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# Dust Suppression of Mine Haul Roads by using Chemical Additives

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**Abstract - The fugitive PM10 and PM2.5 emission from vehicular movement not only degrade air quality but also reduce visibility, increase equipment wear, and pose respiratory risks to mine workers. This study investigates the effectiveness of four chemical additives as Sodium Chloride (NaCl), Calcium Chloride ($CaCl_2$), Magnesium Chloride ($MgCl_2$), and Guar Gum (Biopolymer) as dust suppressants for mine haul roads under tropical climate conditions. The hygroscopic salts NaCl, $CaCl_2$, $MgCl_2$, function by absorbing atmospheric moisture and lowering the vapor pressure of surface water, thereby maintaining road moisture content for extended periods. Guar Gum, a natural biopolymer, acts as a binding agent that agglomerates fine particles and forms a cohesive surface crust to resist re-entrainment by haul truck traffic. The study concludes that chemical additives significantly outperform plain water sprinkling in both efficiency and duration. A blended approach using NaCl,$MgCl_2$,$CaCl_2$ during dry months and guar Gum during monsoon is recommended for sustainable dust control, reduce water usage, and improved haul road safety. In the present study, the reduction of PM2.5 and PM10 has been calculated by mixing of chemical in proper ratio and spraying on the surface of sample and the results are presented in the form of tables.**

**Keywords - fugitive; chemical additive; sustinable; reduction;**

## I. INTRODUCTION

To overcome the limitations of conventional water - based dust suppression in arid, high - temperature, open - pit coal mine haul roads, this study developed an innovative molasses - based suppressant with enhanced water retention and consolidation capabilities. The chemical additives create a durable, homogeneous consolidation layer with substantial mechanical strength when applied. The suppression mechanism combine's immediate dust wetting with prolonged suppression via dust particle solidification post water evaporation. Chemical dust suppressants work by two primary mechanisms:**1. Hygroscopic moisture retention:** Salts absorb moisture from the atmosphere and hold it on the road surface. (Addo et al. 2004). **2. Particle binding/crust formation:** Polymers bind fine particles together to resist re-entrainment by traffic. (Fan et al 2018).

Among inorganic salts,like **Sodium Chloride-NaCl, Calcium Chloride-$CaCl_2$**, and **Magnesium Chloride-$MgCl_2$** have been widely used globally for haul road and highway dust control due to their high deliquescence and low cost. $CaCl_2$ and $MgCl_2$ are particularly effective as they can maintain 4-8% surface moisture even at 30-40% relative humidity. (Sanders et al. 1997). With growing emphasis on "Green Mining" and sustainable practices, **biopolymers** have emerged as eco-friendly alternatives. (Edvardsson and Magnusson 2011). **Guar Gum (GG)**, a natural polysaccharide extracted from Cyamopsis tetragonoloba seeds, forms a viscous film and bridges clay and silt particles. (Bagheri Y 2019). It is biodegradable, non-toxic, and does not cause corrosion of vehicles or equipment, unlike chloride salts. (Cowherd et al. 1988).

In summary, effective dust suppression is no longer just an environmental issue but a productivity and safety issue. This thesis aims to bridge the gap between global chemical additive technology and its practical implementation in Indian mine haul roads.

## II. MATERIALS AND METHODOLOGY

### *A. Selection and Analysis of Dust Sample*

In the present study, the various experiments being performed to achieve the objective and scope which is to reduce the dust of mine haul road like PM2.5, PM10. This is basically conducted in four steps.

In first step, Dust sample is collected from haul road of Tasra project Sindri, Dhanbad Jharkhand and Chemical are procured from Sam Air Product and Equipment, Dhanbad, Jharkhand.

In second stage, performed various tests on dust sample such as:

1. Physical properties of dust sample

a) Natural water content of dust sample. b) Specific gravity of dust sample. c)Atterberg Limits - Shrinkage, liquid, plastic of dust sample. d) Particle size distribution of dust sample by Sieve analysis.

2. Chemical composition of dust sample.

In third stage, Biopolymer and inorganic chemicals are separately mixed into the water to sprinkler on the surface of the dust sample tray.

In the last stage, after getting data from experiment, it were calculated manually and compare the data to reduction of dust particle like PM2.5, PM10 in percentage(%).

### *B. Performance of the Geothenical Properties of Dust Sample*

The Natural water content of the dust sample is 1.874% at the time of sample collection. This result shows the absorbtion capacity of atmospheric water. The specific gravity of the dust sample is 2.227 , this result shows the dust is lighter than sand and soil. (IS 2720 Part 3). The shrinkage limit of dust sample is 8.73%, Plastic limit of the dust sample is 25.26% , (IS 2720 Part 5), and Liquid limit of the dust sample is 34.2%. (IS 2720 Part 5). The Plasticity Index of the dust sample is 8.76%, which is below the A-line equation and liquid limit is

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less than 35% it means that dust is low compressible and lies below the A-line. Hence the dust sample is considered to be ML it means it is low compressible Silt.

The particle size analysis is done by sieve shaker machine and calculated by graph drawn. The graph gives the value of $C_c$ is 0.93 and $C_u$ is 7.869, it means the dust sample is poorly Graded. (IS2720 Part 4)

Chemical composition of the dust sample is determine by SEM and XRD which is mention in the table 1.

| Chemical Composition | *Result (%)* |
|---|---|
| $SiO_2$ | 52 |
| $Al_2O_3$ | 19 |
| $Fe_2O_3$ | 8 |
| Coal + Carbon | 10 |
| MgO | 3 |
| CaO | 2 |
| Other | 6 |

## III. RESULTS AND DISCUSSION

In the present study, the characteristics of the chemical (inorganic and Biopolymer) along with a detailed series of experimental investigation conducted to evaluate their influence on dust particle particulate matter (PM) reduction behaviour. The study incorporates both conventional (like water sprinkler) and chemical additives mixing analysis, including NaCl, $CaCl_2$, $MgCl_2$, and Guar Gum.

### *A. Chemical Additives and their Properties*

**Properties Of NaCl as dust suppressant :-** Sodium Chloride(NaCl) acts as an effective dust suppressant by lowering surface tension, reducing electrical repulsion in water - surfactant mixtures, and enhancing moisture retention on surface like coal or unpaved roads, through it is typically used as a cost - effective and primary wetting agents.

As a monovalent salts, NaCl dissolves to release ions that compress the electrical double layer and screen electrostatic repulsion, helping solutions spread over hydrophobic dust particle. Adding NaCl decreases the liquid contact angle and surface tension on dust particle like coal dust, accelerating particle sinking and agglomeration. It provide an economical, highly soluble additive compared to polymers.

**Properties of $CaCl_2$ as dust suppressant** :- Calcium Chloride ($CaCl_2$) is an effective dust suppressant because it is hygroscopic in nature. It actively pulls water from the air, dissolves into a liquid brine film, and binds loose dirt and gravel particles together to keep unpaved roads damp and stable. Pulls moisture directly from the atmosphere, working even at low humidity levels. Absorbs enough water vapor to melts into a active brine solution that coats fine dust particles. Retains moisture much longer than plain water, resisting hot temperature and dry winds.

**Properties of Magnesium Chloride ($MgCl_2$) as a dust suppressant** :- Magnesium Chloride ($MgCl_2$) is a popular, hygroscopic liquid or flake compound used to control dust on paved roads, construction sites, and paths. It works by absorbing moisture from the air to keep the surface damp, binding fine dust particles together, and lasting much longer than plain water.It pulls humidity from the air to keep the ground wet. It glues small dust and gravel pieces together wet. It forms a hard, stable surface layer that stops wind and traffic from kicking up dust. It's lasts for weeks to reduce dust and is less corrosive than other industrial salts.

**Properties of Guar Gum as a dust suppressant** :- Guar Gum serves as an eco - friendly, biodegradable binder and gelling agents in dust suppressants. When mixed with water and sprayed on loose soil, coal, or unpaved roads, it increase liquid viscosity, agglomerates fine particles, and forms a protective surface crust that resists wind and traffic erosion.Increases the thickness of aqueous solutions, which prevents runoff and keeps droplets attached to fine dust particles. Dries into a cohesive, flexible polymer crust that traps loose material and blocks wind erosion. Contains abundant hydroxyl (-OH) functional groups that readily adsorb onto mineral dust and soil particles. Derived from natural plant seeds (galactomannan polysaccharide), making it entirely safe for the environment. Naturally breaks down over time without leaving behind persistent chemical or petroleum residues in the soil. Because it is biodegradable, it requires reapplication over regular intervals on active haul roads or construction sites.

### *B. Obserbation after application of mixed solution*

- **Performance of NaCl with water solution on dust sample** - Sodium Chloride was tested at 1.0%, 2.0% and 3.0% wt concentration. The application rate was kept constant at 1.5 L/m$^2$ . The performance was evaluated based on dust concentration and visual condition rating. The observation of NaCl at 2.0% wt solution in terms of PM2.5 & PM10 (µg/m$^3$) is shown in pie chart in Fig.1.

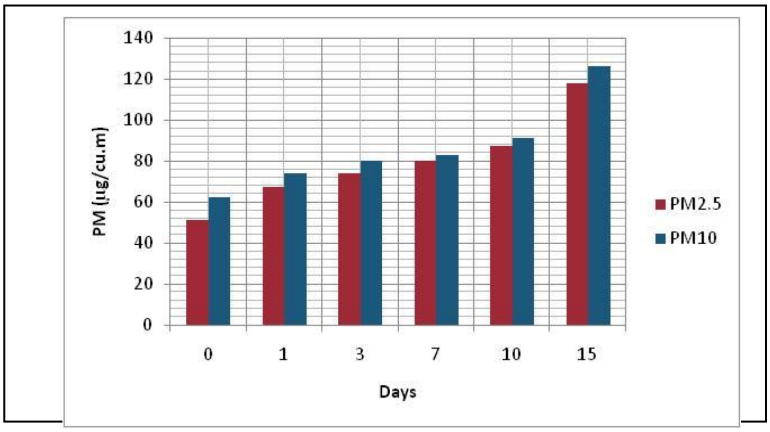


Fig.1. Variation of PM2.5 and PM10 in NaCl.

- **Performance of $CaCl_2$ with water solution on dust sample -** Calcium Chloride was tested at 1.0%, 2.0%, 3.0% wt concentrations at the rate of application 1.5 L/m$^2$ surface area. $CaCl_2$ is highly hygroscopic as compare to NaCl. The observation of $CaCl_2$ at 3.0% wt solution in terms of PM2.5 & PM10 (µg/m$^3$) is shown in pie chart in Fig.2.

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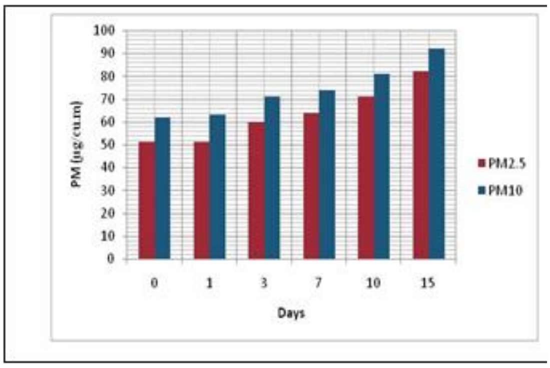


Fig.2. Variation of PM2.5 and PM10 in $CaCl_2$ .

- **Performance of $MgCl_2$ with water solution on dust sample -** Magnesium Chloride was tested at 1.0%, 2.0%, 3.0% wt concentrations at the rate of application 1.5 L/m$^2$ surface area. $MgCl_2$ is highly hygroscopic as compare to NaCl. It is less corrosive than $CaCl_2$ and performs better at low humidity. The observation of $MgCl_2$ at 3.0% wt solution in terms of PM2.5 & PM10 (µg/m$^3$) is shown in pie chart in Fig.3.

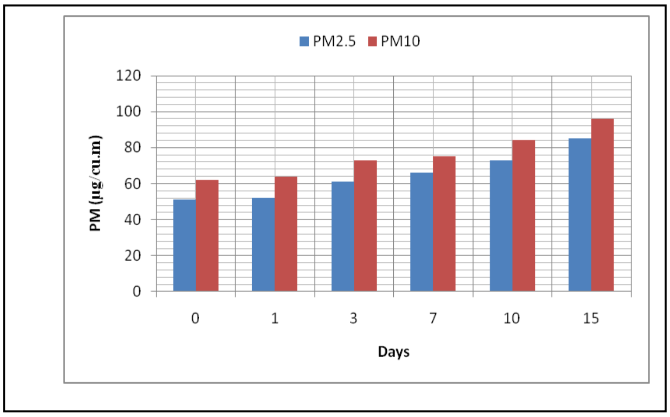


Fig.3. Variation of PM2.5 and PM10 in $MgCl_2$.

- **Performance of Guar Gum with water solution on dust sample -** Guar Gum (Biopolymer) was tested at 0.1%, 0.2%, 0.3% wt concentrations at the rate of application 1.5 L/m$^2$ surface area. Guar Gum (GG) works by biding fines and forming a crust. Pre - hydration for 4 hours was done before application. It is less corrosive than $CaCl_2$ and perform better at low humidity. The observation of Guar Gum at 0.3% wt solution in terms of PM2.5 & PM10 (µg/m$^3$) is shown in pie chart of Fig.4.

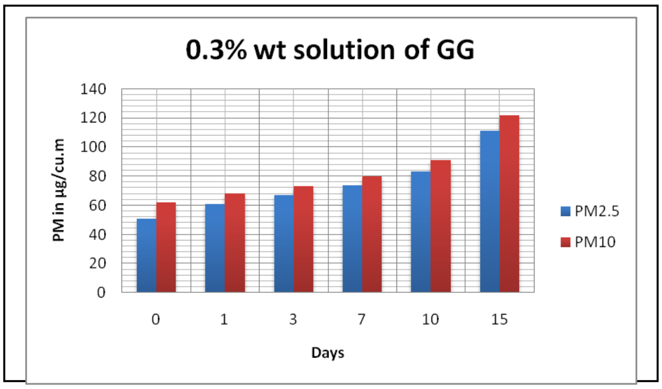


Fig.4. Variation of PM2.5 and PM10 in Guar Gum.

*C. Resuls after performance of mixed solution*

The laboratory investigation report represents the reduction(%) of dust particle at different %wt solution of NaCl in terms of PM2.5 and PM10. The variation of reduction for NaCl is presented in Table 2.

Table 2 :Calculation table for Reduction of NaCl solution @ different wt solution

| **Day** | **1.0% wt solution reduction(%)** | | **2.0% wt solution reduction(%)** | | **3.0% wt solution reduction(%)** | |
|---|---|---|---|---|---|---|
| | ***PM2.5*** | ***PM10*** | ***PM2.5*** | ***PM10*** | ***PM2.5*** | ***PM10*** |
| 0 | 62.33 | 57.53 | 62.33 | 57.53 | 62.33 | 57.53 |
| 1 | 47.40 | 47.27 | 50.37 | 49.32 | 52.57 | 51.37 |
| 3 | 43.70 | 44.52 | 45.18 | 45.21 | 48.15 | 47.94 |
| 7 | 37.78 | 41.02 | 40.74 | 43.16 | 42.23 | 44.53 |
| 10 | 32.60 | 33.57 | 35.56 | 37.68 | 39.26 | 41.78 |
| 15 | 9.63 | 9.59 | 12.60 | 13.70 | 14.82 | 16.44 |

Similarly, the laboratory investigation report represents the reduction(%) of dust particle at different %wt solution of $CaCl_2$ in terms of PM2.5 and PM10. The variation of reduction for $CaCl_2$ is presented in Table 3.

Table 3 : Calculation table for Reduction of $CaCl_2$ solution @ different wt solution.

| **Day** | **1.0% wt solution reduction(%)** | | **2.0% wt solution reduction(%)** | | **3.0% wt solution reduction(%)** | |
|---|---|---|---|---|---|---|
| | ***PM2.5*** | ***PM10*** | ***PM2.5*** | ***PM10*** | ***PM2.5*** | ***PM10*** |
| 0 | 62.33 | 57.53 | 62.33 | 57.53 | 62.33 | 57.53 |
| 1 | 60.74 | 53.43 | 60.74 | 55.48 | 62.33 | 56.85 |
| 3 | 51.86 | 48.64 | 53.34 | 49.32 | 55.56 | 51.37 |
| 7 | 47.41 | 45.90 | 48.89 | 47.95 | 52.60 | 49.32 |
| 10 | 41.49 | 39.05 | 45.19 | 42.47 | 47.41 | 44.53 |
| 15 | 33.34 | 30.83 | 36.30 | 34.25 | 39.26 | 37.00 |

Similarly, the laboratory investigation report represents the reduction(%) of dust particle at different %wt solution of $MgCl_2$ in terms of PM2.5 and PM10. The variation of reduction for $MgCl_2$ is presented in Table 4.

Table 4 : Calculation table for Reduction of $MgCl_2$ solution @ different wt solution.

| **Day** | **1.0% wt solution reduction(%)** | | **2.0% wt solution reduction(%)** | | **3.0% wt solution reduction(%)** | |
|---|---|---|---|---|---|---|
| | ***PM2.5*** | ***PM10*** | ***PM2.5*** | ***PM10*** | ***PM2.5*** | ***PM10*** |
| 0 | 62.33 | 57.53 | 62.33 | 57.53 | 62.33 | 57.53 |

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| Day | 1.0% wt solution reduction(%) | | 2.0% wt solution reduction(%) | | 3.0% wt solution reduction(%) | |
|---|---|---|---|---|---|---|
| | *PM2.5* | *PM10* | *PM2.5* | *PM10* | *PM2.5* | *PM10* |
| 1 | 60.00 | 53.43 | 60.74 | 54.80 | 61.49 | 56.17 |
| 3 | 51.12 | 46.58 | 52.59 | 48.64 | 54.82 | 50.00 |
| 7 | 45.93 | 43.84 | 47.40 | 47.27 | 51.12 | 48.64 |
| 10 | 40.74 | 38.36 | 43.70 | 41.09 | 45.93 | 42.47 |
| 15 | 31.86 | 28.09 | 34.82 | 31.51 | 37.04 | 34.25 |

Similarly, the laboratory investigation report represents the reduction(%) of dust particle at different %wt solution of Guar Gum in terms of PM2.5 and PM10. The variation of reduction for Guar Gum is presented in Table 5.

Table 5 : Calculation table for Reduction of Guar Gum solution @ different wt solution.

| Day | 1.0% wt solution reduction(%) | | 2.0% wt solution reduction(%) | | 3.0% wt solution reduction(%) | |
|---|---|---|---|---|---|---|
| | *PM2.5* | *PM10* | *PM2.5* | *PM10* | *PM2.5* | *PM10* |
| 0 | 62.33 | 57.53 | 62.33 | 57.53 | 62.33 | 57.53 |
| 1 | 51.12 | 50.69 | 52.60 | 51.37 | 58.82 | 53.43 |
| 3 | 45.19 | 45.90 | 47.40 | 47.95 | 50.37 | 49.32 |
| 7 | 40.00 | 41.79 | 41.48 | 43.16 | 45.19 | 45.21 |
| 10 | 34.08 | 32.20 | 35.56 | 35.62 | 38.52 | 37.68 |
| 15 | 12.59 | 10.28 | 14.82 | 13.70 | 17.78 | 16.44 |

## IV. CONCLUSSIONS

By observing various laboratory test results here, we can conclude that the Dust particle in air would reduce by mixing some of the inorganic chemical like NaCl, $CaCl_2$, $MgCl_2$ and Biopolymer like Gum Guar with water in proper %wt solution and spray on the surface of dust particle.

- Water is effective for immediate dust knockdown but not long term. Optimum use of 4 times/day @ 1.5 L/$m^2$ with coarse spray for haul roads.
- The maximum reduction in NaCl is about to 62.33% - 49% in case of pm2.5, and 57.53% - 48% in case of PM10 with 2.0% wt solution of NaCl. However in case of NaCl maximum reduction is absorbed at the solution of 3.0 % wt solution but at this solution spray the upper surface shows more crystal on the surface and wet for longer period also.
- The Maximum reduction in $CaCl_2$ is about to 62.33% - 56% in case of PM2.5, and 57.53% - 52% with 3.0% wt solution of $CaCl_2$. Service life is 10 - 12 Days with spray rate of 1.5 L/$m^2$.
- The Maximum reduction in $MgCl_2$ is about to 62.33% - 55% in case of PM2.5, and 57.53%- 50% in case of PM10 with solution of 3.0% wt solution of $MgCl_2$. Service life is 10-12 Days.
- The Maximum reduction in Guar Gum is about 62.33% - 55% in case of PM2.5, and 57.53% to 50% in case of PM10 with solution of 0.3% wt solution GG. Service life is about to 7-8 Days.

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