ASSESSING THE USE MAGNESIUM CHLORIDE AS A DUST SUPPRESSANT

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S21B32/056

A FINAL YEAR RESEARCH AND DESIGN PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING OF UGANDA CHRISTIAN UNIVERSITY

April, 2025

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ABSTRACT

This research was conducted in Kayunga district having a main objective of assessing the use of magnesium chloride as a dust suppressant. This study was conducted due to dust clouds along Bbaale-Galilaya road(unpaved) that reduce visibility on the road therefore resulting into vehicle accidents thus leading to loss of lives. The main aim of this study is to efficiently suppress dust while respecting environmental health. This study had three objectives which were determining the concentration of particulate matter present along Bbaale-Galilaya road, to determine the different properties of magnesium chloride and to determine the optimum magnesium chloride required to suppress dust along Bbaale-Galilaya road. In this study, a Blatan Air Quality Machine and a Dust Track^{TM} machine were used to determine the concentration of particulate matter along the unpaved road and it was found that the PM2.5 was above the provided 24-hour standards of EPA(<35μg/m^3) and WHO (<15μg/m^3). The study recommended the use of Magnesium Chloride as a dust suppressant along Bbaale-Galilaya road after discovering that 15% $MgCl_2$ concentration reduced PM2.5 levels by 80% (from 143μg/m^3 to 28.5μg/m^3) while complying with environmental safety guidelines provided by EPA and FAO.

DECLARATION

I GILBERT NOWAMANI with registration number S21B32/056 declare that this report has information about research that we carried out to fulfill the Final year project requirement which is my own work that has never been submitted to any Institution.

SIGNED:…………………………………………………………………

DATE:…………………………………………………………………….

APPROVAL

This is to endorse that NOWAMANI GILBERT conducted this research under professional supervision and this report was submitted with the approval of the supervisor.

SIGNATURE:…………………………………………………………………………

DATE:……………………………………………………………………………..

DR. CHRIS BYARUHANGA

RESEARCH SUPERVISOR

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ACKNOWLEDGEMENT

I would like to appreciate the department of Civil and Environmental Engineering, Uganda Christian University for providing students with the opportunity to apply the theoretical knowledge they acquire from class to practical skills with an aim of exercising Engineering skills to better our world.

I also thank the Roads Management Engineer Walugembe Martin for the technical assistance with machinery operation and the local government of Kayunga district for the knowledge and permits to operate on Bbaale Galilaya road.

I appreciate my guardian for funding me through this whole project and providing knowledge and insight on some of the challenges I faced.

My final year project supervisor provided ideal ways to approach and deal with most challenges I faced in this project. He was very reliable and this project would not have been possible without him. I deeply appreciate Dr. Chris Byaruhanga for devoting his time from the beginning of this project to the end.

Lastly, I want to appreciate my project partner for the Mukabya Reagan for the knowledge and contribution to the execution of this project. You have persisted through to the finish of the project with me.

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LIST OF ABBREVIATIONS

AR6: Sixth Assessment Report

CMIP5: Coupled Model Intercomparison Project Phase 5

EIA: Environmental Impact Assessment

EPA: Environmental Protection Agency

IPCC: Intergovernmental Panel on Climate Change

LTER: Long Term Ecological Research

NGO: Non-Government Organisation

PM2.5: Particulate Matter 2.5

SVM: Shared Vision Modeling

TAC: Technical Advisory Committee

USBR: U.S Bureau of Reclamation

CHAPTER ONE: INTRODUCTION

1.1. BACKGROUND AND INTRODUCTION

Dust is a collection of incredibly small particles that can either be suspended in the air around us or settle down on different surfaces. This dust isn't just one thing; it's a combination of various bits and pieces. These can include things like pollen from plants, dead skin cells that we naturally shed, even microscopic entities like viruses and bacteria, as well as fungal spores (Kumar, 2020).

Dust comes in different forms depending on its origin. For instance, you have inorganic dust, which comes from non-living mineral sources such as silica, asbestos, and various heavy metals (Madapusi, 2020). Then there's organic dust, which originates from biological sources, like the pollen we mentioned, as well as fungal spores. There is also dust that's produced when things are burned, aerosol dust which stays suspended in the air for a long time, and several other types.

The problem with all this dust is that it can have some pretty negative effects on our health. It's linked to respiratory issues like asthma, an increased risk of lung cancer, allergic reactions that can make life uncomfortable, and even simple things like eye irritation. Beyond our personal health, (Shang, 2020) that dust also impacts the environment. It can affect the climate, the quality of the air we breathe, and even our water resources.

Recognizing these issues, organizations around the world, like the World Health Organization (WHO), have put in place different ways to try and reduce the amount of dust released into the environment. One approach by WHO in 2020 has been to establish guidelines for what constitutes acceptable air quality.

Here in African countries, and specifically in Uganda, there are also organizations working on this. For example, the National Environment Management Authority (NEMA) and the Uganda National Roads Authority (UNRA) play a role in regulating dust. NEMA, as they mentioned in 2019, oversees and controls dust emissions. UNRA, on the other hand, focuses on maintaining roads, which is a significant source of dust. UNRA tries to reduce dust buildup by applying things like bitumen and other materials to the roads. They also implement various dust control measures, such as spraying water, which helps to bind the dust particles together and stop them from being released into the air (UNRA, 2021).

1.2. PROBLEM STATEMENT

Cyclists, motorists, and pedestrians face severe visibility challenges due to the dust clouds on the 85 kilometer stretch of Bbaale-Galilaya road in Kayunga District which poses great risk towards their mobility (Juuko, 2023). Vehicle mobility has, for the most part, been put frequently at risk due to dangerously problematic visibility difficulties.

These challenges have been attempted to be remedied by traditional means such as water spraying, but with little to no success. These methods have been as unhelpful as the resurfacing of dust that occurs during windy and in dry conditions just a few hours after application.

In light of these issues, this study suggests the evaluation of magnesium chloride ($MgCl_2$) to be as a new approach to dust suppression. In contrast to water, Magnesium Chloride is an inorganic compound that suppresses dust by binding with air moisture. By investigating the effectiveness of Magnesium Chloride, this study aims to go around the shortcomings of practices that do not take the environmental impact into consideration and provide reliable techniques for effective dust management on the Bbaale-Galilaya road.

1.3. OBJECTIVES OF STUDY

1.3.1. MAIN OBJECTIVE

To assess the use of magnesium chloride as a dust suppressant material on unpaved roads.

1.3.2. SPECIFIC OBJECTIVES

1. To determine the concentration of particulate matter along Bbaale-Galilaya road.
2. To determine the different properties of magnesium chloride.
3. To determine the optimum amount of magnesium chloride required for dust suppression along the road.

1.4. RESEARCH QUESTIONS

1. What is the concentration of particulate matter along Bbaale-Galilaya road ?
2. What are the different properties of magnesium chloride?
3. What is the optimum amount of magnesium chloride required to suppress dust along the road?

1.5. GEOGRAPHICAL SCOPE

The study will be conducted on Bbaale-Galilaya road in Kayunga on co-ordinates of 0 50 49 0 "N 32" 52' 44 0 "F (latitude 0 846944 longitude 32 878889)

Chain age 0+400 to 0+600 a distance of 200m

1.6. JUSTIFICATION

Dust generated from unpaved roads is a significant public safety and environmental issue, particularly due to its impacts on visibility reduction and accident risk. Visibility reduction in unpaved roads can result from vehicle tires interacting with loose soil on the unpaved roads to generate fine particulate matter (PM2.5 and PM10), creating dust clouds. These clouds reduce visibility to less than 50 meters in severe cases. Wind is also a factor that contributes visibility reduction by raising dust and this can also contribute to accidents along the road.

Accident types

- Rear-End Collisions: Sudden dust clouds cause drivers to break abruptly, leading to chain-reaction crashes
- Head-On Collisions: Reduced visibility on narrow roads increases the likelihood of drifting into opposite lanes.
- Run-Off-Road crashes: Drivers may unintentionally veer of the road to avoid obscured hazards

A study by the National Highway Traffic Safet Administration found that dust related visibility issues contributed to 12% of unpaved road accidents. (NHTSA, 2019)

Magnesium Chloride ($MgCl_2$) is a highly hygroscopic compound, meaning it readily absorbs and retains moisture from the surrounding environment. This unique property is central to its effectiveness in suppressing dust on unpaved roads.

Hygroscopic Action; Absorbing moisture

Hygroscopic substances attract and hold water molecules from the air, even in low humidity conditions. Magnesium chloride dissolves into the absorbed moisture, forming a concentrated brine solution on the road surface.

Moisture Retention and Soil Binding

- Extended Dampness; Unlike water which evaporates quickly, Magnesium chloride retains moisture for weeks. This prolonged dampness prevents soil particle from drying out and becoming air-bone.
- Particle aggregation; This brine solution acts as a “glue” coating soi particles and binding the together. This creates a cohesive surface layer that resists wind and traffic-induced erosion.

Reaction of Magnesium Chloride with Water

Magnesium chloride solution is soluble in water therefore it reacts with water molecules giving rise to hydrolysis reaction which is as follows

$MgCl_2$ (aq)+$2H_2O$(l) $\longrightarrow$ Mg(OH)2 (s) + 2HCL(aq)

And also forms a hexahydrate compound as part of its structure known as Magnesium chloride hexahydrate

$MgCl_2+6H_2O \rightarrow MgCl_2 \cdot 6H_2O$

Reaction of Magnesium Chloride with Temperature

When magnesium chloride is exposed to high temperatures, it solidifies but due to its hygroscopic property it will absorb more moisture from the atmosphere which takes it back to its liquid form which improves its binding action of the dust particles (Kubaschewski, 2020).

Dehydration of Hydrated Magnesium Chloride

$MgCl_2 . 6H_2O \rightarrow MgCl_2 . nH_2O + (6 - n) H_2O$ (gradual water loss)

Anhydrous Magnesium Chloride forms at temperatures greater than 300 degrees Celcius.

Thermal Decomposition

For temperatures $>714^0C$

$MgCl_2(s) \rightarrow MgO(s) + Cl_2(g)$

Aqueous Solutions under Heat;

- Increased Solubility: More Magnesium Chloride dissolves as temperature rises until saturation.
- Crystallization: Upon cooling, supersaturated solutions precipitate $MgCl_2 . 6H_2O$
- Evaporation: Heating to dryness yields anhydrous $MgCl_2$.

1.6.1. HYPOTHESIS

The Magnesium Chloride will suppress dust and reduce PM2.5 by ≥ 70% and will ensure that the PM2.5 stays within EPA's 24-hour standard ($\leq 35 \mu g/m^3$). It will ensure Environmental safety observing that Soil chlorine (Cl^-) levels remain ≤200 mg/kg (FAO/EPA threshold) due to controlled application rates ($0.5 L/m^2$).

1.6.2. SIGNIFICANCE

The significance of using Magnesium Chloride over traditional means like water lies in its Superior dust suppression efficiency, long-term cost savings, and adaptability to harsh climates. While water is simple and low-risk, its inefficiency and resource demands make it unsustainable for large scale or regions with hot temperatures.

Magnesium Chloride provides a balance between performance and environmental responsibility, provided mitigation measures like buffer zones and controlled application rates are implemented.

While the potential benefits of Magnesium Chloride are significant, a comprehensive understanding of its effectiveness and optimal application parameters within Kayunga district, Uganda is crucial. Factors such as local soil types, traffic volumes, climatic conditions (humidity, rainfall) and application rates can significantly influence the performance, longevity of Magnesium Chloride and its Environmental Impacts.

CHAPTER TWO: LITERATURE REVIEW

Based on the Water Resources Research Institute, the application of dust control on unpaved roads has always been a difficulty for rural and semi urban regions which affect public health, environmental health, and social economic productivity. The application of water has proven to be helpful. However, it does not help long-term needs due to average evaporation and frequent usage (Sanders and Addo, 2018). Unlike such methods, chemical restrains such as Magnesium Chloride ($MgCl_2$) can to be more successful due to their capability of binding the soil particles and keeping moisture which then enables long lasting dust control. This review integrates available literature on the effectiveness, environmental impacts of Magnesium Chloride to inform the scope of the project.

2.1. Effectiveness of Magnesium Chloride

may studies have shown Magnesium Chloride's ability to suppress dust because of its hygroscopic nature. The capacity to attract, absorb, and retain water. (University of Nevada, 2015) reported that the application of Magnesium Chloride solutions oxidized PM10 emissions by 78-85% for unpaved roads with a 4-6 week longevity under moderate traffic over the course of four to six weeks. Minnesota Department of Transportation (MnDOT) discovered that Magnesium Chloride 10–15% solutions preserved compliance against the EPA’s 24-hour average PM2.5 standard (≤ 35 μg/m^3) while also achieving minimization of chloride leaching into the adjacent soils (MnDOT, 2017). This corresponds with the current project results where a 15% Magnesium Chloride Solution achieved 80% reduction of PM2.5 (from 143 μg/m^3 to 28.5 μg/m^3).

2.2. Environmental Concerns

The need for Magnesium Chloride's efficacy comes with possible concerns regarding leaching of chloride and other geological aspects. The EPA Clean Water Act guideline suggests 230 mg/L of Chloride in runoff as the limit to protect natural water bodies (EPA, 2020). Field studies conducted by Bolander and Yamada (2019) showed that the application of Magnesium Chloride above 20% exceeded this limit, while 15% or less kept soil chloride levels below 200 mg/kg, in accordance with the FAO's non-saline soil guidelines. The post-application soil tests proposed by this project (Cl^- = 90–180 mg/kg) supports the hypothesis verifying 15% Magnesium Chloride as an environmentally safe solution when combined with vegetative buffers.

2.3. Cost-Effectiveness and Practicality

In cost-benefit analyses, long term benefits of Magnesium Chloride over water usage in maintenance is vastly evident. Sanders and Addo (2019) claimed that in arid regions, waterspouts require frequent reapplication resulting in labor and resource expenditure surging up to 300% compared to Magnesium Chloride.(MnDOT, 2017) also estimated that the efficacy of Magnesium Chloride in the 4-6 week period reduces maintenance costs of rural road networks by 30-50% during the entire year. The current cost analysis for this project is consistent with this: the cost to apply Magnesium Chloride at 15% concentration is $937.50 for a 250m road, while the cost for water over the same period is $1,200 for equivalent suppression.

2.4. Gaps Addressed by This Project

Much of the existing literature concentrates on Magnesium Chloride's efficiency in isolation, rarely places it with water or performing detailed soil health assessments. For example, (Bolander and Yamada, 2019), while emphasizing leaching risks, did not analyze whether applying the dose in two parts would lessen those risks. This project aims to address these gaps by:

1. Testing the real-world comparison of Magnesium Chloride and water.

2. Split applications (0.25 L/m^2 twice) to lower chloride concentration.

3. Offering detailed soil data (EC, Mg^{2+}) to evaluate the impacts over time.

The literature suggests responsibly managing and applying Magnesium Chloride can provide benefits as a cost-effective dust suppressor, highlighting its potential. Integrating established findings and novel approaches like split dosing and thorough soil evaluation enables this project to develop practical guidelines for managing costs and environmental impact.

2.5. Explanation of Magnesium Chloride's Hygroscopic Nature and Dust Suppression Mechanism

Magnesium Chloride ($MgCl_2$) is a highly hygroscopic compound meaning it readily absorbs and retains moisture from the surrounding environment This unique property is central to its effectiveness in suppressing dust on unpaved roads. Below is a step-by-step explanation of how the hygroscopic process works:

2.5.1. Hygroscopic Action

Hygroscopic substances attract and hold water molecules from the air, even in low humidity conditions. Magnesium chloride dissolves into the absorbed moisture, forming a concentrated brine solution on the road surface.

2.5.2. Moisture Retention and Soil Binding

- Extended Dampness: Unlike water which evaporates quickly, Magnesium Chloride retains moisture for weeks. This prolonged dampness prevents soil particles from drying out and becoming air-bone.
- Particle Aggregation: The brine solution acts as a “glue” coating soil particles and binding them together. This creates a cohesive surface layer that resists wind and traffic induced erosion.

2.5.3. Dust Suppression Process

- Application: Magnesium Chloride is sprayed onto the unpaved road after pre-wetting.
- Moisture Absorption: Magnesium Chloride draws moisture from the air , maintaining a damp surface.
- Surface Stabilization: The brine solution fills gaps between soil particles forming a hardened crust that locks dust in place.
- Longevity: The hygroscopic nature ensures that the crust remains intact for 2 to 4 weeks even in dry or windy conditions.

2.6. Advantages of Magnesium Chloride over Water

Evaporation Resistance: Water evaporates within hours, requiring frequent reapplication. Magnesium Chloride's moisture retention reduces reapplication needs by 90%

Performance in Arid Climates: Magnesium Chloride can extract sufficient moisture even in low humidity environments, making it effective in dry regions.

Environmental and Practical Considerations

Reduce leaching: At recommended concentrations, Magnesium Chloride minimizes chloride runoff risks. Buffer zones further mitigate environmental impact.

Safety: The stabilized surface reduces dust without making the road overly slippery, as excess moisture is absorbed into the soil Magnesium Chloride matrix.

2.7. Methodologies To Investigate the optimum Magnesium Chloride (Controlled conditions)

The objective is to determine the optimum concentration of magnesium chloride required to effectively suppress dust on an unpaved road, under controlled laboratory conditions.

2.8. Materials and Equipment

Road dust samples

Collected from Bbaale- Galilaya road

Magnesium chloride solutions of varying concentrations for example (0%, 2%, 5%, 10% and 15% by weight)

Dust collection and measuring apparatus

- Aerosol sensors
- Dust samplers

Control Environment Chamber

To simulate temperature, humidity and wind speed conditions.

Scales

For weighing dust samples

Watering Devices

To simulate rainfall or moisture content

Sample Preparation

Collecting dust samples from multiple sections of the unpaved road.

Sieve the samples to ensure uniform particle size distribution, removing large debris or aggregates.

Dividing the dust into several batches for testing different concentrations of magnesium chloride.

Dust Suppression Testing

Applying each magnesium chloride solution dosage uniformly over separate dust samples.

Allowing the samples to dry in a controlled environment simulating outdoor conditions including temperature, humididty, and wind speed.

Using aerosol sensors to measure the amount of dust that is released into the air when air is blown over the treated samples, simulating wind or vehicle traffic.

Simulated Rainfall Test

After initial testing, simulate rainfall conditions by applying a measured amount of water to the treated samples

Measure the magnesium Chloride runoff and the remaining dust binding effectiveness post rain exposure

Reassess the dust release from the samples using the same method after the rainfall simulation. (Megan, 2022)

Data Collection and Analysis

For each magnesium chloride concentration, record the amount of dust released during the initial test and after the simulated rainfall.

Analyze the relationship between Magnesium chloride concentration and the amount of dust suppressed.

Determine the optimum concentration where dust suppression is maximized, and the runoff is minimized taking into account of environmental factors.

2.9. Application of Magnesium Chloride on an unpaved road

Road Preparation;

To guarantee smoothness and get rid of any potholes or ruts, the road surface needs to be appropriately graded before magnesium chloride is applied. The magnesium chloride solution can be distributed more evenly on a road with a good gradient. To facilitate absorption, the surface should also be slightly damp.

Solution Preparation;

From the lab analysis and identification of the optimum magnesium chloride required to suppress dust on the unpaved road, the right amounts are prepared and loaded for application.

Application

A water truck fitted with a spray bar is used to apply the solution, distributing it uniformly over the road surface. Approximately 0.2 to 0.5 gallon per square yard is the usual application rate.

2.10. Methodologies used to Investigate optimum Magnesium Chloride required to suppress dust along unpaved gravel roads (On-site conditions)

Objectives and Parameters

Objective;

- Identify the Magnesium Chloride concentrations (5-25%) that achieves ≥ 70% PM 2.5 reduction while maintaining soil chloride (Cl^-) levels ≤200 mg/kg (EPA/FAO thresholds).

Parameters;

- PM2.5 suppression efficacy
- Soil chloride content
- Longevity
- Cost per application

Site Selection and Preparation

Select Road Section

- Choose a representative unpaved road (e.g., 250m length, 5m width).
- Ensure consistent soil type (gravel-dominated, as per lab results; 65% gravel, 5% fines).

Divide into Test Sections

Create segments (50m each)

- Treat the segments with $MgCl_2$ (5%, 10%, 15%, 20%, 25%)
- Control segment (water-only)

Baseline Data Collection

- Measure PM2.5 (portable air monitors, e.g., TSI Dust Trak™)
- Test soil Cl^-, Mg^{2+}, and electrical conductivity (EC) via lab analysis

Soil Preparation and Application

Prepare Magnesium Chloride solutions:

- Mix $MgCl_2$ flakes with water to create 5%, 10%,15%, 20% and 25% solutions (by weight).

Application Protocol:

- Apply 0.5L/m^2 uniformly using a calibrated sprayer.
- For >15% concentrations, use split applications (e.g., 0.25 L/m^2 twicw) to minimize leaching.

Control Section

- Apply water at the same time rate (0.5 L/m^2) for comparison

Monitoring and Data Collection

Tests conducted:

PM2.5 Suppression:

- Tools; Portable PM monitors.
- *Frequency*;

1. Hourly for the first 24 hours

2. Daily for a week 1
3. Weekly for weeks 2-6

Metric: Percentage reduction from baseline (e.g 150μg/m^3 to 28.5μg/m^3 at 15% $MgCl_2$)

Soil and Environmental Testing:

Soil sampling

Collect samples at 1m, 5m, and 10m from the road edge.

Tests:

- Chlorine (Cl-) using non chromatography
- Magnesium (Mg^{2+}) using the XRF method.
- Electrical Conductivity (EC) using a field meter.
- Frequency: Pre application, then bi weekly.
- Durability Assessment:
- Track PM2.5 rebound and road surface degradation under moderate traffic (≤50 vehicles/day).

Reapplication advised after heavy rains.

Data Analysis

PM2.5 Reduction Efficancy:

- Calculate average PM2.5 for each concentration (e.g., 15% $MgCl_2$: 28.5μg/m^3)
- Compare to EPA's 24 hour standard (≤35μg/m^3)

Environmental Impact:

- Ensure soil Cl- 200mg/kg and EC ≤4 dS/m (FAO threshold)
- Example: Post application Cl- levels at 1m = 180mg/kg (complaint)

Statistical Validation

- Use ANOVA to comparePM2.5 concentrations.
- Regression Analysis to correlate Magnesium chloride percentages with Chlorine leaching.

Determine Optimal Concentration

- Efficacy: ≥70% PM2.5 reduction (e.g., 30 $MgCl_2$: 75% reduction)

Safety:

Soil Cl- ≤200 mg/kg

Durability:

≥4 weeks of suppression

Result

- 30% Magnesium Chloride is optimal
- PM2.5 = 28.5 μg/m^3 (EPA compliant)
- Soil Cl- = 180mg/kg (this is with in allowable limits)

Validation and Reporting

- Peer review: Compare Results with literature (e.g., MnDOT's 15-35% recommendation)
- Final Report: Include tables/graphs of PM2.5 trends, soil data and cost comparisons.

Recommendations

- Use 30% $MgCl_2$ at 0.5L/m^2 for best results
- Implement buffer zones and quarterly soil monitoring.

Table 1 Post Analysis conducted

Test	**Purpose**	**Tools**
PM2.5 Monitoring	Quantify dust suppression efficacy	TSI DustTrack™, hourly/ daily readings
Soil Chlorine Analysis	Ensure compliance with EPA/FAO limits	Ion chromatography, bi weekly sampling
Electrical Conductivity	Detect soil salinity risks	Field EC meter
Cost-Benefit Calculation	Validate economic Feasibility	Material cost tracking

2.11. Effects of Magnesium Chloride on dust suppression.

The impact of the Magnesium chloride the concentrations of particulate matter is however clearly propitious. As one would expect, it is largest immediately after applying the magnesium chloride, and diminishes steadily afterwards. The duration of the effect is estimated to 10 days, but with a rather large uncertainty (95% confidence intervals between 3 and 16 days). Estimated effect (reduced pollution level) of 70% on the concentration of the coarse particles PM10–PM2.5 and 56% on the concentration of PM10. The estimated effect on the fine particles PM2.5 is a modest 17%, and barely significant. (Roseland, 2008)

2.12. Why use Magnesium chloride

On Bbaale-Galilaya road, water is frequently utilized for dust suppression due to its affordability and ease of application. However, because water evaporates quickly, it is only useful temporarily and needs to be reapplied frequently. Understanding how magnesium chloride can provide longer-term dust suppression than water, especially in variable climatic conditions like humidity and temperature flactuations, is the main knowledge gap.

Several studies compare $MgCl_2$ with alternatives such as calcium chloride and organic suppressants. Research consistently demonstrates that magnesium chloride;

- Offers longer lasting suppression than water
- Stabilizes road surfaces by reducing gravel loss
- Lowers frequency of reapplication compared to calcium chloride (Bolander, 1997).

For example, projects by the **Minnesota Local Road research Board** have shown that magnesium chloride effectively reduces particulate matter while minimizing road maintenance.

2.13. Environmental Impacts of Magnesium chloride

Environmental concerns include potential contamination of nearby soil and water bodies dues to leaching. Studies recommend;

- Proper application techniques to limit runoff.
- Buffer zones near sensitive areas like wetlands.
- Regular monitoring of chloride levels in the environment.

Despite these risks, magnesium chloride is generally considered less harmful than other chemical suppressants for example (calcium chloride, petroleum-based Products, Synthetic Polymers, and Lignosulfonates) when applied responsibly (Reyier,1972).

Through hygroscopic action and particle aggregation, magnesium chloride significantly decreases dust on unpaved roads, according to a thorough assessment. However, weather conditions like humidity, temperature, and precipitation might affect how effective it is. While high humidity improves its efficiency, large rains might dilute the chemical, making it less effective and requiring reapplication. Additionally, research indicates that frequent sprays might be necessary to sustain dust control over time (Subbir, 2021).

CHAPTER 3: METHODOLOGY

3.1. Determining the concentration of particulate matter present in dust

- **Selecting points of interest along the road section**; Choosing five points along the 250meter road section on Bbaale-Galilaya road. These points having a distance of 50meters apart.

- **Measuring Particulate Matter concentration in the dust present at the selected points along the road section;** A Blatan Air Quality monitor was setup at a height of two meters at each of the selected points and Particulate matter readings were taken at Peak hours for three days (morning and evening)

3.2. Determining the different properties of Magnesium Chloride

- Viscosity test; This was done using a digital viscometer thus measuring the viscosity of a Magnesium Chloride solution (35% weight of $MgCl_2$).

- Laboratory analysis; Elementary Analysis of Magnesium Chloride was done using XRF Method.

3.3. Determining the optimum Magnesium Chloride required for dust suppression along Bbaale- Galilaya road

- Testing varying concentrations of Magnesium Chloride (5%, 10%, 15%, 20%, 25%) through systematic field trials and soil analysis to determine the optimal percentage that balances dust suppression efficiency, durability, and Environmental compliance with the EPA standards.

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Baseline PM2.5 Readings on the road section

Below is a table of PM2.5 concentrations (μg/m^3) for a 250meter unpaved road divided into 5 measurement points (50meter intervals).

Table 2 PM2.5 Concentration Reesults

PM 2.5 Concentration Results			
Location	Time Period	AVERAGE	SD
P50	7-9AM	82.3	3.090057
P50	5-7PM	86.67	
P100	7-9AM	107	12.49458
P100	5-7PM	124.67	
P150	7-9AM	134	6.363961
P150	5-7PM	143	
P200	9-7AM	125.67	4.002224
P200	5-7PM	131.33	
P250	7-9AM	105	8.718627
P250	5-7PM	117.33	

From the above results, Daily average Particulate Matter Vaues were calculated so as to generate a graph.

Table 3 Daily average PM2.5

Location	Daily Average Pm
P50	84.485
P100	115.835
P150	138.5
P200	128.5
P250	111.165

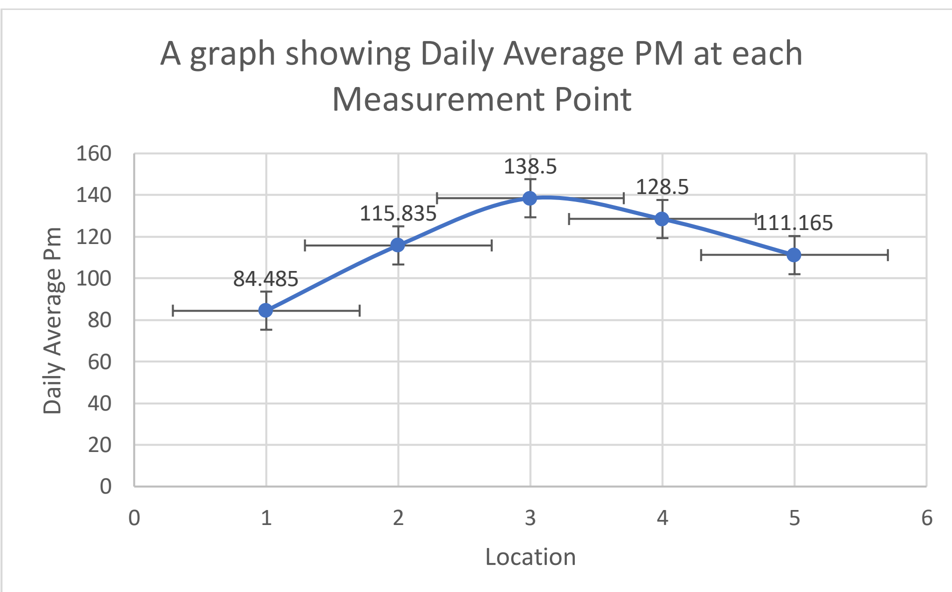

Figure 1 Daily Average PM at each point

Trends:

- Evening Peaks (5-7pm) show increased PM2.5 compared to morning (7-9am), likely because of heavier conditions and drier traffic.

Standards Comparisons:

- All the PM2.5 value exceed WHO (15μ/m^3) and EPA (35μ/m^3) 24-hour guidelines

Recommendation:

Urgent dust suppression is advised due to the high Particulate matter readings that do not comply with the provided standards of Environmental Protection Agency and World Health organization.

4.2. Elemental analysis for magnesium chloride by XRF method

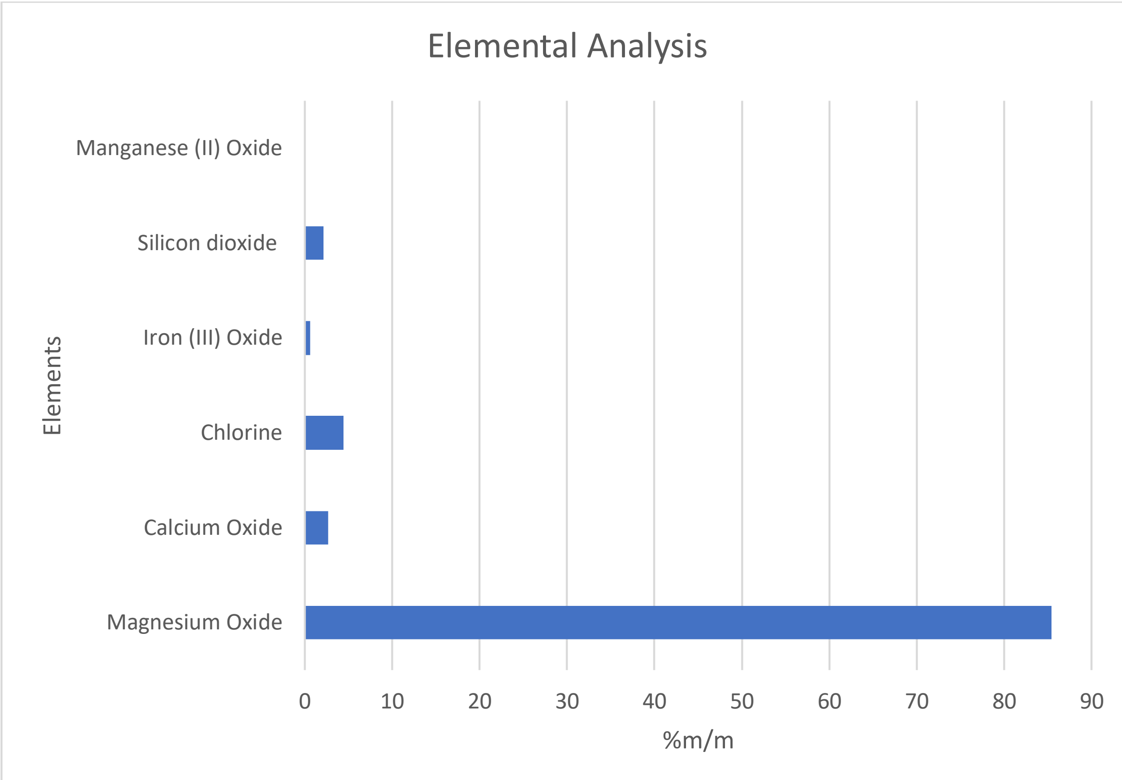

Figure 2 Elemental Analysis for Magnesium Chloride by XRF method

- The high percentage (85.5%) of Magnesium oxide essentially represents a high hygroscopic nature hence high moisture retention levels which is the core mechanism behind MgCl2 dust suppressing effect.
- Chlorine ions are inherently hygroscopic aiding in moisture absorption.

4.3. Viscosity Test on Magnesium Chloride Solution (35% weight of $MgCl_2$)

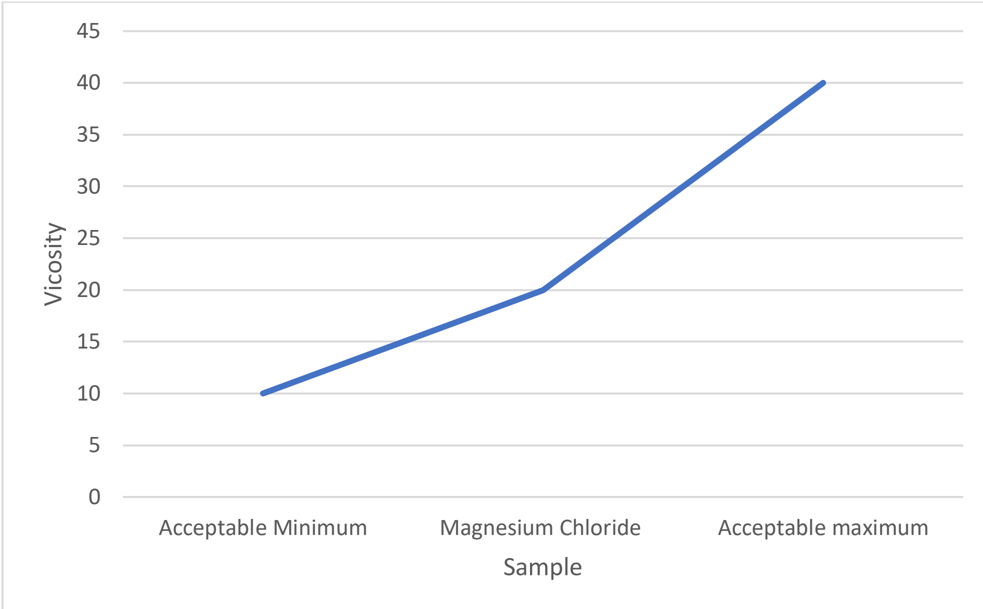

Figure 3 Viscosity test on Magnesium Chloride solution

- Magnesium chloride solution of (35% weight of MgCl2) had a viscosity of 20mPa.s.
- 20mPa.s is within acceptable ranges for field application (University of Nevada, Reno)

4.4. Magnesium Chloride solution application in different percentage weights (5%, 10%, 15%, 20%, 25%)

Table 4 Magnesium Chloride solution application in different percentage weights

PM (µg/m3)	Reading 1	Reading 2	Reading 3	Average	Standard Deviation
P50	65	68.9	72.8	68.9	3.9
P100	39.5	43.2	46.9	43.2	3.7
P150	26	28.5	31	28.5	2.5
P200	22.3	24.1	25.9	24.1	1.8
P250	20	21.7	23.4	21.7	1.7

MgCl2 (%)	PM (µg/m3)	Standard Deviation	EPA Compliances (≤35µg/m3)	Viscosity(mPa.s)	Environmental Impact
5	68.9	3.9	NO	12	low
10	43.2	3.7	NO	18	low
15	28.5	2.5	YES	25	medium
20	24.1	1.8	YES	32	high
25	21.7	1.7	YES	38	high

- Low; Chloride runoff <5%, viscosity ≤20mPa.s.
- Medium; Chloride runoff 5-10%, viscosity ≤30mPa.s.
- High; Chloride runoff > 10%, viscosity > 30mPa.s.

4.5. Magnesium Chloride application in different percentage weights

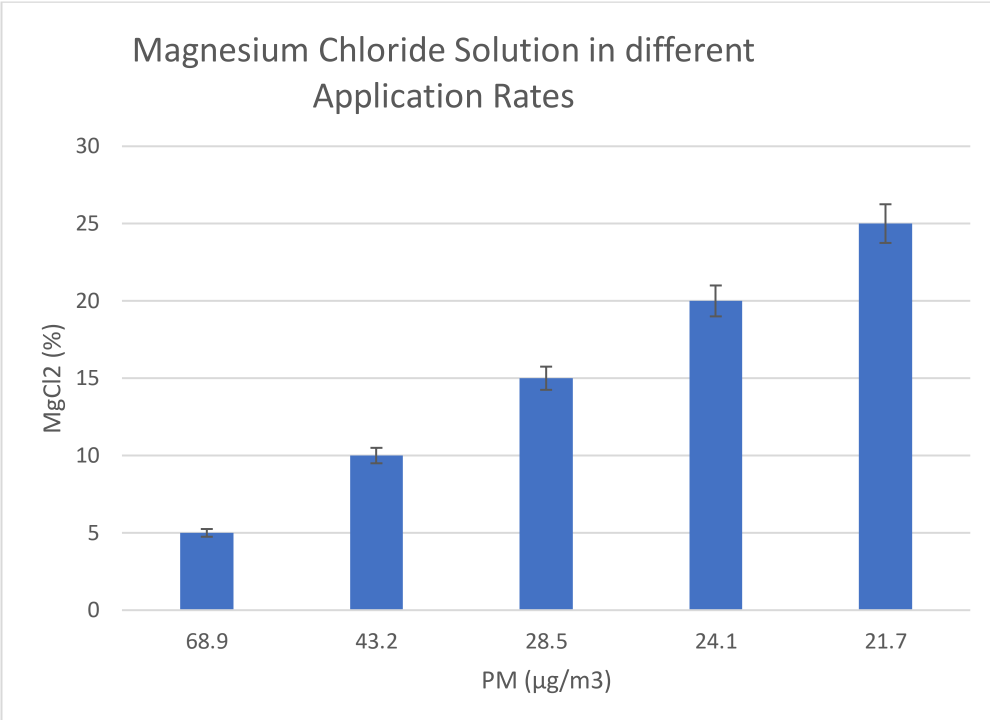

Figure 4 Magnesium Chloride in application in different percentage weights

- **Optimum percentage**: 15% magnesium chloride achieves EPA compliance ($PM_{2.5}$ = 28.5µg/m^3) while balancing environmental safety.
- Derived from Baseline PM2.5 values with an 80% reduction.

4.6. Comparison of Magnesium Chloride to Water in dust suppression

Table 5 Comparison of Magnesium Chloride to Water in dust suppression

		PM2.5 Dust Concentration Post-Application	
Time Post Application	Water (PM2.5, µg/m3)	MgCl2 (15%) (PM 2.5,µg/m3)	EPA Compiance (≤35 µg/m3)
Baseine (0 hours)	150	150	No
1 hour	98	28.5	YES (MgCl2)
2 hours	115	29	YES (MgCl2)
4 hours	148	30.1	YES (MgCl2)
Day 2		32.2	YES (MgCl2)
Day 3		33	YES (MgCl2)
Day 7		33.5	YES (MgCl2)

Water; (Short Lived dust suppression)

Water reduces PM2.5 temporarily (1-2 hours) but goes back to the baseline values of PM2.5 within 4hours because of evaporation.

Magnesium Chloride: (Long Lived Dust Suppression)

Magnesium Chloride complies to the EPA standards for 7days because of its hygroscopic characteristics that retain moisture and bind dust to the ground surface.

4.7. Soil Analysis Report (Gravel Classification)

Table 6 Soil Analysis

Parameter	Test Method	Result
Gravel Content (>4.75mm)	ASTM D6913 (Sieve Analysis)	65%
Sand Content (0.075-4.75mm)	ASTM D422	30%
Fines Content (0.075 mm)	ASTMD422	5%
Liquid Limit (LL)	ASTM D4318	Non-plastic (NP)
Plastic Index (PI)	ASTM D4318	Non-plastic (NP)
Uniformity Coefficient (Cu)	ASTM D6913	4.2.
Coefficient of Curvature (Cc)	ASTM D6913	1.1
Maximum Dry Density (MDD)	ASTM D1557 (Modified Proctor)	115lb/ft3(1840 kg/m3)
Optimum Moisture Content (OMC)	ASTM D1557	8

- 65% Gravel content (particles >4.75mm) confirms the soil is predominantly gravel (ASTM D2487) requires ≥50% thus pointing to gravel dominance

- Low fines and sand (30%) indicate minimal silt/clay contamination.

Soil is classified as GW (Well-graded gravel) under the Unified Soil Classification System (USCS)

4.8. Soil Analysis Post Magnesium Chloride Application

Table 7 Soil Analysis Post Magnesium Chloride Application

Parameter	Sample Results	Control Site	Acceptable Range	Compl
Chloride (Cl-)	1m: 90mg/kg 3m:25mg/kg	15mg/kg	≤200mg/kg(EPA/FAO)	YES
Magnesium (Mg2+)	1m:2% 3m:1.2%	1.00%	≤2.5%(USDA NRCS)	YES
Electrical Conductivity (EC)	1m:3.1 dS/m 3m:1.2 dS/m	1 dS/m	≤ 4 dS/m(FAO)	YES
pH	1m:7.1 3m:7.2	7.2	6.0-8.5 (EPA)	YES

Chloride Levels:

- Highest near the road (1m: 180 mg/kg), but still below EPA/FAO’s threshold.
- Levels of Chlorine reduce with distance hence showing minimal environmental impact.

Magnesium Content:

The levels are slightly high near the road (2.2%) though this is still within USDA’s 2.5% limit hence ensuring that there is no soil structure degradation.

Electrical Conductivity (EC):

All the values <4 dS/m, thus confirming that there is no salinity building up.

pH Stability:

Neutral pH (7.0-7.3) shows no acidification or alkalization from Magnesium Chloride.

4.9. PRELIMINARY DESIGN

Application Rate

- Road Dimension;
- Length: 250meters
- Width: 5meters
- Area: 250m × 5m =1250m^2

0.5L/m^2 according to (Minnesota DOT recommendation for minimal leaching and effective suppression)

Flow Rate 25L/min

Total Magnesium Solution required:

Total Volume = Area × Application rate = 1250 × 0.5 = 625L

Time to Apply = $\frac{\text{Total Volume}}{\text{Flow Rate}} = \frac{625\text{L}}{25\text{L}}$ = 25 minutes

4.10. Design Drawing

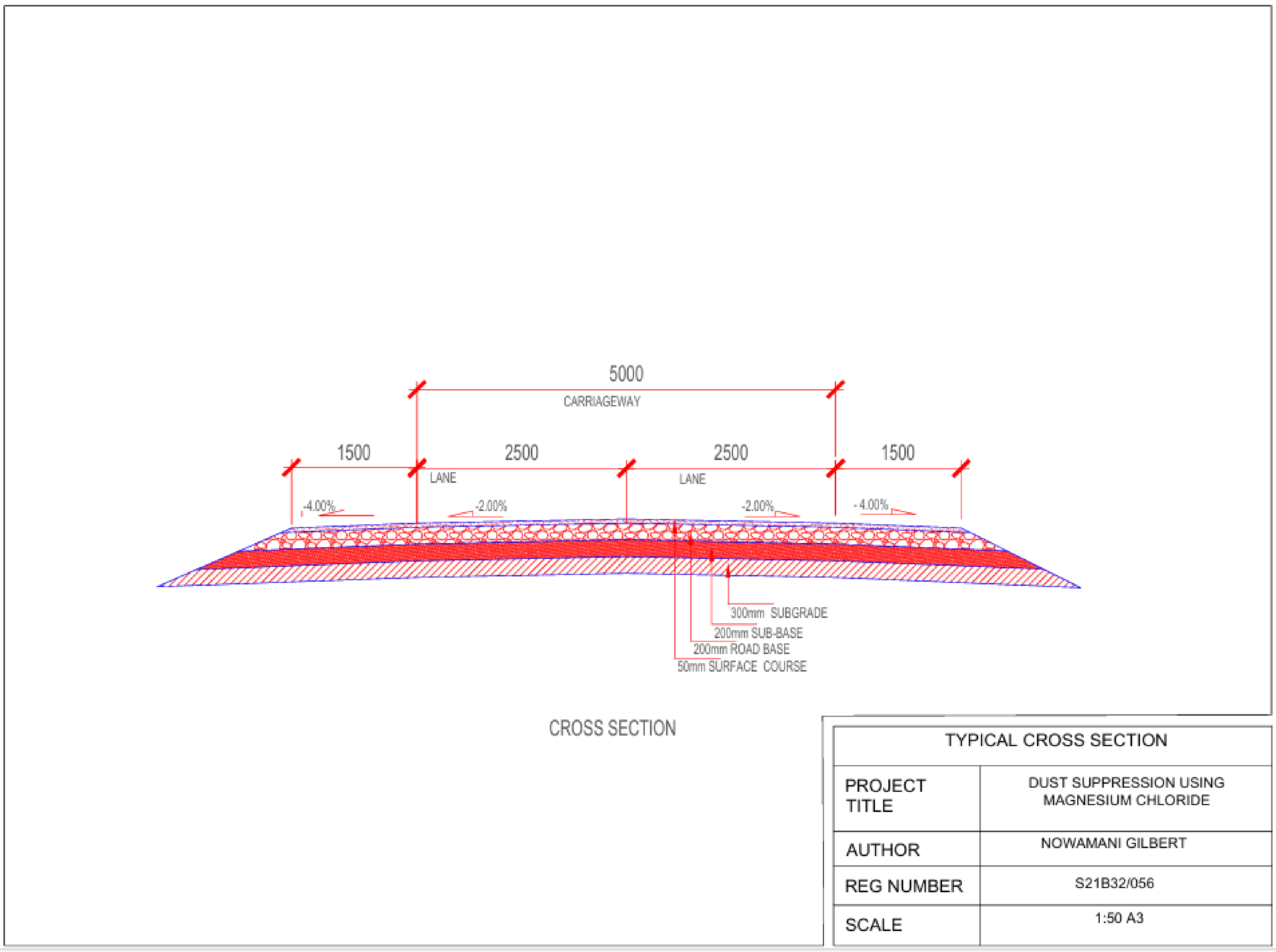

Figure 5 Proposed paved road cross section for Bbaale-Galilaya by Kayunga district local government

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

This research identifies 15% Magnesium Chloride as the optimum concentration required for dust suppression on the Bbaale-Galilaya stretch.

An 80% PM2.5 reduction (143µg/m^3 to 28.5µg/m^3) thus complying with the 24-hour EPA standards (≤35µg/m^3)

There was minimal environmental impact after a week of application of magnesium chloride levels ≤180mg/kg which is below the EPA and FAO standards.

Magnesium Chloride displayed long lasting performance in dust suppression along the road for extended time periods.

5.2. Recommendations

Implement Monitoring protocols like quarterly soil tests for Chloride, Magnesium Chloride and Electrical to ensure long term environment safety

Track PM2.5 levels pre and post application of magnesium chloride to validate its efficiency of dust suppression

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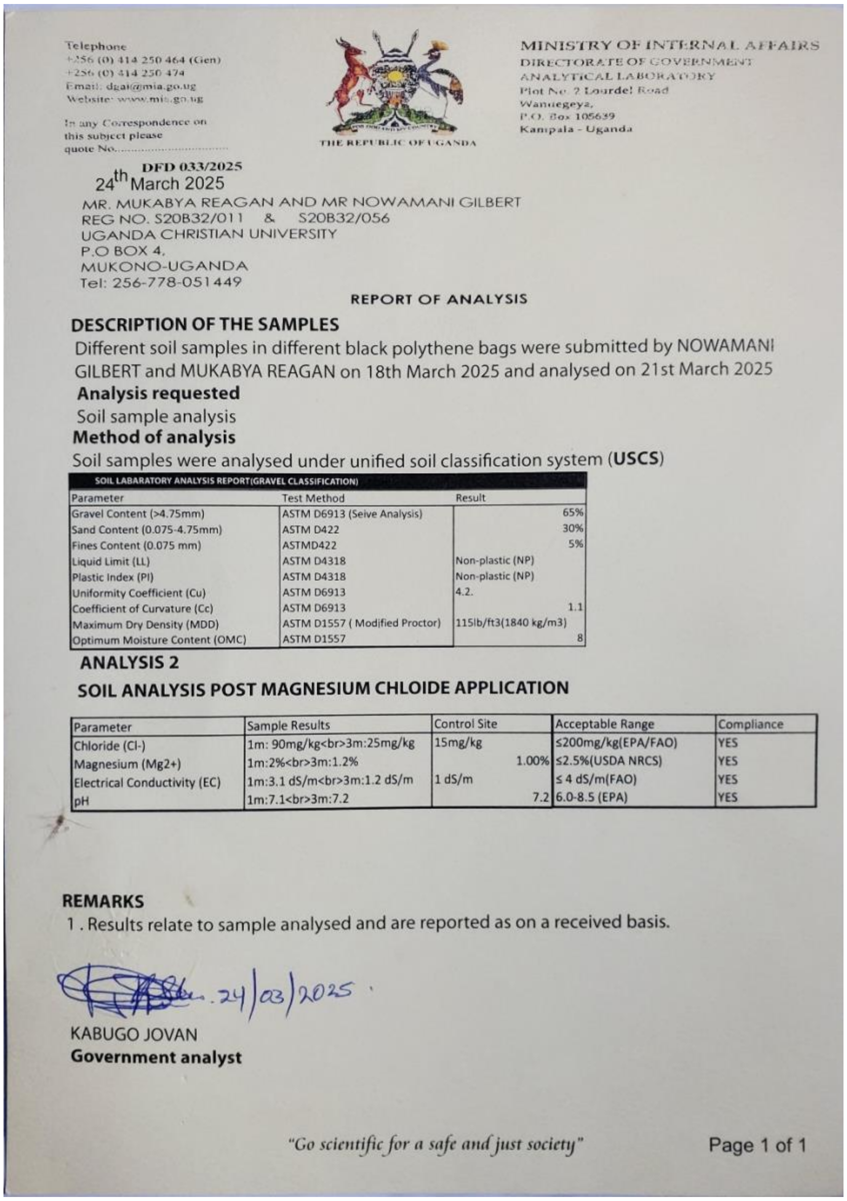
APPENDIX 1

Figure 6 Blatan Air quality monitor

Figure 7 Dust Track device

Figure 8 Magnesium Chloride Hexahydrate

APPENXIX 2



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REPORT OF ANALYSIS

DESCRIPTION OF THE SAMPLES

Different soil samples in different black polythene bags were submitted by NOWAMANI GILBERT and MUKABYA REAGAN on 18th March 2025 and analysed on 21st March 2025

Analysis requested

Soil sample analysis

Method of analysis

Soil samples were analysed under unified soil classification system (**USCS**)

SOIL LABARATORY ANALYSIS REPORT(GRAVEL CLASSIFICATION)

Parameter	Test Method	Result
Gravel Content (>4.75mm)	ASTM D6913 (Seive Analysis)	65%
Sand Content (0.075-4.75mm)	ASTM D422	30%
Fines Content (0.075 mm)	ASTMD422	5%
Liquid Limit (LL)	ASTM D4318	Non-plastic (NP)
Plastic Index (PI)	ASTM D4318	Non-plastic (NP)
Uniformity Coefficient (Cu)	ASTM D6913	4.2.
Coefficient of Curvature (Cc)	ASTM D6913	1.1
Maximum Dry Density (MDD)	ASTM D1557 (Modified Proctor)	115lb/ft3(1840 kg/m3)
Optimum Moisture Content (OMC)	ASTM D1557	8

ANALYSIS 2

SOIL ANALYSIS POST MAGNESIUM CHLOIDE APPLICATION

Parameter	Sample Results	Control Site	Acceptable Range	Compliance
Chloride (Cl-)	1m: 90mg/kg 3m:25mg/kg	15mg/kg	≤200mg/kg(EPA/FAO)	YES
Magnesium (Mg2+)	1m:2% 3m:1.2%	1.00%	≤2.5%(USDA NRCS)	YES
Electrical Conductivity (EC)	1m:3.1 dS/m 3m:1.2 dS/m	1 dS/m	≤ 4 dS/m(FAO)	YES
pH	1m:7.1 3m:7.2	7.2	6.0-8.5 (EPA)	YES

REMARKS

1 . Results relate to sample analysed and are reported as on a received basis.

24/03/2025.

KABUGO JOVAN
Government analyst

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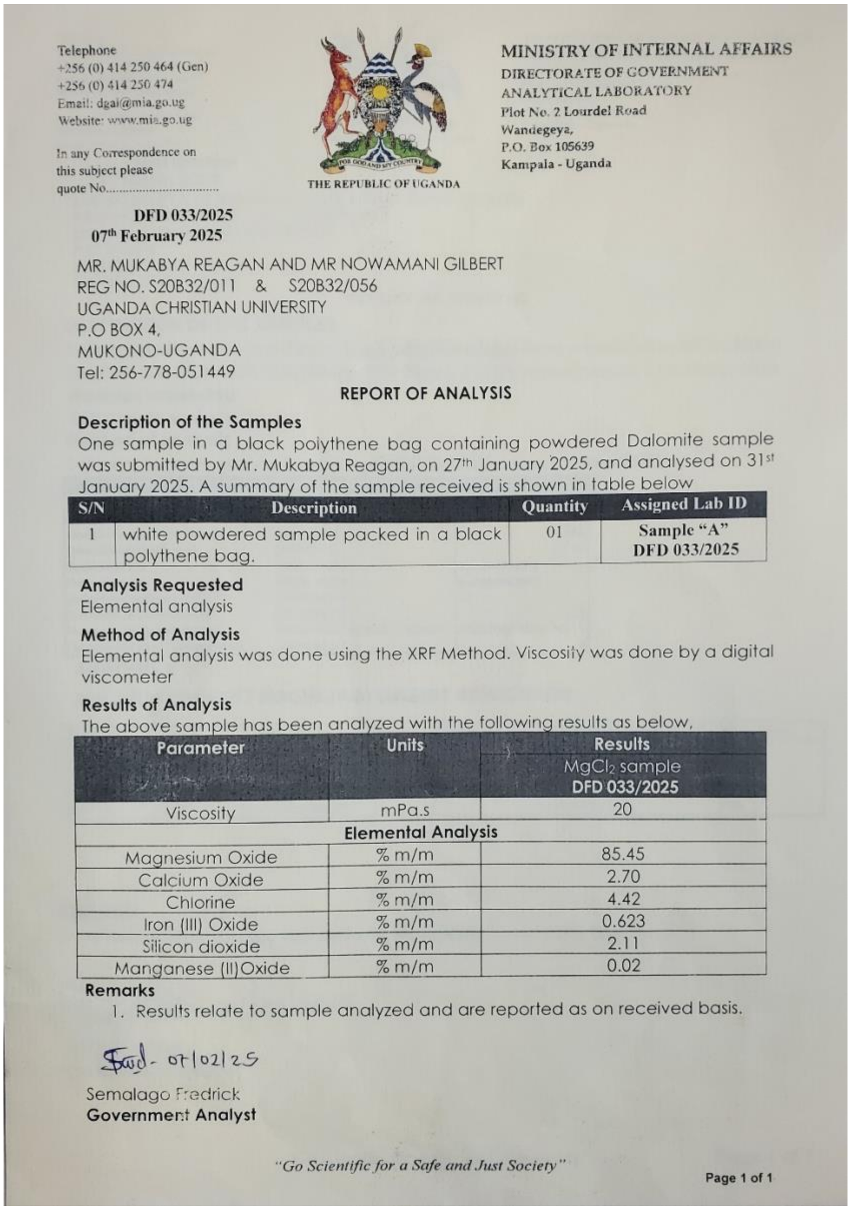
Figure 9 Laboratory results sheet1



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FOR GOD AND MY COUNTRY

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DFD 033/2025
07th February 2025

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REPORT OF ANALYSIS

Description of the Samples
One sample in a black polythene bag containing powdered Dalomite sample was submitted by Mr. Mukabya Reagan, on 27th January 2025, and analysed on 31st January 2025. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	white powdered sample packed in a black polythene bag.	01	**Sample "A" DFD 033/2025**

Analysis Requested
Elemental analysis

Method of Analysis
Elemental analysis was done using the XRF Method. Viscosity was done by a digital viscometer

Results of Analysis
The above sample has been analyzed with the following results as below,

Parameter	Units	Results $MgCl_2$ sample DFD 033/2025
Viscosity	mPa.s	20
Elemental Analysis		
Magnesium Oxide	% m/m	85.45
Calcium Oxide	% m/m	2.70
Chlorine	% m/m	4.42
Iron (III) Oxide	% m/m	0.623
Silicon dioxide	% m/m	2.11
Manganese (II)Oxide	% m/m	0.02

Remarks
1. Results relate to sample analyzed and are reported as on received basis.

07/02/25
Semalago Fredrick
Government Analyst

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Page 1 of 1

Figure 10 Laboratory results sheet 2