ASSESSING THE USE OF MAGNESIUM CHLORIDE AS A DUST SUPPRESSANT

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ABSTRACT

Dust on unpaved roads is one of the major tragedies affecting Uganda and the world at large especially in sub-Saharan climates with high temperature and traffic which results into the disintegration of the soil particles by moving trucks on the road surface. The study aims at assessing the use of magnesium chloride as a dust suppressant on unpaved roads in Uganda with the focus on Bbaale-Galilaya road in Kayunga district due to high dust levels on this road which reduces visibility resulting into accidents. So the material aims at the reducing on particulate matter to correspond with the air quality standards of Environment Protection Agency (EPA) and World Health Organization (WHO).The study identifies key and specific objectives such as Assessing the use of magnesium chloride as a dust suppressant as the main objective and determining the concentration of particulate matter present in dust, assessing the properties of magnesium chloride and the optimum amount required to suppress the dust levels along Bbaale-Galilaya road. On Bbaale-Galilaya road, the particulate matter was above the environmental protection agency (EPA) and the World Health Organization (WHO) standards which included 84.485μ/m^3, 115.835μ/m^3,138.5μ/m^3, 128.5μ/m^3 and 111.165μ/m^3 at various distances of 50m, 100m, 150, 200m and 250m which were 50m apart or away from each other. After magnesium chloride application, the optimum percentage attained or obtained was 15% of the magnesium chloride solution which achieved the environmental protection agency compliance with a particulate matter of 28.5μ/m3 which is below 35 standard for environmental protection agency therefore balancing environmental safety and indicating a 80% reduction in particulate matter present in dust along Bbaale-Galilaya road in Kayunga district.

DECLARATION

I hereby declare to the best of my knowledge that the content in here are mine and have not been shared to any university or any learning institution

MUKABYA REAGAN

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APPROVAL

This final year project has been studied, analyzed and submitted by MUKABYA REAGAN, S21B32/011 with approval to the department of engineering and environment at Uganda Christian university for Examination

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LIST OF ABBREVIATIONS

PM-Particulate matter

WHO-World Health Organization

EPA-Environmental Protection Agency

OC-Optimum Concentration

CaO-Calcium Oxide

FeO-Iron(ii)Oxide

MgO-Magnesium Oxide

SiO_2-Silicon dioxide

$MgCl_2$-Magnesium Chloride

H_2O-Water

Mpa.s-Milli Pascal Per Second

CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Dust is a collection of tiny particles that are suspended in air or settled on surfaces (Kumar et al.,2020). This dust is made up of various substances such as pollen, dead skin cells, viruses, bacteria, fungal spores etc. and the different forms of dust include inorganic dust which is derived from mineral such as silica, asbestos and heavy metals, organic dust which is obtained from biological sources for example pollen fungal spores, combustion derived dust, aerosol dust and many others. (Madapusi et al., 2020). This dust however has various effects on humans such as respiratory problems like asthma, allergies, ski and eye irritation etc. and environmental impacts which affects climate, air quality and water resources (Shang et al., 2020).

Different mitigation measures have been put in place globally by the World Health Organization (WHO), to reduce dust emissions, such as setting guidelines for air quality (WHO, 2020). However, in African countries, for example Uganda, dust has been regulated through organizations such as the National Environment Management Authority (NEMA) and Uganda National Roads Authority (UNRA), which regulate dust emissions and maintain roads (NEMA, 2019). UNRA reduces dust accumulation by applying bitumen and other substances to roads and implementing various dust control measures, such as the application of water, which binds dust particles and prevents their release into the atmosphere (UNRA, 2021).

1.2. PROBLEM STATEMENT.

Dust is a prevalent tragedy on many roads in Uganda today more especially on the unpaved or gravel roads, this dust is composed of different particles sizes therefore it is lost as a fine material referred to as particulate matter i.e. PM10 and PM2.5 (Barnes, 2021).Dust levels are normally high during the dry seasons due to heavy trucks and other vehicles which disintegrate the soil particles down on the ground and they become airborne resulting into high dust levels which later gives rise to air pollution.

Bbaale-Galilaya road which has a stretch of approximately 85kilometres in Kayunga district experiences a challenge of high dust levels which reduces on the visibility of the pedestrians, cyclists and other road users resulting into accidents (Raihan, 2021). The number of accidents on this road is however increasing due to lack of enough vision by mostly the cyclists and pedestrians as they sometimes fail to see the high speeding vehicles and trucks resulting into collisions or head ons and this are mainly due to the high concentration of dust particles along this road (Juuko, 2023).

Different measures have been put in place along this road to mitigate this tragedy such as the application of water to suppress the high dust levels but however this has not been all that effective as the dust rises few hours after its application.

This study therefore aims at the use of a salt based chemical known as MAGNESIUM CHLORIDE due to the different properties it has for effective dust suppression such as hygroscopic and deliquescent properties which enables it to absorb moisture from the air that it use during binding action and stabilization of the soil particles thereby holding them on the ground (Murata et al., 2023).

1.3. OBJECTIVES OF THE STUDY

1.3.1. Main Objective

To assess the use of magnesium chloride as a dust suppressant along Bbaale-Galilaya road

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 needed in dust suppression.

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 needed to suppress dust?

1.5. JUSTIFICATION

Magnesium chloride is an inorganic salt compound composed of one magnesium and two chloride ions i.e. MgCl2. (Zhitao, 2024). When it's applied or added to the soil, it attracts and retains moisture from the air since it's a hygroscopic material and this forms a liquid solution which helps it to bind with the fine particles thereby reducing on the dust particles on the road hence suppressing more dust particles per gallon compared to water (Kakinaga et al., 2023).

Magnesium chloride has a high affinity for water molecules due to their ionic and polar nature therefore it is composed of both positive and negative ions i.e. magnesium and chloride ions respectively which are highly polar which implies that they attract polar water molecules and attraction occurs through "ion-dipole" interactions where Positive and negative ends of water molecules are drawn to opposite charges on the ions (Shukla et al.,2020).

Magnesium chloride mode of application on this road will be through spraying since it will be applied in a liquid form or solutions and sprayed on the road surface using specialized equipment such as trucks mounted with spray nozzles(Bingyi et al.,2022) and the following are the different reactions of magnesium chloride with water and temperature.

1.5.1. Reaction 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

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

1.5.2. Reaction at high temperatures

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). The quantity of magnesium chloride to be applied however varies depending on several factors such as traffic volume, road width, road surface type therefore on Bbaale-Galilaya road since it's a medium traffic road the quantity of magnesium chloride per kilometer applied will range between 2500 to 4000 liters or 660 to 1056 gallons for effective dust suppression and this will help in the binding action of the soil particles down on the ground thereby preventing their rise into air which in the end improves the visibility for road thereby minimizing on the accidents caused due to high dust levels and at the same time mitigating air pollution (Yong et al., 2022).

1.6. GEOGRAPHICAL SCOPE

The study will be conducted on Bbaale-Galilaya road in Kayunga Road on co-ordinates of 0 50 49 0 "N 32" 52' 44 0 "F (latitude 0 846944 longitude 32 878889) at Chainage 0+400 to 0+600 a distance of 200m

1.7. SIGNIFICANCE OF THE STUDY

The major aim of the study to reduce the high dust levels of dust along Bbaale-Galilaya road through assessing the use of magnesium chloride as a dust suppressant so as to reduce on the number of accidents which occur due to limited visibility by the motorists, cyclists and pedestrians who use this road

CHAPTER 2: LITERATURE REVIEW

2.1. DUST

This refers to tiny particles suspended in air or settled on surfaces, and it exists in various forms each with distinct characteristics and potential impacts on human health and the environment. (D'Alessandro et al., 2021).

2.1.1. Forms of dust

2.1.1.1. Inorganic dust

This refers to the type of dust derived from mineral sources such as silica, asbestos, heavy metals etc. (NIOSH, 2020).

2.1.1.2. Organic dust

This refers to dust derived from biological sources such as pollen, fungal spores, bacteria etc. (Samet & Spengler, 2018).

2.1.1.3. Combustion derived dust

This refers to dust which results from burning fossil fuels for example particulate matter which involves particulate matter of PM10 and PM2.5 implying particulate matter ≤ 10μm and particulate matter ≤ 2.5μm respectively. This particulate matter is composed of various substances such as minerals like silica, alumina, iron oxide etc. and metals like lead, cadmium, arsenic etc., organic compounds such as hydrocarbons and biological particles like pollen, fungal spores etc (WHO, 2021).

2.1.1.4. Settled dust

This refers to dust, which is deposited on surfaces for example house dust, industrial dust etc. (Madapusi et al., 2020).

2.1.1.5. Aerosol dust

This refers to suspended particles in air for example fog, smoke, haze etc. (EPA, 2020).

2.1.1.6. Total suspended particulates (TSP)

This refers to all particles suspended in air.

2.2. DUST CLASSIFICATIONS

Dust can also exist in different forms depending on.

2.2.1. Size

- ✓ Coarse particles (PM10) which is 10μm or larger
- ✓ Fine particles (PM2.5) which is 2.5μm or smaller
- ✓ Ultrafine particles (PMO.10) which 0.1μm or smaller

2.2.2. Composition

- ✓ Mineral dust i.e. silica, asbestos
- ✓ Metallic dust i.e. iron, copper
- ✓ Biological dust i.e. pollen, fungal spores

Dust has various sources on which it accumulates along the road which is as follows

2.3. SOURCES OF DUST

1. Natural sources for example soil, sand
2. Human activities such as construction, mining
3. Industrial processes such as grinding, crushing
4. Vehicle emissions

However, when this dust accumulates more on the road it poses health risks on human being for example respiratory problems like asthma, skin irritations, eye irritations etc. therefore to reduce these risks, different mitigation measures have been put in place to suppress dust and some of them include

2.4. WATER

This refers to a clear, colorless and odorless liquid substance that is essential for life on earth and it's a vital component of all living organisms therefore it plays a vital role in many biological, chemical and physical processes and the following are some of its properties which are divided into two i.e. Chemical properties and physical properties

2.4.1. Chemical properties

- Water has a molecular weight of 18,015g/mol
- It has a density of 1g/cm liquid and 0.92g/cm ice
- Water has a boiling point of 100 degrees Celsius and freezing point of 0

2.4.2. Physical properties

- Water is clear i.e. colorless liquid
- Water is odorless i.e. it has no smell

- ➢ Water is tasteless i.e. no taste

Water is a commonly used dust suppressant on many roads in Uganda today and it's because of the following reasons.

- ✓ Water reduces on the dust particle movement through binding the dust particles together which prevents them from becoming airborne (Kumar et al.,2020)
- ✓ Increases the particle size. This is because water absorption increases the dust particle weight which makes them less likely to be suspended in air (Madapusi et al., 2020)
- ✓ Lowers dust cloud formation. This is because water wets dust particles which prevents them from becoming airborne (Puppala et al.,2019)

During this dust suppression, water application rates vary depending on the light, medium and heavy dust control therefore its applied through various methods which include spraying , misting and use of irrigation systems(Yulong, 2020) and after being applied, dust is suppressed through agglomeration where the water causes dust particles to clump together thereby increasing their size and weight which prevents them from being re-suspended into the atmosphere (Sanjay, 2021).

Dust however accumulates again few hours of approximately 1 to 3hours after its application since water is effective for short term dust suppression (Wang et al, 2019)as it suppresses dust to a percentage of 50-70% making it less effective compared to Magnesium chloride which as a long term dust suppression period as it suppresses dust on a long run to a period of approximately 1 to 7 days after its application which 80 to 95% effectiveness and also suppresses more dust per gallon compared to water.

2.5. COMPARATIVE ANALYSIS BETWEEN PARTICULATE MATTER OF PM10 AND PM2.5

2.5.1. Size and Penetration

PM10

PM10 is composed of larger particles up to 10 μm in diameter and penetrates the upper respiratory tract, nose, throat, and bronchi but is often trapped by natural defenses like nasal hair or mucus. PM10 cause irritation of the eyes, nose etc. (WHO, 2021).

PM2.5

PM2.5 consists of smaller particles of 2.5 μm or less in diameter and penetrates deeper into the lungs and can reach the alveoli, the tiny air sacs responsible for gas exchange in the lungs (EPA, 2020). PM2.5 can enter the bloodstream which affects the cardiovascular system and other organs (WHO, 2021).

Therefore, in conclusion basing on size and penetration, PM2.5 is more dangerous because its smaller size allows it to penetrate deeper into the body.

2.6. CHEMICAL COMPOSITION AND TOXICITY

PM10

This consists of coarse particles from natural sources such as soil, dust, and pollen and carries toxic substances that are less concentrated compared to PM2.5.

PM2.5

This Contains finer particles often originating from combustion processes, including vehicle emissions, industrial processes, and burning fossil fuels.

PM2.5 carries more toxic compounds such as polycyclic aromatic hydrocarbons (PAHs), heavy metals, and sulfates which have a higher potential for causing harm (Chen et al., 2020).Therefore PM2.5 poses greater health risks due to its higher toxicity compared to PM2.5

2.7. HEALTH EFFECTS

PM10. PM10 irritates the eyes, nose, throat, and upper respiratory tract and with long exposure, it causes respiratory diseases such as asthma and bronchitis. (NIOSH, 2020)

PM2.5

PM2.5 is associated with more serious health effects which includes increased risk of heart attacks and strokes, worsening of chronic diseases like asthma therefore Long-term exposure has been linked to reduced lung function and cancer. (WHO, 2021; Samet & Spengler, 2018).

In conclusion PM2.5 has more serious and systemic health effects than PM10.

2.8. AIR QUALITY STANDARDS

Air quality guidelines set by international organizations demonstrate the differing dangers of PM2.5 and PM10

Table 1 Air quality guidelines

Parameter	PM2.5	PM10
WHO Guidelines	5 μg/m³ (annual mean); 15 μg/m³ (24-hour mean)	15 μg/m³ (annual mean); 45 μg/m³ (24-hour mean)
EPA Standards	12 μg/m³ (annual mean); 35 μg/m³ (24-hour mean)	50 μg/m³ (annual mean); 150 μg/m³ (24-hour mean)

The stricter limits for PM2.5 reflect its greater impact on health therefore PM2.5 is considered a critical pollutant for public health interventions globally (WHO, 2021).The Air quality standards highlight that PM2.5 as more hazardous due to its lower allowable concentrations.

2.9. MAGNESIUM CHLORIDE AS A DUST SUPPRESSANT

This is an inorganic salt chemical compound which is composed of magnesium ions and chloride ions with 23.3% and atomic mass of 24.305g/mol and 76.7% with atomic mass of 35.453g/mol respectively. It is used as a dust suppressant because of its effectiveness and environmental benefits which makes it desirable during dust suppression.

2.9.1. Properties of magnesium chloride.

Physical Properties

Magnesium chloride is highly hygroscopic, meaning it absorbs moisture from the atmosphere, which is critical for its effectiveness in binding fine dust particles (Chase, 2021). It exists as a crystalline solid, typically colorless, and forms hydrates like magnesium chloride hexahydrate ($MgCl_2 \cdot 6H_2O$) under humid conditions. These hydrates enhance its ability to retain moisture, crucial for stabilizing dust on roads (NIST, 2023). The compound has a melting point of 714°C and is highly soluble in water hence easily applied in liquid solutions (USGS, 2023).

Chemical Properties

When dissolved in water, magnesium chloride dissociates into magnesium (Mg^{2+}) and chloride (Cl^-) ions. It is these ions that, through ion-dipole interactions with dust and water molecules, build a binding matrix that resists the release of dust into the air (Chase, 1998). Under certain conditions, this chemical also reacts with water, leading to hydrolysis and the formation of magnesium hydroxide and hydrochloric acid, further indicating the reactivity and possible impacts on specific environments (NIST, 2023).

Thermal Properties

Magnesium chloride has very good thermal stability, with a hygroscopic capacity unaffected by increasing temperature; it works efficiently in a wide range of climate conditions. The values for heat and enthalpy have been documented in scientific literature to date and supplement its ability in dust suppression and industry applications (NIST, 2023).

2.9.2. Environmental Considerations

Magnesium chloride is considered environmentally friendly because it naturally degrades with minimal ecological effects, over-application can result in soil salinity and contaminate water. Thus, its use has to be done responsibly to maximize benefits with minimum risk. USGS, 2023.

Benefits of magnesium chloride during dust suppression

- ✓ Magnesium chloride is highly effective. This is because it reduces dust emissions by 80 to 95% (Kumar et al.,2020)
- ✓ Long lasting. Magnesium chloride remains effective for several months after its application (Madapus et al., 2020)
- ✓ Environmental friendly. It is a biodegradable and non-toxic chemical therefore has no harm on the environment (EPA, 2020)
- ✓ Soil stabilization. Magnesium chloride helps to bind down the soil particles which reduces on erosion and increases stability

The application of magnesium chloride however also varies depending on the kind of suppression needed i.e.

- ✓ 0.5-1.5 kg/m for light dust suppression
- ✓ 1.5-3kg for moderate dust suppression
- ✓ 3-5kg/m for heavy dust suppression

Magnesium chloride mode of application along roads during dust suppression involves different methods but the most used method is the spraying method

2.9.3 SPRAYING METHOD

This is a method where spray nozzles are mounted onto trucks to allow easy spray of a chemical or a substance and the following is how magnesium chloride is applied using this method

- Selected chain age to be suppressed is graded using graders to clear the surface
- The surface is then pre-wetted with Water to ensure that magnesium chloride penetrates effectively when it is moist
- Magnesium chloride is then mixed with water to create a liquid solution with a concentration of 25% to 35%
- Water Truck is mounted with spray nozzles that are then used to spray the chemical uniformly along the selected section of the road
- The chemical is then absorbed and binded with the soil particles and due to its hygroscopic property, it absorbs moisture from the atmosphere that it uses to bind down the soil particles which prevents them from becoming airborne

Precautions followed during the application of magnesium chloride during dust suppression

- ✓ Wearing of protective gears when handling magnesium chloride
- ✓ Avoiding the application of magnesium chloride during strong winds or heavy rainfall

2.9.4. MODE OF ACTION OF MAGNESIUM CHLORIDE DURING DUST SUPPRESSION

Magnesium chloride mainly achieves it dust suppression effectiveness through the following ways

Hygroscopic property

When magnesium chloride is applied, it absorbs moisture from the atmosphere which it uses to reduce on the mobility of the dust particles (Kumar et al, 2020)

Surface tension reduction. It then reduces on the surface tension of the absorbed moisture or water molecules which enhances its ability to bind dust particles that are more likely to become airborne (Chen et al, 2020)

Particle aggregation

It achieves this through making dust particles heavier due to the attracted moisture which reduces on the rise of dust particles into the atmosphere. (Samet & Spengler, 2018).

What makes magnesium chloride a good dust suppressant method?

Magnesium chloride is hygroscopic in nature therefore this implies that it can absorb water molecules from the atmosphere that improves its binding action.(Chen et al., 2016). It's composed of the magnesium and chloride ions which have strong electro static forces that its uses to pull or attract water molecules from the atmosphere. After water molecules are absorbed these form a brine solution that acts a sticky coating that help to trap dust particles down onto the ground which prevents it from becoming airborne resulting into the deliquescent property therefore magnesium chloride is a good dust suppressant because of its hygroscopic and deliquescent property(Kumar et al.,2020).

2.9.4. COMPARISON OF MAGNESIUM CHLORIDE WITH WATER DURING DUST SUPPRESSION

Long-lasting

Magnesium chloride forms a brine solution when applied to the surface which creates a sticky layer on the ground thereby binding soil particles together therefore this brine effect is long lasting and resists evaporation and wear compared to water which tends to evaporate quickly and loses its effectiveness (Hammond et al.,2013)

Reduced dust resuspension

When magnesium chloride is applied, it reduces dust resuspension because it form a thin sticky film on the surface that binds dust particles together unlike water which temporarily suppresses dust as it does not have the same binding effect as magnesium chloride therefore results into more dust rise into the atmosphere once water Evaporates (Nash et al.,2010).

Hygroscopic nature

Magnesium chloride is highly hygroscopic which enables it to attract and absorb moisture from the air. This ability helps to keep the surface moist or damp which reduces the likelihood of dust particles being lifted by wind while water on the other hand evaporates quickly especially in the hot or dry conditions and lacks the same ability to retain moisture (Pasternald et al.,2006)

2.9.5. IMPACT OF WEATHER CONDITIONS ON MAGNESIUM CHLORIDE AFTER APPLICATION

WIND

Magnesium chloride absorbs and retains moisture due to its hygroscopic nature therefore this makes the surface moist or damp and reduces on the effect of being carried away by wind (Pasternald et al., 2006)

RAIN

Moderate rain dissolves magnesium chloride and spreads it more evenly across the road thereby improving its ability to retain moisture and suppression of dust (Smith et al., 2018)

TEMPERATURE

In warm temperature with moderate or high humidity, magnesium chloride attracts moisture which keeps the road surface damp thus reducing dust and this is due to its hygroscopic property however at very high temperature i.e. temperatures above 40℃, rapid evaporation occurs which reduces on the moisture being absorbed by Magnesium chloride since the humidity in the atmosphere is low

LEACHING OF CHEMICALS

Leaching

This refers to the process by which soluble substances for example chemicals, minerals, nutrients or other contaminants are dissolved and carried away by water moving through the soil or other materials. Leaching occurs when rain water or ground water percolates through the soil dissolving chemicals and carrying them downwards (Brady et al.,2016) leaching can however be addressed through use of acceptable concentrations of magnesium chloride corresponding to the environmental protection agency EPA as this reduces on the leaching effect of the chemical after its application.

TIME SERIES ANALYSIS TEST IN DUST SUPPRESSION.

Time series analysis is a standard statistical methodology applied to research into trends, patterns, and relationships in data gathered over time. When proposed to dust suppression studies on unpaved roads, this encompasses everything regarding the effectiveness of the intervention through the analysis of particulate matter concentrations before, during, and after the implementation of dust suppression measures.

2.9.6. APPLICATION OF TIME-SERIES ANALYSIS TO DUST SUPPRESSION

Monitoring of Particulate Matter Concentrations.

The time series data of the PM10 and PM2.5 concentrations from air quality monitoring devices provide records for a time continuum that is irrefutably required for the determination of dust concentration variability due to some natural causes such as wind speed, humidity, and other human activities; the quantification of the effectiveness of dust mitigation methods such as water application and/or chemical dust suppressants; the understanding of seasonal variability in dust emissions; among others.

Evaluating Intervention Effectiveness

Time series analysis will, therefore, have the authors assess the dust suppression interventions for durability and consistency. The major approaches include:

1. **Pre- and post-intervention comparison.**

- ✓ Detection of a trend or anomaly by fitting models like ARIMA, or Seasonal Decomposition of Time Series (STL).
- ✓ Delineation of time lags between interventions and associated reductions in PM concentrations.

2. **Impact of Environmental Variables**

The times-series methodologies have thus far been quite helpful in teasing out the effect of exogenous factors like wind, temperature, and vehicle traffic itself on dust suppression performance. Incorporating covariates allows the detection of the Synergistic or antagonistic action of environmental factors on dust levels with the optimum application conditions for dust control measures.

Long-term monitoring and evaluation of sustainability

Long-term series help describe the sustainability of the dust mitigation measure; they are needed when decision-makers want to judge cost-effectiveness through time-i.e., eventual needs for reapplication or complementary measures-with a view to attainment of standards.

VISCOSITY

This refers to the measure of a fluids resistance to deformation or flow therefore it describes how thick or thin a fluid is and results from internal friction between molecules i.e. Internal friction within a material that resists motion or how thick a material is. High viscosity implies greater resistance to flow and low viscosity indicates that the fluid flows easily without much resistance (white, 2016). The instrument used to measure viscosity or carry out viscosity tests is a digital viscometer as a certain concentration of a solution or a fluid is poured into the digital viscometer which gives a reading in Milli-pascal per second (Munson et al.,2018).

Viscosity involves the fluid's resistance to flow therefore it further describes how thick or sticky a fluid is. Viscosity can be high or low hence a highly viscous fluid flows slowly for example honey and a low viscos fluid flows with ease for example water and this depends on the internal fiction between molecules in the fluid as they move past each other (Munson et al., 2013).Viscosity is influenced by factors such as temperature where heated fluids become less viscous and more viscous when cooled (cengal et al., 2014)

X-FLUORESCENCE METHOD

This is a non-destructive analytical technique used to determine the elemental composition of materials for example magnesium chloride therefore this indicates the various compounds present in the magnesium chloride solution for example magnesium oxide, chlorine ions, manganese (ii) oxide which are vital during dust suppression as they increase the effectiveness of magnesium chloride during dust suppression through improving on the binding action of magnesium chloride solution after being applied(Beckhoff et al.,2006).

COMPOUNDS PRESENT IN MAGNESIUM CHLORIDE SOLUTION

Magnesium oxide

This comprises of relatively a bigger percentage compared to the rest of the compounds in magnesium chloride as this constitutes of 85.54% which indicates that 85.54% of the total analyzed mass of magnesium chloride solution was composed of magnesium oxide. When magnesium chloride is applied along a road section, it absorbs water molecules from the atmosphere due to tis hygroscopic property and these water molecules react with the magnesium oxide present 4in magnesium chloride solution forming magnesium hydroxide which boosts on the binding effect of magnesium chloride solution.

Equation

$$MgO + H_2O \rightarrow Mg(OH)_2$$

This reaction is a neutralization process where the basic oxide i.e. magnesium oxide dissolves in water to form a slightly soluble hydroxide, magnesium hydroxide is a weakly soluble in water and often appears as ca white precipitate.

Chlorine ions

These are negatively charged atoms of chlorine that have gained an extra electron and are commonly found in nature particularly in salts like magnesium chloride (Atkins, 2018). These are smaller ions which have a low charge density and in magnesium chloride solution, these constitute to a percentage of 4.42% which is also vital as they also help in attracting water molecules from the atmosphere which boosts on the binding action of magnesium chloride solution thereby improving on the effectiveness of magnesium chloride.

However, there are other compounds such as manganese (ii) oxide, silicon dioxide, calcium oxide etc. constitute the rest of the percentages of magnesium chloride solution and these help in improving soil stability i.e. soil stabilization and also improves on the forces which enable attraction of water molecules from the atmosphere which represents the hygroscopic nature of magnesium chloride solution.

CHAPTER THREE: METHODOLOGY.

3.1. Concentration of particulate matter present in dust on Bbaale-Galilaya road.

Selected different points along the chain age of 0+250m which were 50m away from each other i.e. 50m, 100m, 150m, 200m and 250m.

Placed the Blatn air quality monitor at a height of 2m from the ground which gave us various readings of particulate matter at this selected point. This was carried out during the peak hours of the day i.e. morning and evening and at each point we measured particulate matter thrice and later got the average for accuracy and repeated the same procedure for the second time in the evening for three days at each point.

The procedure was repeated for the remaining points and the daily average particulate matter was noted and recorded for each point along our chain age of Bbaale-Galilaya road

3.2. Properties of magnesium chloride

X-Fluorescence test. This was carried out using the X-fluorescence method to determine the elemental composition in magnesium chloride and various compound were present in magnesium chloride such as magnesium oxide, chlorine ions, iron(ii) oxide, silicon dioxide, calcium oxide and manganese(ii) oxide with magnesium oxide and chlorine ions having the highest percentages of 85.45% and 4.42% respectively

Viscosity test. This was carried out using a digital viscometer to measure how thick or the internal resistance of magnesium chloride solution to motion after being applied along the road section.

We used 35% weight of magnesium chloride solution so as to minimize on errors due to air bubbles, to obtain a well-defined ratio of magnesium chloride to water etc. and the viscometer reading was 20millipascal per second (20mpa s)

3.3. Optimum amount of magnesium chloride needed to suppress dust

Trial runs.

- ✓ Different magnesium chloride solutions of different weights i.e. 5%, 15%, 20% and 25% were applied at along the chain age of 0+250 at a distance of 0+50m since the soil was gravel along the Bbaaale-Galilaya road.
- ✓ A Blatn air quality monitor was later used to measure the new particulate matter while raised at a distance of 2m from the road surface and this was to ensure compliance with the environmental protection agency and also to avoid mixture of dust with other unnecessary materials on the ground.
- ✓ With comparison with the particulate matter achieved in objective one, the new particulate matter significantly reduced with the concentration of magnesium chloride solutions of 5%, 25%, 20% and 25% to 68.9μg/m^3, 43.2μg/m^3, 28.5μg/m^3 24.1μg/m^3 and 21.7μg/m^3 respectively.
- ✓ According to the Environmental protection standards of particulate matter, the magnesium chloride concentration of 15% achieved the EPA compliance with a particulate matter of 28.5μg/m^3 which is below 35μg/m^3 .This therefore indicated a 80% reduction dust along Bbaale-Galilaya road achieving our optimum amount of magnesium chloride needed for dust suppression along this road.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0. RESULTS AND DISCUSSION

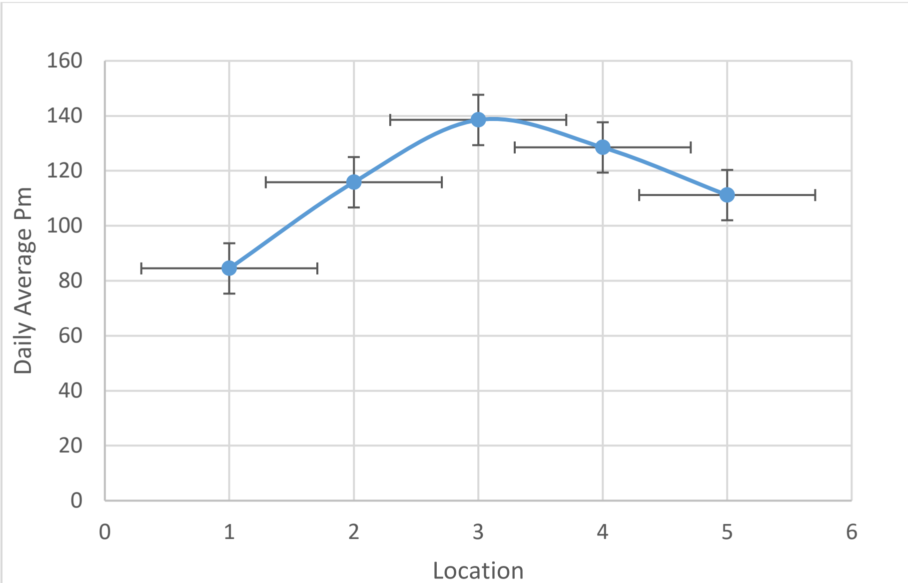

Figure 1a graph of daily average particulate matter against distance

Table 2 Daily Average particulate matter

Location	Daily Average Pm (μg/m^3)
P50	84.485
P100	115.835
P150	138.5
P200	128.5
P250	111.165

All values exceed WHO (15µg/m^3) and EPA (35µg/m^3) 24-hour guidelines.

Explanation of the graph

Particulate matter gradually increased from 80µg/m^3 to 140µg/m^3 and this was due to higher levels of tiny solid particle which were suspended in air along the selected section of the road from sources such as vehicle emissions, dust etc. and slightly decreased from 140µg/m^3 to 111.165µg/m^3 due to reduced levels or fewer tiny solid particles in air.

Particulate matter monitored along the selected chain age of 0+250m were all above the standards of Environmental Protection Agency(EPA) and World Health Organization (WHO) of particulate matter not exceeding 35µ/m^3 and 15µ/m^3 therefore this indicated high dust levels along this road due to high concentration of particulate matter.

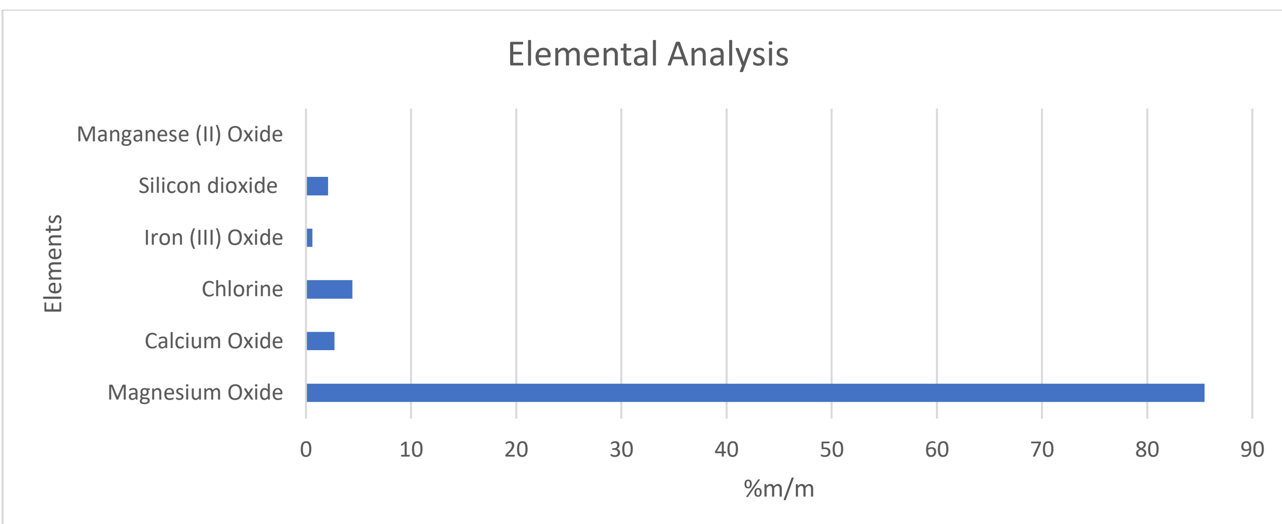

Figure 2 A graph of elements present in magnesium chloride with their composition

X fluorescence test indicated different compositions of elements in magnesium chloride for example magnesium oxide, calcium oxide, chlorine, iron (ii) oxide, silicon dioxide and manganese (ii) oxide with a composition of 85.45%, 2.70%, 4.42%, 0.623%, 2.11% and 0.02% respectively.

High percentage of magnesium oxide of 85.45% indicated that out of the total analyzed sample of magnesium chloride in the laboratory, 85.45% was comprised of magnesium oxide and this when reacted with the water molecules absorbed by magnesium chloride due to its hygroscopic nature, it form magnesium hydroxide which help during the binding action of magnesium chloride since it improves on the water retention capacity of the chemical during dust suppression ie

MgO(s) + H2O(l)   Mg(OH)2(aq)

The high percentage (85.5%) of Magnesium oxide also represents a high hygroscopic nature hence high moisture retention levels which is the core mechanism behind $MgCl_2$ dust suppressing effect.

Chlorine ions were also present in small quantities of 4.42% elemental composition as indicated on the graph and these had a low charge density however also play a vital role during dust suppression as they are inherently hygroscopic which aids in moisture absorption during dust suppression whereas on the other hand elements such as calcium oxide, iron(ii)oxide, silicon dioxide and manganese(ii)oxide also help in soil stabilization during dust suppression which keeps the dust down on the ground thereby preventing it from becoming airborne

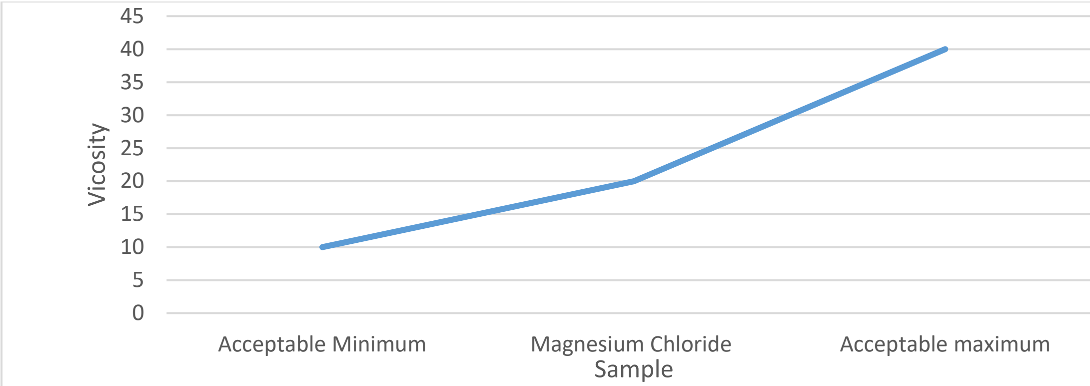

Figure 3 A graph of the viscosity range of magnesium chloride solution

Magnesium chloride solution of (35% weight of $MgCl_2$) had a viscosity of 20mPa.s.

20MPa.s is within acceptable ranges for field application (Wang et al., 2021).the viscosity value of 20mpas obtained from the digital viscometer lies between the required standards for field application therefore this indicates that magnesium chloride spreads with ease after being applied during dust suppression which implies that at every particular section of the road, dust suppression would be effective due to the ability to spread or flow easily along the road section

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

Table 3 Magnesium chloride percentage weights with their environmental impacts

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 indicates that Chloride runoff was less than 5% with viscosity ≤20 mPa.s, Medium indicates that Chloride runoff 5-10%, viscosity ≤30 mPa.s and High implies that Chloride runoff was greater than 10% with viscosity > 30 mPa.s.

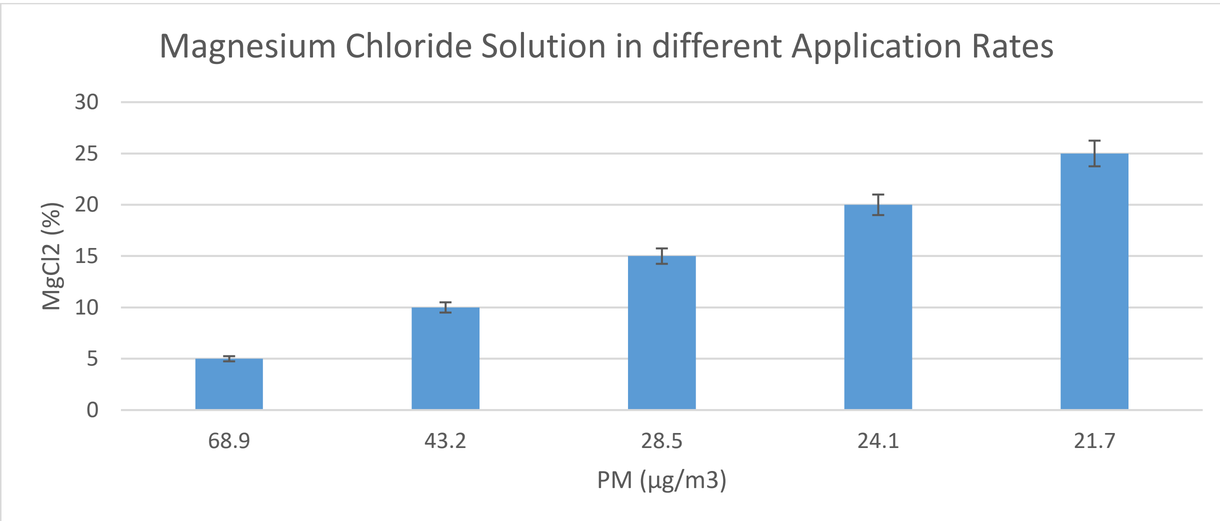

Figure 4 magnesium chloride concentrations with the new particulate matter after application

The optimum percentage of 15% magnesium chloride solution achieves the environmental protection agency compliance with particulate matter of 28.5µg/m^3 which is below 35µg/m^3 standard for EPA while balancing environmental safety and was Derived from Baseline PM2.5 values with an 80% reduction

Table 4 Post particulate matter dust concentration

		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 reduced dust temporarily for about 1 to 2 hours and dust raised again in air resulted into a short lived suppression period due to its evaporation within 4 hours and Magnesium Chloride solution Maintained compliance for 7 days due to its Hygroscopic and deliquescent properties that enable it to retain moisture from the atmosphere and bind down the dust particles on the ground.

4.1. Design

Road Dimensions

Length; 250meters

Width; 5meters

Area; 250m*5m= 1250m2

Application rate; 0.5L/m^2 (Minnesota DOT recommendation for minimal leaching and effective suppression)

Flow rate; 25l/min

Total magnesium chloride solution required

Total volume= area* application rate = 1250*0.5 = 625L

Time= $\frac{total\ volume}{flow\ rate}$= $\frac{625}{25}$= 25minutes

A proposed paved cross section for Bbaale Galiliya road is shown in Appendix A

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

CONCLUSION

This research obtained 15% Magnesium Chloride as the optimum concentration for dust suppression on unpaved roads i.e. Bbaale-Galilaya road which achieved.

- ✓ 80% pM2.5 reduction from 143µg/m^3 to 28.5µg/m^3 complying with EPA's 24-hour standard (≤35µg/m3).
- ✓ Minimal Environmental impact with Chloride levels ≤180mg/kg (below EPA/FAO Thresholds) and viscosity (25mPa.s) within acceptable limits.
- ✓ Long-lasting performance suppressing dust levels for extended time periods.

RECOMENDATION

- ✓ Implement Monitoring Protocols to monitor the particulate matter along Bbaale-Galilaya road in Kayunga district to enable the particulate matter comply with the EPA standards.
- ✓ Quarterly soil tests for Cl-, Mg2+, and Electrical conductivity to ensure long-term environmental Safety
- ✓ Track PM2.5 levels pre and post-application to validate efficacy.

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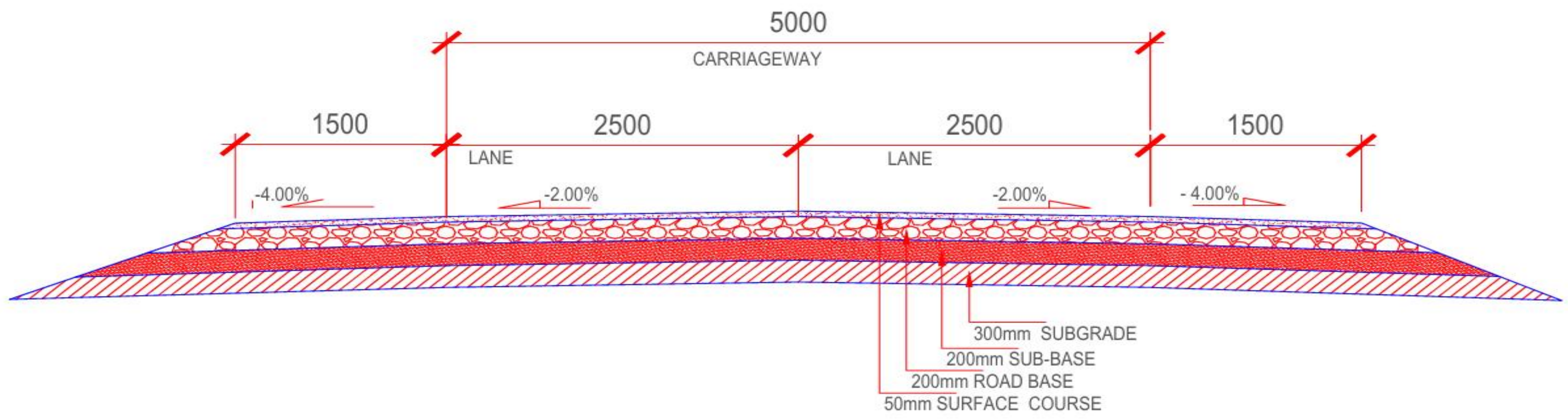
Appendix A: A proposed paved cross section for Bbaale Galiliya road



CROSS SECTION

TYPICAL CROSS SECTION	
PROJECT TITLE	DUST SUPPRESSION USING MAGNESIUM CHLORIDE
AUTHOR	MUKABYA REAGAN
REG NUMBER	S21B32/011
SCALE	1:50 A3

Figure 5. Air Quality Monitor Machine

Figure 6. Blatn air quality monitor machine.

Figure 7.Hexahydrate magnesium chloride

Figure 8. Dust accumulation from a lorry carrying sugarcane on the Kayunga-Bbaale – Galilaaya.

Appendix C

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DFD 033/2025
07th February 2025

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UGANDA CHRISTIAN UNIVERSITY
P.O BOX 4,
MUKONO-UGANDA
Tel: 256-778-051449

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.

Fwd- 07/02/25

Semalago Fredrick
Government Analyst

"Go Scientific for a Safe and Just Society"

Page 1 of 1

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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