgCl_2$ are affordable, readily available, non-toxic, and biodegradable options. Overall, they enhance road safety and air quality by reducing dust on paved surfaces.

A study on Norwegian tunnel and applied $MgCl_2$ at a range of 20-40 g/m^2 on a daily basis. This led to a 56% reduction in PM_{10} emissions [26]. A study in the Netherlands using $CaCl_2$, but the specific quantity and frequency were not mentioned. The study reported a 12% reduction in PM_{10} emissions over a 4-month period [27]. A study in Sweden using a combination of CMA (Calcium Magnesium Acetate), $CaCl_2$, and $MgCl_2$. They applied 20 g/m^2 every 4-5 days, resulting in a 30-40% reduction in PM_{10} emissions [28]. A study in Helsinki, Finland, using $CaCl_2$. They applied 20-30 g/m^2 on a daily basis, leading to a 60% reduction in PM_{10} emissions [29]. Two separate studies in the United Kingdom (UK). In Manor Road, they used CMA at a rate of 10 grams per square meter daily, resulting in a 41% reduction in PM_{10} emissions [30].

Sampling

The study used primarily locally-collected data to estimate road dust emissions. All the fieldwork for this project occurred in 2023 and was divided into a winter (20/02/2023–25/02/2023) and a summer (12/03/2023–17/03/2023) portion. The field study included procurement of road dirt samples for silt analysis of road dust (as shown in Fig. 1, Sampling being carried out along the road side with the help of portable vacuum cleaner), surveys of streets in PCMC, to measure road dust emissions factors over the same set of streets on 02 different seasons for 2 consecutive days at each location.

Two stages of sampling were completed. One for the winter season and one for the springtime (early summer). Two days in a row of sampling were carried out at each location. Three dry samples were taken on day one from a 1 m^2 area [21] using a portable vacuum cleaner that was run for 8 to 10 min each. Similarly, samples were collected in same area after 5-10 min after spraying with $CaCl_2$ and $MgCl_2$.Allthe samples were collected between 10 p.m. to 12 p.m. in the night for summer and winter seasons.

Fig. 1. Sampling being carried out along the road side with the help of portable vacuum cleaner

Sampling for day 1

On Day-1, again Industrial road type was covered. The sampling was conducted on the 20th of February 2023, during the winter season. The samples collected on this day are labelled with different sample numbers and corresponding descriptions. In set A, three samples (i.e. 1 m^2 area each) were collected from the Industrial road type following a dry sampling method. This implies that no additional substances or solvents were used during the sampling process. Firstly, in set B, three samples (i.e. 1m^2 area each) were collected on the same date. In first sample dry sampling technique was adopted. Solution of 20 g/m^2 of $CaCl_2$ and water was sprayed for remaining two samples before dust collection. Sampling was done after approximately 5-10 min after spraying the solution. Additionally, in set C, three samples (i.e. 1m^2 area each) were collected on the same date. In first sample dry sampling technique was adopted. Solution of 20 g/m^2 of $MgCl_2$ and water was sprayed for remaining two samples before dust collection. Sampling was done after approximately 5-10 min after spraying the solution. Continuing further, in set D, three samples (i.e. 1m^2 area each) were collected on the same date. In first sample dry sampling technique was adopted. Solution of 30 g/m^2 of $CaCl_2$ and water was sprayed for remaining two samples before dust collection. Sampling was done after approximately 5-10 min after spraying the solution. Lastly, in set E, three samples (i.e. 1m^2 area each) were collected on the same date. In first sample dry sampling technique was adopted. Solution of 30 g/m^2 of $MgCl_2$ and water was sprayed for remaining two samples before dust collection. Sampling was done after approximately 5-10 min after spraying the solution.

Sampling for day 2: (24 h later)

On day-2, Industrial road type was covered. The sampling was conducted on the 21st of February 2023, during the winter season. The samples collected on this day are labelled with different sample numbers and corresponding descriptions. Firstly, in set A, three samples (i.e. 1m^2 area each) were collected from the Industrial road type following a dry sampling method. This implies that no additional substances or solvents were used during the sampling process. In set B, three samples (i.e. 1m^2 area each) were collected on the same date. In first sample dry sampling technique was adopted. Solution of 20 g/m^2 of $CaCl_2$ and water was sprayed for remaining two samples before dust collection. Sampling was done after approximately 5-10 min after spraying the solution. Additionally, in set C, three samples (i.e. 1m^2 area each) were collected on the same date. In first sample dry sampling technique was adopted. Solution of 20 g/m^2 of $MgCl_2$ and water was sprayed for remaining two samples before dust collection. Sampling was done after approximately 5-10 min after spraying the solution. Continuing further, in set D, three samples (i.e. 1m^2 area each) were collected on the same date. In first sample dry sampling technique was adopted. Solution of 30 g/m^2 of $CaCl_2$ and water was sprayed for remaining two samples before dust collection. Sampling was done after approximately 5-10 min after spraying the solution. Lastly, in set E, three samples (i.e. 1m^2 area each) were collected on the same date. In first sample dry sampling technique was adopted. Solution of 30 g/m^2 of $MgCl_2$ and water was sprayed for remaining two samples before dust collection. Sampling was done after approximately 5-10 min after spraying the solution. (Fig. 2. $CaCl_2$ and $MgCl_2$ solutions sprayed on 1m^2 area of the road) depicts the solution sprayed at 1m^2 area along the road.

Similar sampling methodology was adopted for location 2 and location 3 for summer and winter season. Sampling for location 2 i.e., residential road was carried out on 22nd and 23rd February, 2023 for winter season. And, sampling for location 3 i.e., commercial road was carried out on 24th and 25th February, 2023 for winter season. Sampling during spring time i.e. early season for location 1 i.e., industrial road was carried out on 12th and 13th March, 2023. For location 2, on 14th and 15th March and for location 3 on 16th and 17th March, 2023 respectively.

Approach-1: Sieve analysis

Samples were sieved and weighed to determine the silt content of the road soil. The silt contents were then used to calculate the silt loading on each of the road sampled. Silt is frequently used as a stand-in for PM_{10} road dust emissions. Silt is defined operationally as the material that passes through a 200-mesh sieve (equivalent to around 75 µm in particle diameter).

The term "Silt loading (sL)" describes the build-up or presence of silt, a fine material made up of particles ranging in size from sand to clay. It is frequently used to define the amount of silt in soil, the amount of silt suspended or deposited in water bodies, or the presence of silt as part of particulate matter in the atmosphere.

Approach-2. Particle emission factor

The quantity of particulate emissions from vehicle traffic on a dry paved road may be estimated using the empirical expression: [31]

$$E=k\,(sL/2)^{0.65}\,(W/3)^{1.5} \quad (1)$$

Where:

E = particulate emission factor in g/VKT (grams per vehicle kilometre travelled)

k = particle size multiplier for particle size range as shown in Table 2

sL = road surface Silt loading (sL) in g/m^2 (grams per square meter)

W = average weight (tons) of the vehicles travelling the road as shown in Table 1

For the analysis and based on Average Daily Traffic (ADT) the three roads considered for sampling are considered Industrial Road as “Highway”, Residential Road as “Residential” and Commercial road as “Major road”.

Table 1. Weight of vehicles in tons based on types of roads

Road type	W in tons
Highway	0.96
Major Road	0.96
Residential Road	0.62

Table 2. Particle size multiplier for particle size range

Size range	Particle Size Multiplier k in g/VKT
$PM_{2.5}$	1.1
PM_{10}	4.6

Approach-2. Particle size distribution

Road dust samples' particle size distribution analysis sheds important light on the make-up and properties of airborne particulate matter found on road surfaces. Researchers can comprehend the range and abundance of different particle sizes by analysing the size distribution of the particles, which aids in understanding the potential health concerns and environmental effects linked to road dust pollution. Road dust particles can range in size from coarse (more than 10 μm) to fine (less than 2.5 μm), depending on their shape. In order to determine the size distribution of particles in the collected samples, the particle size distribution analysis uses methods like sieve analysis, laser diffraction, or microscopy.

The range and distribution of particle sizes found in the dust found on paved road surfaces are referred to as the "road dust particle size distribution." Road dust is made up of a variety of particles that can range in size, including soil, mineral debris, organic compounds, and pollutants. For the analysis, a microscope with the right magnification and imaging capability "LABOMED Lx 300" was chosen. To enable size measurements, the microscope contained a calibrated eyepiece or stage micrometre. A tiny portion of the prepared sample was put on a microscope slide, then examined under a microscope (as shown in Fig. 3; Image of particles under microscope). Particles of interest were focussed when the sample was scanned under the microscope. Using an image analysis programme or the reticule on the microscope, specific particles were measured. Depending on the shape, the length or diameter of the particles can be used to calculate their size. The particle size can be measured manually by comparing it to the calibrated scale on the microscope, or for more accurate readings, automatic image analysis software "PixelPro" was used. As the particle size do not possess a regular shape the maximum length was measured using the length tool in PixelPro. From the measured lengths the maximum length was considered as the size or diameter of the particle [32] (as shown in Fig. 4: Measurement of size of particle under PixelPro).The data was then analysed to create a particle size distribution. To display the relative frequency or cumulative percentage of particles in various size ranges, the distribution can be displayed as a histogram or a cumulative distribution curve.

Fig. 2. $CaCl_2$ and $MgCl_2$ solutions sprayed on $1m^2$ area of the road

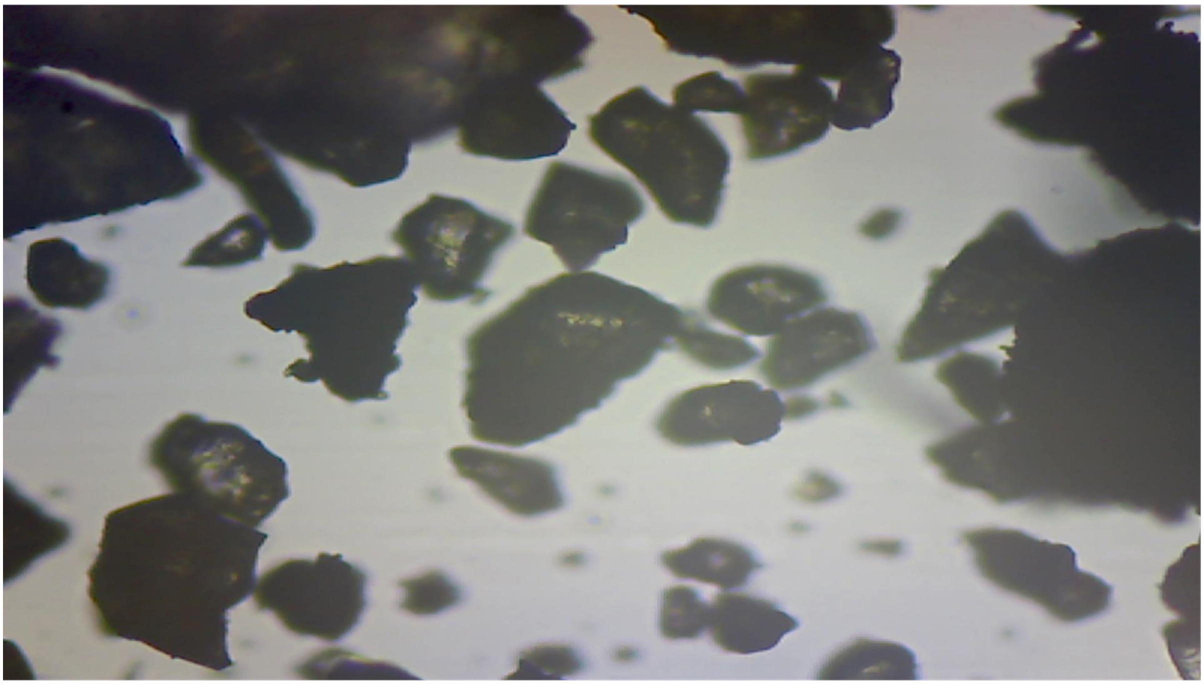

Fig. 3. Image of particles under microscope

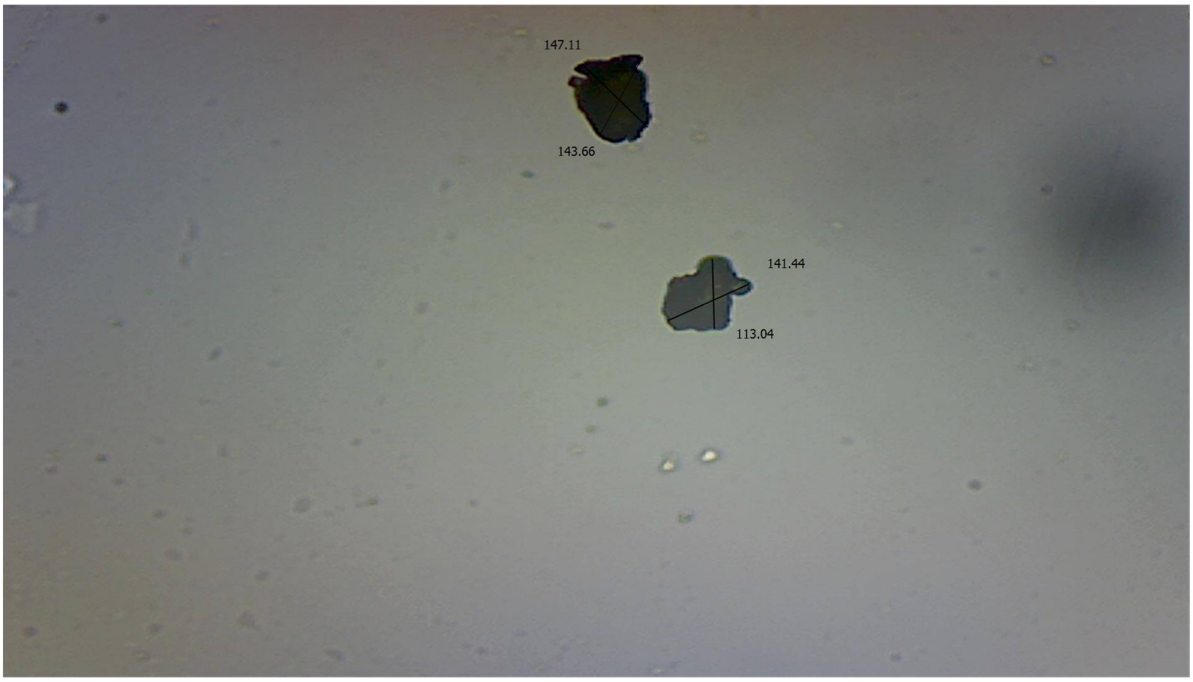

Fig. 4. Measurement of size of particle under PixelPro

Table 3. Samples collected and analysed at location 1 for summer and winter season

Location 1 Jagtap Dairy, Aundh Ravet BRTS Road (Highway road)					
Day	Season	Sample No.	Silt loading (sL)	Emission factor $PM_{2.5}$	Emission factor PM_{10}
Day - 1	Winter	A = Dry	22.87	0.94	2.38
		B = 20 $CaCl_2$ (g/m^2)	0.86	0.11	0.28
		C = 20 $MgCl_2$ (g/m^2)	1.71	0.17	0.44
		D = 30 $CaCl_2$ (g/m^2)	0.45	0.07	0.19
		E = 30 $MgCl_2$ (g/m^2)	0.29	0.05	0.14
Day - 2	Winter	A = Dry	27.72	1.06	2.70
		B = 20 $CaCl_2$ (g/m^2)	0.82	0.11	0.27
		C = 20 $MgCl_2$ (g/m^2)	1.68	0.17	0.43
		D = 30 $CaCl_2$ (g/m^2)	0.24	0.05	0.12
		E = 30 $MgCl_2$	0.26	0.05	0.13
Day - 1	Summer	A = Dry	27.72	1.06	2.70
		B = 20 $CaCl_2$ (g/m^2)	0.82	0.11	0.27
		C = 20 $MgCl_2$ (g/m^2)	3.55	0.28	0.71
		D = 30 $CaCl_2$ (g/m^2)	0.13	0.03	0.08
		E = 30 $MgCl_2$ (g/m^2)	0.31	0.06	0.14
Day - 2	Summer	A = Dry	28.44	1.08	2.74
		B = 20 $CaCl_2$ (g/m^2)	1.95	0.19	0.48
		C = 20 $MgCl_2$ (g/m^2)	2.79	0.24	0.61
		D = 30 $CaCl_2$ (g/m^2)	0.12	0.03	0.08
		E = 30 $MgCl_2$ (g/m^2)	0.21	0.04	0.11

Results and discussion

To assess the effectiveness of the chemical suppressant experiments are carried out for 2 days and on three different road sites selected as per the methodology. The results of these experiments are tabulated in Tables 3, 4, and 5.

Table 3 consists of the result of silt loading and emission factor of $PM_{2.5}$ and PM_{10} of location 1 i.e., highway. From Table 3 it is observed that maximum silt loading reduction is observed for the summer season on day 2 readings with minimum emission factor $PM_{2.5}$ and PM_{10}.

Table 4. Samples collected and analysed at location 2 for summer and winter season

Location 2 Location 2 Euro School, Wakad (Residential Road)					
Day	Season	Sample No.	Silt loading (sL)	Emission factor $PM_{2.5}$	Emission factor PM_{10}
Day - 1	Winter	A = Dry	45.89	0.77	1.94
		B = 20 $CaCl_2$ (g/m^2)	1.21	0.07	0.18
		C = 20 $MgCl_2$ (g/m^2)	1.10	0.07	0.17
		D = 30 $CaCl_2$ (g/m^2)	3.15	0.13	0.34
		E = 30 $MgCl_2$ (g/m^2)	4.32	0.16	0.42
Day - 2	Winter	A = Dry	43.53	0.74	1.88
		B = 20 $CaCl_2$(g/m^2)	1.17	0.07	0.18
		C = 20 $MgCl_2$ (g/m^2)	3.00	0.13	0.33
		D = 30 $CaCl_2$ (g/m^2)	1.23	0.07	0.18
		E = 30 $MgCl_2$	1.07	0.07	0.17
Day - 1	Summer	A = Dry	42.04	0.72	1.83
		B = 20 $CaCl_2$ (g/m^2)	7.85	0.24	0.62
		C = 20 $MgCl_2$ (g/m^2)	6.50	0.22	0.55
		D = 30 $CaCl_2$ (g/m^2)	7.51	0.24	0.60
		E = 30 $MgCl_2$ (g/m^2)	6.80	0.22	0.56
Day - 2	Summer	A = Dry	41.40	0.72	1.82
		B = 20 $CaCl_2$ (g/m^2)	1.42	0.08	0.20
		C = 20 $MgCl_2$ (g/m^2)	3.50	0.14	0.36
		D = 30 $CaCl_2$ (g/m^2)	0.20	0.02	0.06
		E = 30 $MgCl_2$ (g/m^2)	1.00	0.06	0.16

The result of the second location residential road site was summarized in Table 4 where minimum silt loading occurred on the second day of the summer season for 30g/m^2 application of $CaCl_2$ as a suppressant. While for the same chemical application emission factor for $PM_{2.5}$ and PM_{10} were observed at their lowest values 0.02 g/VKT and 0.06 g/VKT respectively. For location 3 of the major road site from Table 5 it was observed that minimum silt loading was for 30g/m^2 application of $CaCl_2$ which was applied in the winter season, similarly, the emission factor of $PM_{2.5}$ and PM_{10} observed at the lowest value for this chemical application. A comparison between $CaCl_2$ and $MgCl_2$ in terms of % silt loading reduction is tabulated in Table 6. The maximum silt loading reduction observed for 30g/m^2 application of $CaCl_2$ is 99.57% while the average % silt loading reduction maximum occurred in the case of $CaCl_2$ as suppressants but as compared with $MgCl_2$ it shows performance in % reduction in silt loading is nearly equal to $CaCl_2$ also as per average comparison $CaCl_2$ performance is better than $MgCl_2$.

Table 5. Samples collected and analysed at location 3 for summer and winter season

Location 3 Hinjewadi Kasarsai road, Hinjewadi (major road)					
Day	Season	Sample No.	Silt loading (sL)	Emission factor $PM_{2.5}$	Emission factor PM_{10}
Day - 1	Winter	A = Dry	62.22	1.80	4.56
		B = 20 $CaCl_2$ (g/m^2)	0.59	0.09	0.22
		C = 20 $MgCl_2$ (g/m^2)	0.88	0.11	0.29
		D = 30 $CaCl_2$ (g/m^2)	0.20	0.04	0.11
		E = 30 $MgCl_2$ (g/m^2)	1.83	0.18	0.46
Day - 2	Winter	A = Dry	67.53	1.90	4.81
		B = 20 $CaCl_2$(g/m^2)	0.39	0.07	0.17
		C = 20 $MgCl_2$ (g/m^2)	0.82	0.11	0.27
		D = 30 $CaCl_2$ (g/m^2)	0.19	0.04	0.10
		E = 30 $MgCl_2$	1.01	0.12	0.31
Day - 1	Summer	A = Dry	62.87	1.81	4.59
		B = 20 $CaCl_2$ (g/m^2)	1.05	0.13	0.32
		C = 20 $MgCl_2$ (g/m^2)	10.42	0.56	1.43
		D = 30 $CaCl_2$ (g/m^2)	0.41	0.07	0.17
		E = 30 $MgCl_2$ (g/m^2)	4.88	0.34	0.87
Day - 2	Summer	A = Dry	64.28	1.84	4.66
		B = 20 $CaCl_2$ (g/m^2)	0.95	0.12	0.30
		C = 20 $MgCl_2$ (g/m^2)	8.94	0.51	1.29
		D = 30 $CaCl_2$ (g/m^2)	0.26	0.05	0.13
		E = 30 $MgCl_2$ (g/m^2)	3.56	0.28	0.71

The % reduction in emission factor of PM_{10} and $PM_{2.5}$ is tabulated in table 7. It was recorded that max reduction observed in the emission factor of $PM_{2.5}$ and was 97.78 for the application of 30 g/m^2 $CaCl_2$ at major road site. Size distribution analysis was done using PixelPro under specific calibration, particle size was calculated from the total sizes.

Table 6. Comparison between $CaCl_2$ and $MgCl_2$ in percentagewise effectiveness in reduction of silt loading

Season	Chemical application (g/m^2)	Industrial		Residential		Commercial	
		% reduction in silt loading on application of $CaCl_2$	% reduction in silt loading on application of $MgCl_2$	% reduction in silt loading on application of $CaCl_2$	% reduction in silt loading on application of $MgCl_2$	% reduction in silt loading on application of $CaCl_2$	% reduction in silt loading on application of $MgCl_2$
Winter - Day 1	20	96.24	92.55	97.36	97.61	99.06	98.59
	30	98.03	98.75	93.15	90.60	99.69	97.07
Winter - Day 2	20	97.04	93.96	97.31	93.11	99.42	98.79
	30	99.13	99.08	97.19	97.55	99.73	98.51
Summer - Day 1	20	94.81	83.69	81.34	84.54	98.33	83.43
	30	99.40	98.60	82.15	83.84	99.36	92.24
Summer - Day 2	20	93.16	90.19	96.58	91.55	98.53	86.09
	30	99.58	99.26	99.52	97.60	99.60	94.47
Average		97.18	94.51	93.07	92.05	99.21	93.65

Table 7.Comparison between $CaCl_2$ and $MgCl_2$ in percentagewise effectiveness in reduction of emission factor of $PM_{2.5}$ and PM_{10} at all 3 locations

Season	Day	Sample No.	% Reduction in emission factor					
			Highway		Residential		Major	
			$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
Winter	Day-1	B = 20 g/m^2 $CaCl_2$	88.30	88.24	90.91	90.72	95.00	95.18
		C = 20 g/m2 $MgCl_2$	81.91	81.51	90.91	91.24	93.89	93.64
		D = 30 g/m^2 $CaCl_2$	92.55	92.02	83.12	82.47	97.78	97.59
		E = 30 g/m^2 $MgCl_2$	94.68	94.12	79.22	78.35	90.00	89.91
Winter	Day-2	B = 20 g/m^2 $CaCl_2$	89.62	90.00	90.54	90.43	96.32	96.47
		C = 20 g/m^2 $MgCl_2$	83.96	84.07	82.43	82.45	94.21	94.39
		D = 30 g/m^2 $CaCl_2$	95.28	95.56	90.54	90.43	97.89	97.92
		E = 30 g/m2 $MgCl_2$	95.28	95.19	90.54	90.96	93.68	93.56
Summer	Day-1	B = 20 g/m^2 $CaCl_2$	89.62	90.00	66.67	66.12	92.82	93.03
		C = 20 g/m^2 $MgCl_2$	73.58	73.70	69.44	69.95	69.06	68.85
		D = 30 g/m^2 $CaCl_2$	97.17	97.04	66.67	67.21	96.13	96.30
		E = 30 g/m^2 $MgCl_2$	94.34	94.81	69.44	69.40	81.22	81.05
Summer	Day-2	B = 20 g/m^2 $CaCl_2$	82.41	82.48	88.89	89.01	93.48	93.56
		C = 20g/m2 $MgCl_2$	77.78	77.74	80.56	80.22	72.28	72.32
		D = 30g/m2 $CaCl_2$	97.22	97.08	97.22	96.70	97.28	97.21
		E = 30g/m2 $MgCl_2$	96.30	95.99	91.67	91.21	84.78	84.76

for each location and each sample. Table 8 indicates average size observed in most of the cases after the application of the suppressant. 27.88 microns was the maximum size observed after the application of 30 g/m^2 of $CaCl_2$.

Table 8. Average particle size observed under particle size distribution method at each location

Sample	Highway Location 1	Residential Location 2	Major Location 3
A = Dry	22.09	22.77	13.10
B = 20 $CaCl_2$ (g/m^2)	23.74	20.19	22.35
C = 20 $MgCl_2$ (g/m^2)	23.47	16.86	10.61
D = 30 $CaCl_2$ (g/m^2)	27.88	14.04	22.37
E = 30 $MgCl_2$ (g/m^2)	25.05	22.71	15.03

Conclusion

It can be observed that $MgCl_2$ and $CaCl_2$ are efficient in suppressing road dust in a sufficient amount.

It is visible that lesser silt loading can be seen on Day 2 as compared to Day 1. Both $MgCl_2$ and $CaCl_2$ solutions are effective separately.$CaCl_2$ is a better dust suppressant than $MgCl_2$ because it is highly effective in reducing dust re-suspension, more ecologically friendly, typically less expensive, and effective at higher temperatures. $CaCl_2$ is a good dust suppression because it is non-corrosive to metals and concrete surfaces and is highly successful at reducing dust emissions. It is also less expensive than other dust suppressants. It can be stated that as our study was carried out at the end of February and the start of March, there is not much variation seen in the readings obtained in the case of dust loadings and the effectiveness of the suppressants. However, $CaCl_2$ and $MgCl_2$ both function well as dust suppressants, but $CaCl_2$ is typically more hygroscopic and has superior dust-binding characteristics.

As dust suppressants are substances added to surfaces to bind dust particles, creating larger, heavier aggregates. It can be observed that the average particle size observed under particle size distribution analysis is greater than 15 microns in each sample. Therefore, $CaCl_2$ and $MgCl_2$ contain airborne reducing particles thus reducing the emission factor. It's crucial to remember that, although microscope analysis enables visual examination and measurement of individual particles, it might not give a complete picture of the full sample due to the small sample size and the possibility for bias during particle selection. Therefore, to gain a more thorough understanding of the particle size distribution in road dust samples, microscope analysis is frequently employed in conjunction with other particle size measuring techniques, such as sieving or laser diffraction.

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Competing interests

The authors declare they have no conflicts of interest or competing interests

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Ethical considerations

"Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely ob-served by the authors."

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