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POLYETHYLENE GLYCOL 8000 (PEG 8000): POTENTIAL DUST SUPPRESSANT TO SANDY LOAM PRESENT IN CONSTRUCTION AND MININGSITES

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ABSTRACT

Constant exposure to dusts generated from construction and mining sites as well as from farming activities poses danger to one's health. A possible treatment to sandy loam to address this concern is the Polyethylene Glycol (PEG) 8000 which has been utilized as an adhesive for industrial purposes. This study therefore attempts to uncover PEG's potential as a dust suppressant to sandy loam soil to minimize dusts' negative effects. The soil's cohesion disclosed from the direct shear test served as a basis in selecting the best combination whereby 5%, 12.5% and 20% concentrations of PEG 8000 solution were added to soil at 15% by weight of sandy loam. The water as binding material to sandy loam served as the control to check the effectiveness of treatment. The dust control test applied the cohesion revealed in the direct shear test, which was at 12.5% without compromising the shear strength. The loss in dry mass of sandy loam after exposure to air action was compared to control. The results showed 2.90% and 0.15% loss in dry mass for control and PEG 8000 respectively, indicate that the treatment utilized is effective.

Key words: Polyethylene glycol, sandy loam, cohesion, dust suppressant

1. INTRODUCTION

Dust particles are generated in construction and mining sites. It is also present on unpaved roads, particularly in the countryside. Its presence is a nuisance and a considerable health risk to workers on the said sites as well as in the immediate community. It occurs primarily as soil disaggregates due to decrease in cohesion. Sandy loam for instance is described by Wall (1987) as an erodible material due to the action of wind and water. Fine particles are easily removed by raindrop splash and run off water due to limited binding materials such as clay and organic matter.

The World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) indicate that numerous scientific studies have associated particle pollution exposure to a variety of health effects, including increased respiratory conditions, such as irritation of the airways, coughing, aggravated asthma, development of chronic bronchitis, and breathing difficulty through decreased lung function, irregular heartbeat, and non-fatal heart attacks, and premature death in people with heart or lung disease (Department of Environment and Conservation 2011). These drawbacks should be properly dealt with to render its effects at an acceptable level. The use of polyethylene glycol (PEG) 8000 may address such problem since its binding property has been utilized in industries.

This study revealed the ideal amount of PEG concentration based on cohesion without sacrificing as uncovered in the direct shear test; checked its effectiveness compared to water-treated sandy loam; and disclosed the environmental implications of the treatment. No actual test is done for this study.

2. LITERATURE

Soil parameters play important role in the behavior of soil. Soil organic matter content (SOM) has a direct relationship with soil erodibility. It binds soil particles into aggregates improving soil structural stability (Baldock et. al. 2004). In the study of Morgan (1986) as cited by Emadodin et. al. (2009), the stability of soil aggregates is enhanced where organic material combined with clay particles contribute to chemical bonding. Emadodin (2009) also cited Stevenson (1999), Gami et. al. and Caravaca et. al. (2001), that soils with higher content of organic matter and an improved soil structure have greater resistance against soil erosion by water and wind. A low status of organic matter (naturally low or due to soil degradation) is an important reason for the instability of soil aggregates. Soil derives its shear strength from two sources: (1) cohesion between particles which is a stress independent component caused by cementation between sand grains and electrostatic attraction between clay particles; and (2) frictional resistance between particles which is a stress dependent component (Das 2010).

2.1 Polyethylene Glycol (PEG) 8000

Polyethylene Glycol is theoretically known as PEG with its general formula of $H(OCH_2CH_2)_nOH$ where n represents the number of ethylene glycol units contained in the PEG polymer (Chemicalland21). These polymers are built up by the repetition of low molecular weight units. Liquid Polyethylene Glycols are very hygroscopic, although hygroscopicity decreases with increasing molecular weight. Solid grades, e.g. PEG 4000 and above, are not hygroscopic (Vinensia Corporation 2012). This molecular weight range helps to determine the characteristics of each type of PEG to make it excellent materials for use.

PEG is widely used in a variety of applications related to engineering practices or construction operations and agriculture. It is utilized for "agricultural formulations as anti-dusting agent, polyester resin preparation to enhance water dispersability and water-based coatings, dimensional stabilizer in woodworking operations, and plasticizer to increase lubricity and impart a humectant property in adhesives and binders (Vinensia Corporation 2012)."

Physically, PEG 8000 is flaky or powder in form, white in color, and mild in odor. When used in experiments, proper handling should be executed to avoid any reaction from the body as well as for respiratory protection. Toxicity appears to be greatest with PEG of low molecular weight (Vinensia Corporation 2012).

2.2 Dust

The Department of Environment and Conservation defined dust as an aerosol formed by mechanical subdivision of bulk material into airborne fines, having the same chemical composition. The dust comes in the form of very fine invisible particles known as PM_{10} (particulate matter with a diameter of 10 microns or less in size) and $PM_{2.5}$ (particulate matter with a diameter of 2.5 microns or less in size) that are so small that most people do not even know they are inhaling it (Cypher International Ltd. 2002; Michigan Department of Environmental Quality 2005; and Department of Environment and Conservation 2011).

2.2.1 Sources of Dust

Man also contributes great amounts of dust to the atmosphere, directly and indirectly. Man-made sources of dust can be found in the following activities: wind-borne dust from exposed surfaces such as cleared land and construction sites, remediation works on contaminated sites, stockpiles of material such as sawdust, coal, fertilizer, sand and mineral ores, vehicle movements on paved and unpaved roads, agriculture and forestry activities, mines and quarries, road works and road construction, residential and commercial developments, such as demolition and construction works, municipal landfills and other waste handling facilities. (Department of Environment and Conservation 2011 and Michigan Department of Environmental Quality 2005).

2.3 Environmental Impacts

Dust and other air pollutants can cause acute and chronic health effects, as well as nuisance and visibility impacts (Vinensia Corporation 2012). Any level of dust generation is considered air pollution. Wind generation of dust particles can cause the erosion of valuable topsoil and contribute to the soiling and discoloration of personal property, requiring monetary costs for repeated cleanup activities. Constant soiling can lead to adverse effects on property and land values in areas where fugitive dust generation is a known problem. Like any air pollution problem, dust can also be a health nuisance. The smallest particles (2.5 microns or less in diameter) can easily be inhaled into the deepest parts of the lungs, thus, causing nose and throat irritation and respiratory illnesses such as bronchitis, asthma. This may also cause lung damage and worse, even premature death in sensitive individuals. In construction sites and in the cement industry, the most affected are the workers due to their constant exposure to cement dust that results in lung function impairment, chronic obstructive pulmonary disease, restrictive lung disease, pneumoconiosis, and carcinoma of the lungs, stomach and colon (World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) Department of Environment and Conservation 2011). Generation of fugitive dust can also reduce visibility (i.e., haze) enough to cause moving vehicle or work site equipment accidents that can result in serious injury or death.

According to the National Center for Biotechnology Information (2004), cement dust may enter into the systemic circulation and infiltrate the essential organs of the body such as the heart, liver, and spleen, as well as the bones, muscles, and hairs. Ultimately, the dust may adversely affect the micro-structure and physiological performance of the human body.

In China, approximately 700 million are in the active labor force, of which a large proportion is engaged in construction, mining, and other occupations with potential exposure to silica. The number of workers exposed to silica containing dusts may be as high as 12 million. Pneumoconiosis has long been the most serious and yet preventable occupational disease. The annual total economic losses to China as a result of pneumoconiosis, based on data from the Shanghai survey, can be estimated at US$978 million annually (Liang 2003).

3. CONCEPTUAL FRAMEWORK

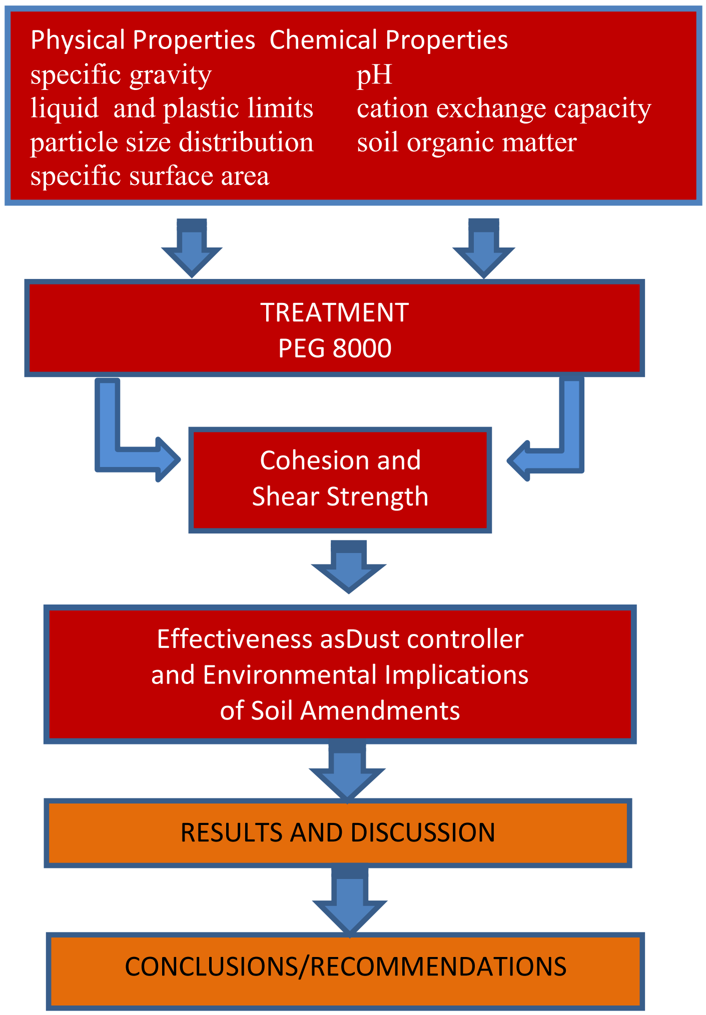


Figure 1. Flow chart of the study

4. METHODS

4.1 Sampling and Soil Characterization

Soil samples were collected at a depth of 50mm to150mm below ground surface. The soil samples were prepared for determination of its properties, following the procedure in ASTM D421-85 – *Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil*

Constants. Its organic matter content as prescribed in ASTM D 2974 – 00 – *Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*. A representative portion of soil collected were air dried or oven dried at 60^{o}C, after which quartering followed. Each quartered part was prepared for soil characterization.

1. Specific gravity determination: (ASTM D 854-02) – *Standard Test Methods for Specific Gravity of Soil Solids by Volumetric Flask*). Soil sample was passed on No. 40 sieve (0.425 mm)
2. pH determination: (ASTMD 4972 -01 – *Standard Test Method for pH of Soils*). Soil sample was passed on # 20 sieve (1 mm). A pH meter was calibrated and used to measure the value of soil's pH.
3. Particle Size Distribution: ASTM D 422 - 63(2002) – *Standard Test Method for Particle-Size Analysis of Soils*). Soil sample retained # 200 sieve (0.075 mm) underwent Sieve Analysis while the one that passed was subjected to Hydrometer Test.
4. Liquid and plastic limits (ASTM D 4318-10) – *Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index*). Soil sample was passed on # 40 sieve (0.425 mm). The result of these tests served as basis for percentage of water or solution of PEG 8000 to be added to the soil.
5. Cation exchange capacity and the specific surface area will be determined from secondary sources.

4.2 Soil Cohesion and Shear Strength

The optimum amount of cohesion or shear strength was revealed through Direct Shear test. The soil samples taken were air dried and pulverized using the wooden mallet and sieved using 2.00 mm sieve size opening. The material passing # 10 sieve (2.00 mm) was oven-dried and combined with either water or polyethylene glycol (PEG) solution after drying. The mixtures were molded manually in three layers using a spatula. The mold size is 5.99 cm in diameter with a thickness of 2.01 cm. The molded soils were cured for two days in an incubator at 30^{o}C.

After the direct shear test, representative samples (two samples for each treatment) were taken for SEM analysis. This step provided images of the soil structure showing the effect of the treatment in a magnified manner.

To validate the effectiveness of the optimum amount of PEG solution as a treatment for sandy loam, dust control was done in three trials.

4.3 Dust Control Test

Samples were prepared for each treatment. All the materials were combined thoroughly and placed in one layer in a 6 in x 6 in x 3 in mold. A 6 in x 6 in metal plate is positioned on top of the placed soil and tamped 5 times using a tamper with a rammer weight of 5.5 pounds and a free fall of 12 inches. Samples were cured for two days.

The dust control test was performed after the curing period. Soil samples were placed 0.5 meters away from an industrial fan and subjected to its maximum wind for one hour. The remaining soil was dried for 10 hours and percent loss in dry mass computed using the formula given below:

$$Percent\ loss\ in\ dry\ mass = \frac{initial\ dry\ mass - final\ dry\ mass}{initial\ dry\ mass} \times 100\%$$

The lower the average % loss in dry mass of the three treatments compared to the average % loss in dry mass of the control specimen, implied effectiveness of the treatment. The environmental implications of the soil amendments were evaluated based from secondary sources. The Material Safety and Data Sheet (MSDS) was also referred if studies on the materials' environmental effects were very limited.

5 RESULTS

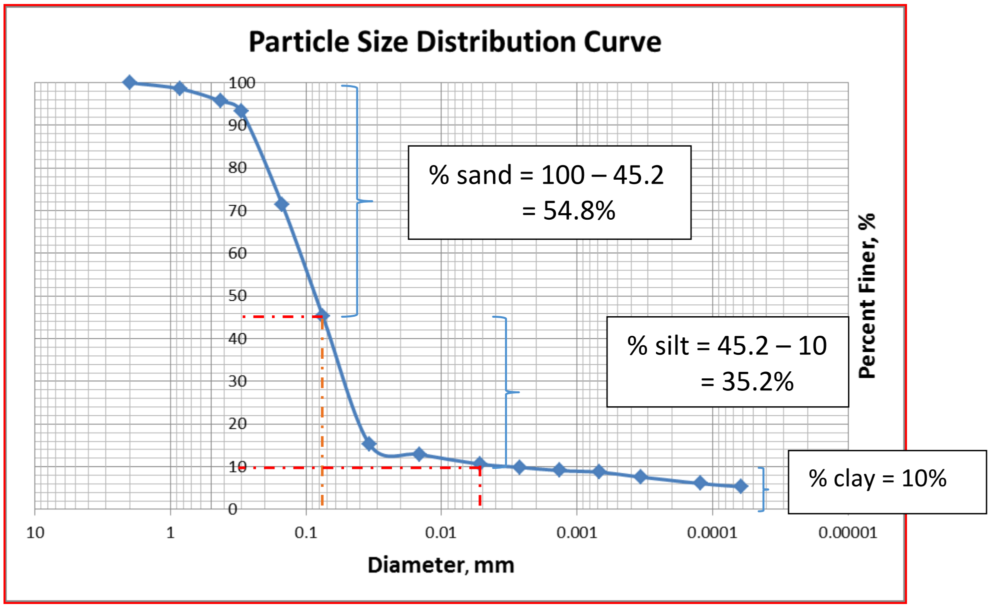
Sandy loam properties were determined from the experiments conducted and obtained from secondary sources. Table 1 displays the corresponding values of specific gravity, liquid limit, plastic limit, specific surface area, soil organic matter, pH and cation exchange capacity.

Table 1. Properties of sandy loam

Properties	Normal Values	Values
Specific Gravity	2.60 – 2.75	2.64
Liquid limit, %	-	19.1
Plastic limit, %	-	14.8
Specific surface area, m^2/g*	-	0.1
Soil organic matter, %	2 – 10	2.5
Ph	-	5.8
Cation exchange capacity, meq/100g*	-	5-10

*From secondary source

Normally, sandy loam has values ranging from 2.60 – 2.75 for its specific gravity, which was confirmed by the test performed yielding a value of 2.64. Liquid limit and plastic limits were also drawn to specifically reveal the percentage of water or liquid to be added to sandy loam soil. The results indicate that within the range of 14.78% and 19.1% moisture contents soil is at plastic state where mixing and molding is facilitated. Thus, a moisture content of 15% was selected and maintained for the untreated and treated sandy loam in this study. The specific surface area of 5 – 10 m^2/g and a cation exchange capacity of 5 – 10 meq/100g are both low values. To increase the CEC of sandy loam soil, the specific surface area has to increase. This could be possibly achieved by blending it with clay soils. The low value of CEC is further proven by low organic content of 2.51% and the acidic pH of 5.8. Aggregation of sandy loam can be enhanced by increasing the amount of organic matter at optimum level. Soil erosion can therefore be mitigated, a positive implication when polymers are applied to sandy loam.



Graph 1. Particle size distribution curve

Sieve analysis and hydrometer test disclosed the distribution of particle sizes as presented in Graph 1. The graph clearly emphasized that sandy loam is composed primarily of sandy soil at 54.8%, followed by silt at 35.2% and clay at 10% only. Sandy soil is non-cohesive and exists as single grained. Silt may exhibit plasticity but not as much as clay particles (McCarthy 1998). Apparently the meager amount of clay is not enough to bind sand and silt. Hence, enhancement of sandy loam by combining clay soils is an option to increase its cohesive property thereby minimizing soil erosion.

5.1 Direct Shear Test

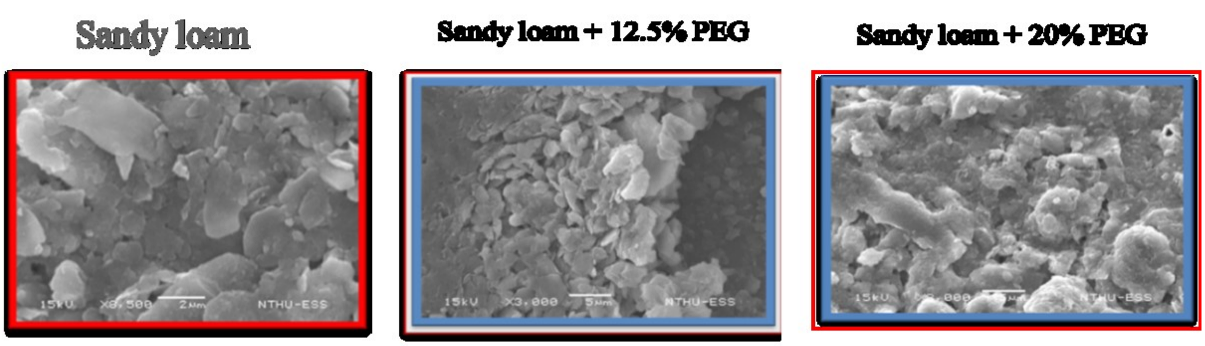
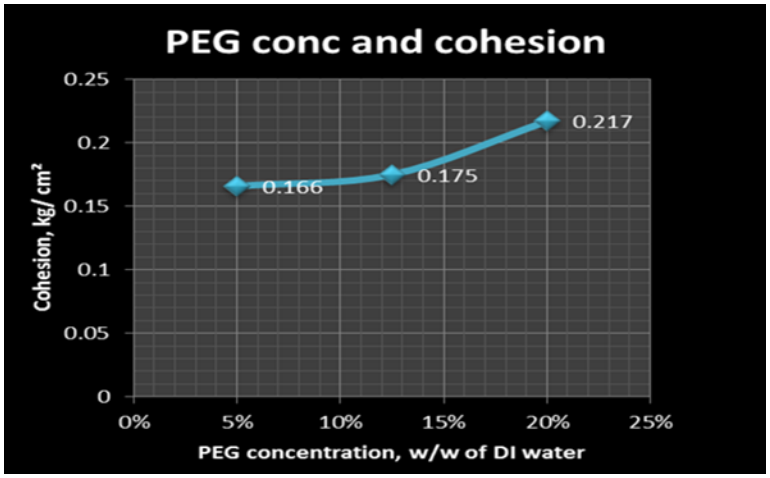
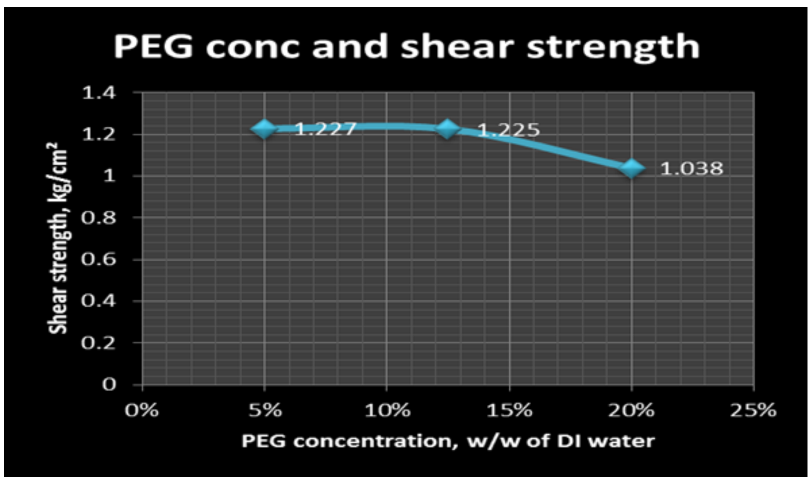


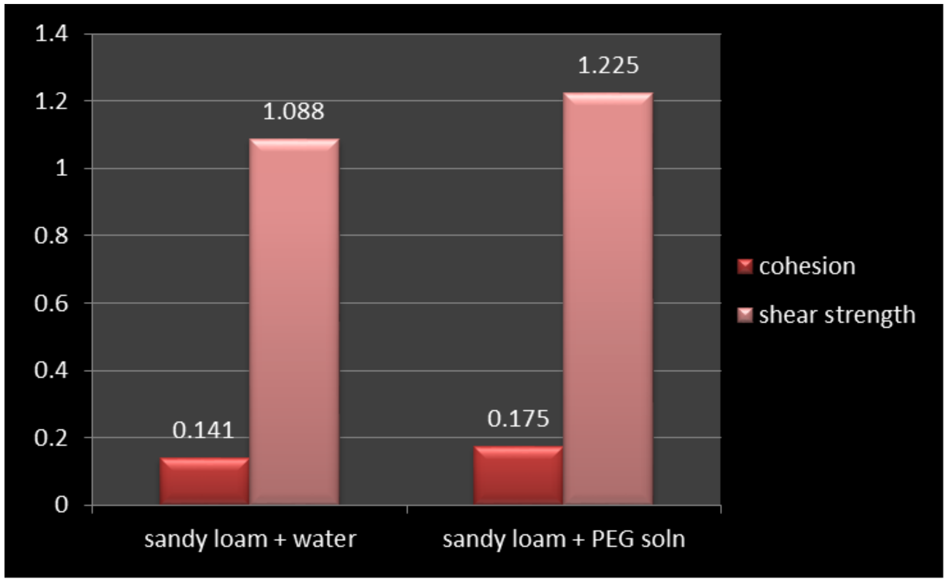
Figure 2. SEM Images



Graph 2a. Effect of PEG concentration on cohesion



Graph 2b. Effect of PEG concentration on shear strength

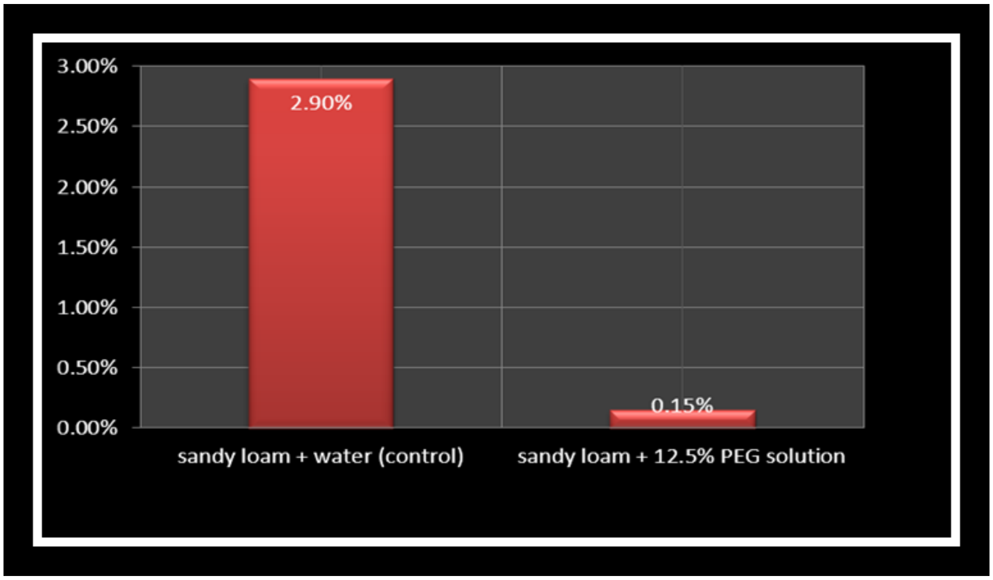


Graph 3. Comparison of cohesion and shear strength of control and treated sandy loam

PEG 8000-treated sandy loam with concentration of 5% by weight of deionized water showed presence of water upon application of 1.0 kg/cm^2 normal stress. The amount of drained water increased until failure occurred. However, increased concentration of PEG 8000 restricted release of water since at 20% PEG 8000 concentration, water was no longer visible. The presence of PEG 8000 in higher concentration restricted the release of water as PEG 8000 coated the sandy loam preventing the expulsion of water (Figure2). It was also shown in Graph 2a that cohesion increases with added concentration of PEG. However, the shear strength reached an optimum value at 12.5% PEG by weight of DI water as displayed in Graph 2b. At this point, increased PEG concentration weakens the soil as reflected by lower shear strength. SEM images confirmed this finding (Graph3). The increasing concentration of PEG allows the particles to move closer, but further increase saturation and softened the mixture but maintaining the bond between particles.

5.2 Dust Control Test

Meanwhile, Graph 4 shows the effectiveness of added PEG solution to sandy loam. The exposure to wind action of PEG-treated soil reveals that little disaggregation took place contrary to water-treated sandy loam.



Graph 4. Comparison of % loss in dry mass of control and the treatment in the dust control test

5.3 Environmental Effects of PEG 8000

According to DOW Chemical Canada ULC (2007), proper handling and storage of PEG 8000 is necessary to avoid conditions that may cause hazardous effects to people and the environment. It may cause slight temporary eye and skin irritation, problems in inhalation and ingestion, and kidney failure in repeated exposure to the chemical.

6. CONCLUSION

Sandy loam has low plasticity that ranges at moisture contents of 14% to 19% only. This type of soil is also prone to disaggregation or erosion as substantiated by low organic matter content of 2.51% which subsequently resulted to acidic pH of 5.8. Organic matter improves soil property by aggregating soil particles mitigating erosion. Low specific surface area and low cation exchange capacity further confirmed the low water-holding capacity. PEG- amended sandy loam increases cohesion as PEG concentration increases. Angle of internal friction reduces with increased concentration of PEG resulting to a decrease in shear strength. Polyethylene glycol 8000-treatment turned out to be the most effective for dust control. PEG 8000 causes eye and skin irritation and repeated exposure may at most result in kidney failure. PEG 8000 is non-toxic and ecological information indicates that it has no adverse effects.

7. RECOMMENDATIONS

1. The binding property and fertility of sandy loam can be enhanced by natural means. It is therefore suggested that dried leaves or other organic material should remain in the soil and be allowed to decompose and become part of soil material.

2. Other combinations of treatment not covered in this study may be considered by future researchers.
3. The degree of slopes other than the 60^o with varying amounts of treatment should also be evaluated.
4. Furthermore, it is suggested to explore the use of biopolymers as an option in lieu of polyethylene glycol 8000 for economic and environmental viability.
6. In order to decrease adverse health effects from occupational exposure to PEG 8000 the following are recommended as suggested by the World Health Organization:
   a. set limits for occupational exposure to clay materials, taking into consideration the quartz content;
   b. enforce and ascertain compliance with the limits by regular exposure monitoring;
   c. prepare guidelines to ensure good workplace practice such as use of safety glasses, wearing of mask and gloves, and use of long sleeves to cover skin to avoid dermal exposure;
   d. disseminate information on the hazards to exposed workers in an appropriate form; and
   e. institute appropriate medical monitoring programs to protect populations at risk

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