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REVIEW ON SOIL STABILIZATION WATER RESISTANCE SOIL BASES AND DUST CONTROL METHOD.

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ABSTRACT

Water resistance soil bases and dust control are common climatic phenomena in arid and semi-arid regions. In Iran, one of the environmental concerns is increasing dust storms. There are several ways to control this phenomenon, each of which has its limitations. Conventional methods for reducing dust storms (especially in arid and semi-arid areas) have been the stabilization of the dust generating center using chemical polymers and petroleum products, which in the current situation, due to the high cost and disagreement about the effects on their environment is not cost-effective. Therefore, due to the problems of this type of soil cover, the use of biopolymers, bio-mulch, and organisms to stabilize dust in recent years has been recommended as a suitable alternative. Water resistance soil bases and dust control form a continuous or partially structured structure with each other by forming granulation soils, bonding fine particles together, and forming larger particles.

Key words: Atterberg limits, geotechnical tests, Lateritic soil, Stabilization, terrasil solution

I. INTRODUCTION

Soil is the essential component of this nature and road development industry knows the significance of it for pavement work. India is confronted with the colossal test of protecting and upgrading the transportation framework to meet the constantly expanding hassles because of heavier burdens delivering layers to the hidden soil. Roads running through expansive soil regions are subjected to severe distress resulting in poor performance and increased maintenance cost. An imperative step is being taken by this study to accomplish monetary utilization of development materials by endeavouring to keep the wastage of soil material through the change of its properties to meet the prerequisites of pavement configuration from its planned utilization. Chemical stabilization of expansive soil comprises of changing the physico-synthetic around and within clay particles where by the earth obliges less water to fulfill the static imbalance and making it troublesome for water that moves into and out of the framework so as to fulfil particular designing road ventures and administration life of the asphalt. The most widely recognized chemical admixtures utilized as a part of soil adjustment are water resistance soil bases and dust control.

II. RESEARCH MOTIVATION

Soil stabilization is a process by which the physical properties of a soil are transformed to provide permanent strength gains before construction. Stabilized soils outperform non-stabilized soils when materials, design, and construction are properly considered. When the stabilized soil layer is incorporated into the structural design of the pavement, the subsequent layers can be thinner, resulting in sizable cost savings and minimizing the need for virgin materials. In addition to adding strength, stabilized soil forms a solid monolith that decreases permeability, which in turn reduces the shrink/swell potential and the harmful effects of freeze/thaw cycles.

Soil stabilization can improve in situ, or natural state, soils eliminating the need for expensive remove-and-replace operations. Often job sites where roads, building pads, parking lots, runways or other pavement structures need to be built contain naturally wet, weak soils. Those soils can be chemically treated to add strength through stabilization and improve engineering properties including moisture content and plasticity, through modification. Ex situ, or off site, soil stabilization processes are possible but are usually reserved for environmental projects rather than typical construction operations.

III. GROUND IMPROVEMENT

Ground improvement has always been one of the major thrust areas of geotechnical engineering. It is vertically crucial in the design of the structure in weak soil. Before any development or construction work for either civil structures or mining activities, it is crucial to know the local soil type, present and future use of the land area, required strengths for holding the above structural loads, and estimated cost of the project. In case the soil of the selected site does not have desired structural properties, e.g., appropriate cohesion, internal angle of friction, bearing capacity, swelling factor, etc., it becomes necessary to improve these properties using external means. The effect of soil instability can be diverse, including cases of liquefaction, heaving, swelling, and plastic deformation. The effects of unstable soil are correspondingly catastrophic, ranging from slope failures and foundation sinkage to total collapse of the tunnels and mine dumps, overlying buildings, and other structures.

Several methods are used for improving the ground conditions for safe and reliable construction. Based on the treatment method, the engineering techniques of ground improvement can be broadly grouped into three categories: mechanical, biological, and chemical stabilisation. Among these, mechanical stabilisation is the most common and oldest technique of ground improvement where the soil's density is increased by the application of mechanical force and compacting the surface layers by static and dynamic loading. Soil biological stabilisation techniques are the combined applications of engineering practices and ecological principles for designing and building a system that will contain living plant materials as the structural component. The biological method of stabilisation not only beneficial from the engineering point of view but is also beneficial because of the ecological and environment-friendly nature.

The intention is not to have an immediate effect; instead, develop a system that will be sustainable and will ensure long-term remediation. In chemical stabilisation, ground improvement is achieved by mixing various chemicals with soil to develop desirable characteristics. Uses of Inorganic pozzolanic/cementitious binders like fly ash, cement, lime, or some calcium-based chemicals are some of the most commonly used chemical methods. These methods have shown a long-term change in ground properties, but usually, some degree of environmental concerns is associated with them. In modern times, various types of complex chemical polymers are being used to improve the soil. These polymers react to form strong polymeric structure binding soil particles and fill up the soil voids to strengthen the overall structure. Some of the popular polymeric chemical stabilisers include polyurethane, polyacrylamides, and poly-acrylates.

The ground improvement as a sub-branch of the Geotechnical Engineering domain has made considerable advances since the practices began to develop in the mid-20th century. Most techniques have undergone drastic changes in terms of application and optimisation. The present paper discusses the use of chemical stabilisers as ground improvement techniques which includes biochemical and electrochemical methods along with various admixture and chemical reagents. Several detail literature studies on the use of chemical stabilisers are present; however, all of them were limited to a particular specific soil type or a particular type of chemical stabiliser.

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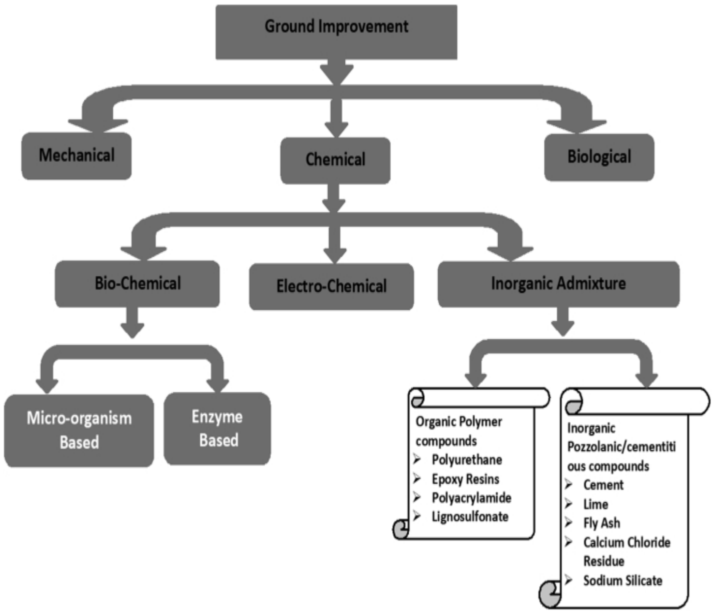

Fig.1. A flow-chart showing the chemical methods of ground improvement.

IV. SOIL STABILIZATION METHODS

AggreBind is ideal for Specialty Applications and can replace traditional house construction methods and road construction soil stabilization methods such as:

- Soil-cement base (SCB)
- Soil nailing
- Jet grouting and Grout of the soil
- Erosion Blanket and Erosion control for dust control
- Sediment Control and management of mine dumping waste
- Soil stabilization products are varied on the market and often mislead the user because they refer to their product as a soil stabilizer. This is a very misused term and unfortunately it misleads the users. In many parts of the world, Indonesia and Malaysia, India, in various countries of Latin America and Africa, there have been stabilized soil projects that failed or did not perform as promised and represented.
- Some of these products simply neutralize the interaction between clay particles to allow the platelets to be compacted with no true binding or soil stabilization action.
- Some soil-binders do not work with non-cohesive materials such as sand.
- Some soil stabilizers improve the CBR by only 2-3 times. (Any conventional soap product can do this.)

- Some products require medium to high clay content for stabilizing, essentially lubricating the clay to bind when compacted. (Sometimes they call this increasing plasticity and to do so they say add clay. In fact, they are actually clay-based soil stabilizers.)
- Some soil stabilizer products are based on tree resins, presenting themselves as "ionic stabilizers" and a "green" alternative to bitumen, etc. This class of resin-based soil stabilizers generally needs a minimum of 15% clay content and an annual maintenance program or topping-up of the surface. (There claim is to be bio-degradable. A bio-degradable road is guaranteed to breakdown rapidly.)

BACKGROUND TO THE STUDY

To date, in the United States, no comprehensive coordinated national research has been undertaken—that is, research based on a scientific experiment design covering region, climate, material type and properties, traffic, and chemical treatment categories—to understand the interrelation between the performance of unpaved roads, their material properties, and the chemical treatments applied. There are also no formal specifications for unpaved road chemical treatments, or a national agency overseeing the development and promulgation of these specifications. Consequently, most currently available guides to unpaved roads maintenance, and specifically on chemical treatments, are based on the experiences of their authors, who have pieced together the results from multiple independent, uncoordinated, and often short-lived field trials. A comprehensive study incorporating the long-term evaluation of the use of the treatments through multiple rejuvenation applications is needed. Results from such a study could be used to quantify the benefits of unpaved road chemical treatments, and to develop performance-based unpaved road material specifications, selection criteria for chemical treatments, performance criteria for different chemical treatment categories, life-cycle assessment criteria for undertaking cost-benefit analyses for different treatment options, and to provide criteria for determining potential environmental impacts (1). All this information could then be used to better justify the use of chemical treatments as part of unpaved road management practice. Many agencies manage their unpaved road networks and make decisions on whether or not to use dust control and/or stabilization treatments using the available published information discussed above, past experience of how the treatment performed, its local availability, and/or its price when the treatment is needed. In the absence of appropriate guidance and documentation, the primary data on which practitioners must base their selection and application decisions often comes from vendor marketing and product manufacturing information.

OBJECTIVES

To study the transformation of soil index properties of untreated weak local soil and restrict the volume change potential of a soil by using as stabilizers of (water resistance soil bases and dust control) for road construction to give some structural value or credit in the pavement design process.

V. LITERATURE REVIEW

Hamed A. Keykha et al. [1] This study aims to introduce alternative environmentally friendly compositions for soil-dust suppression. Carbon dioxide was utilized to produce free carbonate (CO_3^{2-}) by a laboratory electrolysis cell. Different carbonate mineral compositions were then provided by adding Fe^{2+}, Mg^{2+}, and Ca^{2+} ions to the sodium carbonate solution. Different carbonate minerals were eventually used as soil stabilizing agents for sandy soil-dust suppression. Laboratory tests including unconfined compressive strength (UCS), direct shear test, California bearing ratio (CBR), and permeability tests in addition to field tests were performed to assess the feasibility of using CO_2 induced carbonate minerals as soil stabilizing agent. It was found that the UCS and cohesion intercept of the treated specimens increased in comparison with the untreated specimens. CBR rating of the treated specimens indicated a harder surface which resulted in a lower permeability of the treated specimens. The study showed this alternative approach is a promising effort in utilization of CO_2 for soil surface stability improvement. The potential of marble dust as a stabilizing additive to red tropical soils was evaluated. The evaluation involved the determination of the geotechnical properties of three different red tropical soils in their natural state as well as when mixed with varying proportions of marble dust. The parameters tested included the particle size distribution, specific gravity, Atterberg limits, the standard compaction characteristics, the compressive strength and the California bearing ratio (CBR). The strength tests were repeated after normal 28 day curing of the treated samples and also after accelerated 24 h curing at temperatures of 40°C, 60°C and 80°C.

Results showed that the geotechnical parameters of red tropical soils are improved substantially by the addition of marble dust; plasticity was reduced by 20 to 33% and strength and CBR increased by 30 to 46% and 27 to 55% respectively. The highest strength and CBR values were achieved at 8% marble dust. Results also showed that normal 28 day curing improved the strength of the marble dust-treated soil with over 80% strength gain achieved after 7 to 10 days of normal curing. Higher strength development was realised following accelerated 24 h curing at 60°C.

Danish Shuja et al. [2] The soil developed in arid places with salt-bearing strata is known as sabkha soil. These soils are risky and unpredictable in theory, and are typically found in the Middle East. Due to the rapid expansion of building activity in the Middle East's offshore and nearshore areas, it is now necessary to examine geographical issue soils such as Sabkha soil. The purpose of this research is to determine the difficulty that arises during building owing to sabkha soil. Find a method or technique for stabilizing sabkha soil so that it may be used in infrastructure. The Arabian Gulf's intended and vast shoreline area is covered with sabkha soil. For the purpose of stabilizing this soil, several research, trials, and examinations have been conducted. Many projects, including the world's largest petrochemical factories and an oil reserve, are planned to be developed atop these grounds. These soils have a high incompressibility and poor shear strength. The qualities of sabkha soil are determined by the amount and kind of salt present. These sorts of soils have a significant risk of settlement and bearing capacity failure, which means they can't be used in construction since they're not appropriate for infrastructure support, thus it's critical to enhance their qualities so they may be utilized in building. The samples of sabkha soils collected from coastal regions of Al-Azaiba, Sultanate of Oman, were analyzed for this study. The stability of sabkha soil and improvement of its qualities using cement and C.K.D (Cement Kiln Dust) were investigated in this research, and the findings were compared to determine whether additional material is more efficient and useful for long-term infrastructure. The findings of this study reveal that the short-term durability and strength qualities of sabkha soils have improved; consequently, more research is needed to determine the long-term durability and strength of these combinations. This study describes the technical issues encountered during the stabilization of sabkha soil using various materials, as well as the geotechnical behavior of the soil before and after stabilization.

Bui Van Duc et al. [3] The effect of ordinary Portland cement, OPC+Quarry Dust, QD on the adsorbed moisture, diffused double layer (DDL), dielectric constant, density and repulsion potential (RP) of treated lateritic soil was investigated through laboratory tests. The preliminary tests showed that the natural soil was an A-2-7 soil, according to the AASHTO classification system, highly plastic soil and high swelling potentials. The soil was treated with a fixed 5%

OPC and varying proportions of QD at 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50% by weight of the dry soil. The stabilization results showed that the compaction properties improved consistently, with the addition of the QD. Also, the addition of the QD reduced the adsorbed moisture and consequently reduced the double diffused layer and the repulsion potential, which constitute the properties investigated within the adsorbed complex in the stabilization operation. These observations brought about the cation exchange reaction between the metallic ions that were attracted to the adsorption complex, resulting to densification, flocculation from the natural state of dispersion of particles and strength gain in the stabilization procedure. Results also showed that the repulsion potential increased in magnitude with the distance between the reactive particles and the clay surface and reduced with increased proportions of QD. The dielectric constant also reduced considerably with adsorbed moisture, which indicated that the dielectric was affected by the moisture and the ions released within the adsorbed complex.

Kennedy Onyelowe et al. [4] Scheffe's second-degree polynomial was used to formulate models for predicting the swelling potential, California bearing ratio, unconfined compressive strength and loss of strength on immersion durability of quarry dust treated soil. These models could predict the swelling potential, California bearing ratio, unconfined compressive strength and loss of strength on immersion durability of treated soil if the mix ratios are known and vice versa. The response predicted by the models are in good agreement with the corresponding experimentally observed results. The result of these tests shows the feasibility of using quarry dust in soil stabilization. The student *t*-test and the analysis of variance (ANOVA) test were used to check the adequacy of the models, and the models were found to be adequate at 95% confidence level. With the optimized equations, the properties' design, behaviour, and performance of treated soft clay soil as a pavement subgrade material will be appropriated and monitored. This will be for any possible volume changes, shear failures, strength failures and durability failures when the material used as a hydraulically bound material is in contact with moisture beyond its optimum and subjected to dynamic load beyond its design value.

A.A. Amadi et al. [5] Combined treatment techniques have been adopted by many pavement designers and site engineers to improve the strength and stability of subgrades or foundation soils of expansive sites. In this regard, research was conducted to investigate the effect of curing time on strength development of black cotton soil (BC soil) stabilized with 10% quarry fines (QF) and varying percentages (0–16%) of cement kiln dust

(CKD). Preliminary tests such as Atterberg limits, compaction parameter test together with a series of unconfined compression tests were conducted on soil mixtures. Specimens for unconfined compression tests were prepared at their respective optimum moistures, compacted using British standard light (BSL) compaction effort and tested at curing times of 7, 14, 21 and 28 days. Data from the study revealed that the curing duration exerted a significant influence on the stress–strain behavior of soil mixtures together with the strain at failure which decreased by about 30–50% as the curing time increased. Unconfined compressive strength data showed improved strength values ranging from 1.25 to 5.25 times higher than the value for specimens tested immediately after preparation. Data developed in this study are expected to be useful to pavement designers and site engineers in the field implementation of the stabilization scheme such as when to open the stabilized layer to construction traffic or when to proceed with further construction works.

Agapitus Ahamefule Amadi et al. [6] For soil materials to be effective as pavement subgrades, satisfying the durability conditions is essential especially in tropical latitudes where wet and dry climatic conditions prevail. This study investigated the use of cement kiln dust (CKD) to enhance the durability of black cotton soil (BC soil) subgrade modified with quarry fines (QF). Durability was assessed by California bearing ratio (CBR) swell and loss of strength upon immersion tests carried out on soil mixtures prepared with BC soil mixed with constant dosage of 10% QF and five levels of CKD concentration (0%, 4%, 8%, 12% and 16% by dry weight of soil). Specimens were compacted using British standard light (BSL) effort under optimum moisture condition, cured and then subjected to prolonged soaking. Test results show that mixtures containing 0% and 4% CKD failed the CBR and associated swell limits as well as the resistance to loss of strength criterion while both tests deemed soil mixtures containing 8–16% CKD durable. Moisture content evaluation revealed that inclusion of CKD reduced the moisture susceptibility of mixtures. Overall, the testing programmed produced data showing that mixtures with CKD admixture have significant durability when exposed to prolonged saturation.

In-Ho Yoon et al. [7] In this study, the mechanism for the stabilization/solidification (S/S) of arsenic (As)-contaminated soils with Portland cement (PC), and cement kiln dust (CKD) using 1 N HCl extraction fluid, X-ray powder diffraction (XRPD), X-ray absorption near edge structure (XANES) and Extended X-ray absorption fine structure (EXAFS) spectroscopy was investigated. The degree of As immobilization after stabilization was assessed using a 1 N HCl

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extraction on the basis of the Korean Standard Test (KST). After 1 day of curing with 30 wt% PC and 7 days of curing with 50 wt% CKD, the concentration of As leached from the amended soils was less than the Korean countermeasure standard (3 mg L^{-1}). The As concentrations in the leachate treated with PC and CKD were significantly decreased at pH > 3, indicating that pH had a prevailing influence on As mobility. XRPD results indicated that calcium arsenite (Ca–As–O) and sodium calcium arsenate hydrate ($NaCaAsO_4 \cdot 7.5H_2O$) were present in the PC- and CKD-treated slurries as the key phases responsible for As(III) and As(V) immobilization, respectively. The XANES spectroscopy confirmed that the As(III) and As(V) oxidation states of the PC and CKD slurry samples were consistent with the speciated forms in the crystals identified by XRPD. EXAFS spectroscopy showed As–Ca bonding in the As(III)-PC and As(III)-CKD slurries. The main mechanism for the immobilization of As-contaminated soils with PC and CKD was strongly associated with the bonding between As(III) or As(V) and Ca.

Deok Hyun Moon et al. [8] Stabilization/solidification (S/S) processes were utilized to immobilize selenium (Se) as selenite (SeO_3^{2-}) and selenate (SeO_4^{2-}). Artificially contaminated soils were prepared by individually spiking kaolinite, montmorillonite and dredged material (DM; an organic silt) with 1000 mg/kg of each selenium compound. After mellowing for 7 days, the Se-impacted soils were each stabilized with 5, 10 and 15% Type I/II Portland cement (P) and cement kiln dust (C) and then were cured for 7 and 28 days. The toxicity characteristic leaching procedure (TCLP) was used to evaluate the effectiveness of the S/S treatments. At 28 days curing, P doses of 10 and 15% produced five out of six TCLP-Se(IV) concentrations below 10 mg/L, whereas only the 15% C in DM had a TCLP-Se(IV) concentration <10 mg/L. Several treatments satisfied the USEPA TCLP best demonstrated available technology (BDAT) limits (5.7 mg/L) for selenium at pozzolan doses up to 10 times less than the treatments that established the BDAT.

Biki Niraj et al.[9] The purpose of this experimental study is intended to explore if SCBA (Sugarcane Bagasse Ash and Marble Dust) may help clayey soil stabilize and hence to overcome environmental pollution. BA (Bagasse Ash) is the waste produced by the sugar factory after the processing of sugarcane. Factories dispose of the BA in the landfills which affect the environment, one of the reasons to do this experiment is to make use of this waste product for a sustainable environment. At the time of marble manufacturing, marble dust is produced. The soil around a building's foundation plays an important influence on its stability.

As a result, the engineer should have a complete understanding of the components that influence soil behavior and can be affected by the soil stabilization process. The soil is treated with bagasse ash and a partial replacement of marble dust (13 percent, 17 percent, and 21 percent) (10 percent, 12 percent, and 14 percent). In this study, a large number of specimens were made, and then the test specimens were analyzed for compaction characteristics and CBR. It was discovered that an increase in MD (Marble Dust) and BA increased the compaction and CBR characteristics to a certain extent.

The interaction of CKDs with a given soil depends on the chemical and physical characteristics of the CKDs. Hence, the characterization of CKDs and their hydration products may lead to better understanding of their suitability as soil stabilizers. In the present article, four different CKD powders are characterized and their hydration products are evaluated. A detailed chemical (X-ray diffraction), thermogravimetric and morphological (scanning electron microscope) analyses of both the CKD powders and the hydrated CKD pastes are presented. In general, high free-lime content (~ 14–29%) CKDs, when reacted with water produced significant amounts of calcium hydroxide, ettringite and syngenite. These CKDs also developed higher unconfined compressive strength and higher temperature of hydration compared to CKDs with lower amounts of free-lime. An attempt was made to qualitatively correlate the performance of CKD pastes with the chemical and physical characteristics of the original CKD powders and to determine their potential suitability as soil stabilizers. To that effect a limited unconfined compressive strength testing of CKD-treated kaolinite clays was performed. The results of this study suggest that both the compressive strength and the temperature of hydration of the CKD paste can give early indications of the suitability of particular CKD for soil stabilization.

Deok Hyun Moon et al. [10] A stabilization/solidification (S/S) process for arsenic (As) contaminated soils was evaluated using cement kiln dust (CKD). Laboratory-prepared slurries, made of either kaolinite or montmorillonite, and field soils spiked with either As^{3+} or As^{5+} were prepared and treated with CKD ranging from 10 to 25 wt%. Sodium arsenite and sodium arsenate at 0.1 wt% were used to simulate arsenite (As^{3+}) and arsenate (As^{5+}) source contamination in soils, respectively. The effectiveness of treatment was evaluated at curing periods of 1- and 7-days based on the toxicity characteristic leaching procedure (TCLP). As–CKD and As–clay–CKD slurries were also spiked at 10 wt% to evaluate As immobilization mechanism using X-ray powder diffraction (XRPD) analyses. Overall, the TCLP results showed that only the As^{5+} concentrations in kaolinite amended with 25 wt% CKD after 1 day of curing were less than the TCLP regulatory limit of 5 mg/L. Moreover, at 7 days of curing, all As^{3+} and As^{5+} concentrations obtained from kaolinite soils were less than the TCLP criteria. However, none of the CKD-amended montmorillonite samples satisfied the TCLP–As criteria at 7 days. Only field soil samples amended with 20 wt% CKD complied with the TCLP criteria within 1 day of curing, where the source contamination was As^{5+}. XRPD and scanning electron microscopy (SEM)–energy dispersive X-ray spectroscopy (EDX) results showed that Ca–As–O and $NaCaAsO_4 \cdot 7.5H_2O$ were the primary phases responsible for As^{3+} and As^{5+} immobilization in the soils, respectively.

VI. CONCLUSION

Soil stabilization is a very critical method in any shrinkage project and requires sophisticated technology that provides a solid foundation that can carry traffic loads. The higher cost of chemical and mechanical stabilization techniques has created the need for safe, cheap and easy soil stabilization techniques. For this reason, local production of bio enzymes is the best choice in which cost-effective technologies are the main benefits to the economy. Enzymes have been used as soil stabilizers to improve the strength of substrates due to their low cost and relatively wide application compared to standard stabilizers.

Sand mobilization can be reduced by using various applications. Products for dust control are based mainly on synthetic or natural polymers, which are applied by wetting the soil surfaces. A wide range of the products has been tested for dust emission by human activity such as mining and vehicles traveling on unpaved roads. Yet, there is a lack of fundamental research examining the efficiency of diverse products in the suppression of dust emission by wind. Moreover, further study is needed to investigate the possible environmental impacts of the diverse dust suppression substances, including the toxicity of atmospheric particulate matter when dust is emitted from the treated soils and/or soil-groundwater pollution because of vertical fluxes of the applied solutions on the surfaces.

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