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An Overview of Methods and Materials for Sandy soil stabilization: Emerging Advances and Current Applications

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ABSTRACT

Aims: Nowadays, the depletion of renewable resources and the production of particulate matter brought on by desertification and the subsequent dust storms pose a serious and immediate threat to human health. The purpose of this study is to investigate the stabilization methods applicable to desert dust as well as sandy soils to prevent desertification and dust-related negative consequences.

Materials & Methods: The methodology used in this research is a complete review of the provided sources and an evaluation of their results in the last two decades in this field. This review deeply investigates the methods and Materials for the stabilization of desert sandy soil.

Findings: Chemical stabilizers of loose sand, including cement, lime, nanoclay, blast furnace slag, polymer, fly ash, and other stabilizers, have been used in different countries of the world and have shown acceptable results. The results of the studies show that by using these methods and stabilizing materials, wind erosion can be reduced by 70% and the compressive strength of the soil can be increased by up to 2 times its initial value.

Conclusion: We conclude that we will require a green and reasonably priced stabilizer to stabilize the desert dust based on the study we have done and the analysis of the papers that have been presented in this sector. Given the limitations and drawbacks of the aforementioned stabilizers, a good stabilizer doesn't destroy the soil's vegetation, doesn't significantly alter the soil's color, texture, or chemical composition, and doesn't interfere with the roots' ability to breathe.

Keywords: Desertification; Dust storm; Environment; Chemical stabilizers; Wind erosion.

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Introduction

Currently, many countries are facing the desertification problem, especially developing countries [1]. Climate change is the most fundamental human challenge, and its consequences are more severe in arid land and semi-arid regions. This phenomenon negatively affects soil, the atmosphere, plants, and animals [2]. The result of this phenomenon is the depletion of renewable resources in each of these countries. Desertification includes the processes originating from natural factors and improper human actions. Desertification is the reduction of arable and stable lands by erosion as a result of one or a combination of multiple processes, such as wind erosion, water erosion, destruction of vegetation, destruction of water resources, salinization and alkalinization of soil, etc. [1]. Arid and semi-arid regions cover about 30% of the Earth's surface. These lands have been endangered due to various interventions, such as climate change and human disturbances (overgrazing, over-cultivation, and the use of plants as firewood) [3]. One of the main forms of land degradation is soil erosion, which is expected to have a significant negative impact on current and future generations [4]. Desertification affects about one-sixth of the world's population, 70 percent of all dry lands; amounting to 3.6 billion hectares, and one-quarter of the total land area. The most obvious impact of desertification is the degradation of 3.3 billion hectares of rangeland with a low potential for human and animal carrying capacity. Desertification is one of the most critical ecological and environmental issues in the world. It is a phenomenon that is expanding day by day. Desertification in dry and semi-arid countries is a danger that should be taken seriously [5]. Desertification and Dust particles from the soil with different origins in different regions are the source of one of the main components of global aerosols. An estimated 3000 million tons of dust are produced globally each year, including suspended particles with a diameter smaller than 10 micrometers [6]. In the deserts of Iran, the average annual rainfall is less than 50 mm. Deserts and desert areas together cover about 40 million hectares of Iran's land, from which 20 million are under wind erosion, 7 million are among the critical centers of desertification in the country, and 3 million hectares are among the first-class crisis centers that produce dust, loose sand, and is in the priority of preventive measures for desertification. Also, 12 million hectares are sandy or covered with quicksand.

Water evaporation in Iran is three times more than the global average, due to its location in an arid region. Experts claim that the global expansion and development of deserts have put more than 250 million people in direct danger. Only 20 to 25 percent of dust storms are thought to be brought on by destructive human activity, but this is enough to put many nations through environmental severe issues and annual economic losses amounting to billions of dollars. Iran is one of those countries that is dealing with the issue of sand and dust storms [7]

Dust storms are one of the serious environmental phenomena in many regions of the world, which cause significant problems in communication and land and air transportation and ultimately affect the health of humans and animals [8]the Middle East, and central and northeastern Asia. Dust originating from these regions can be dispersed across oceans and in some cases globally. The storms occur throughout the year and vary in frequency and intensity. The biological agents (e.g., fungi, bacteria and viruses. This occurrence is one of the consequences of desertification that frequently occurs in arid and semi-arid regions. This phenomenon includes three phases: the release of surface material, its transport through the atmosphere, and its deposition on the earth's surface [9]. Dust aerosols exert a wide range of impacts on global climate, ambient air quality, atmospheric chemistry, and biogeochemical mechanisms. Dust includes soil-based solids, anthropogenic metal compounds, and natural biogenic substances. The formation of dust storms is related to the regional climate system, short-term rainfall, soil moisture, expansion of deforestation, and long-term droughts [10]. The phenomenon has been increasing in recent years in the Middle East region. Figure 1 shows the map of dust potential in the world [9].

The main challenge is that specific measures are needed on the soil bed or the ground to provide the conditions, through which dust particles are not carried by the wind. Reducing vegetation is another essential factor in wind erosion and desertification [11]. Desertification is affecting more than 30% of the planet's dry land, and it is extending into semi-arid areas. The limitation of precipitation and soil particles are significant active factors in land erosion and desertification (particles as small as 0.002 mm) [12] Wind erosion is the main tectonic force in desert regions. It has been reported that the total erosion produced by water is twice as much as that caused by wind. Therefore, increasing soil resistance to water erosion, i.e., undisturbed shear strength, is an efficient approach to prevent desertification [13].

Reducing the causes and mechanisms of soil erosion by wind is of major interest, according to the aforementioned subjects. The investigation of soil stabilizing techniques and materials is the overall focus of this study, and chemical soil stabilizers are examined in great detail concerning their mechanism and intended use. Due to the dearth of fundamental studies on the capacity of various existing chemicals to prevent the creation of dust, the current research is being presented. This is the hypothesis that has been taken into account for this research, which deals with resolving this problem and providing a framework for more study in this area.

Materials & Methods

In recent years, investigations and research in the fields of stabilization of sandy soil, desertification, and stabilization materials have been of great interest to many researchers. In this research, a comprehensive review of the studies conducted in the field of stabilizing materials for sandy soils related to desertification, dust problems, and challenges has been presented. In this way, effective studies and research backgrounds for search engines were examined and analyzed. According to the studies conducted on soil stabilization methods and related mechanisms, chemical stabilizers and the stabilization mechanisms of these materials were investigated. Finally, a conclusion was presented based on the materials and methods used for soil stabilization. Finally, according to the studied methods and materials, it was concluded that the most important factors that should be taken into account for the stabilization of desert sands and quicksands, as well as the stabilization of dust, are the issue of the environment and non-toxicity, preservation of natural resources and affordable It is economical. The investigated background of many of these papers suffers from the lack of attention to the criteria listed above, according to the present research's final analysis. As a result, while taking into account the aforementioned aspects, appropriate procedures and materials should be replaced and introduced with high efficiency.

Findings

Soil Stabilization

In cases where assets with high financial value, such as historical and cultural heritage, are at risk, remedial actions usually suffer from economic justification and are therefore impractical. The use of surfactants, spreading sand, spreading irrigation for moistening the soil surface, mechanical compaction, and returning water flows

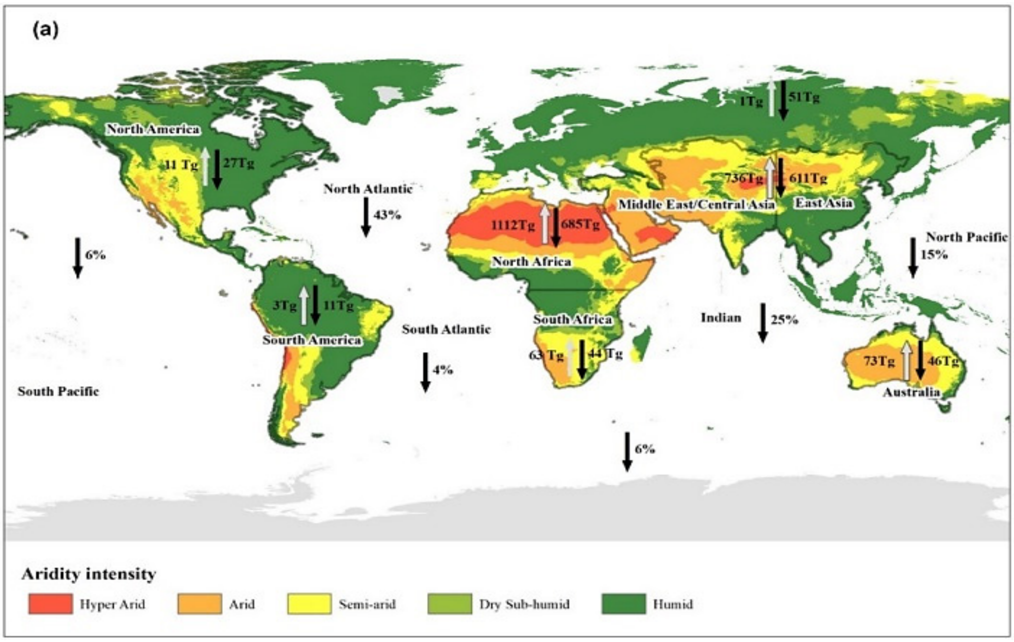

Figure 1) Map of global dust emissions and deposition (2022) [9].

to refill old lake beds are a few examples of soil stabilization measures. Desert dune stabilization typically offers some temporary primary protection against sand movement and promotes the establishment of vegetation. Mulching, soaking, using chemical stabilizers, biological encrustation, or covering the ground with anything else, like plastic sheets or nets, are all methods of primary stabilization [14].

Stabilization techniques can improve different qualities of soil by changing its geotechnical properties including compressive strength, Plasticity, Liquidity, Consistency, Permeability, etc., to produce improved soil. The advantages of soil stabilization include improving soil resistance, hardness, and durability and lowering soil flexibility, swelling, or shrinkage [15]. When exposed to external forces, the soil's ability to rearrange solid particles and pore spaces is referred to as the stability of soil structure [15]. In Table. 1, some studies were conducted on the stabilization of collected soil and quicksand and their results are summarized and compared.

Soil stabilization methods

The term "stabilization process" refers to the blending of two or more different types of soils or soil with chemicals that can alter their geotechnical properties to suit the project's requirements. The following are the main characteristics of stabilized soil:

1. Increasing the soil's strength, bearing capacity, and other engineering characteristics
2. Dust control in work environments
3. Creating an indestructible layer to preserve the natural or human-made structures
4. Encouraging the use of waste materials in stabilizing and increasing the resistance of soil and sand [25]

For more severe cases, mechanical stabilization may also involve soil surface slope modification, barrier installation, artificial vegetation, revegetation, and materials like rock mulch and plant material. Numerous biological and non-biological indicators, including the presence of vegetation and biological soil crusts, physical traits like soil texture and surface slope, and weather conditions all play a role in how well these various techniques prevent soil erosion [25]. With various additives like lime, cement, fly ash, etc., or by adding chemicals, polymers, and enzymes, chemical stabilization refers to altering the properties of soil by changing its chemical composition. Information on commercially

Table. 1) Recent studies on the stabilization of soil and quicksand.

Row	Title	Year	Soil Stabilization Methods	Results	Reference
1	Site application of biopolymer-based soil treatment (BPST) for slope surface protection: in-situ wet-spraying method and strengthening effect verification	2021	in-situ wet-spraying method	The compressive strength of the soil was linearly increased by increasing the dry density of the treated soil, regardless of the binding phase and mixing condition.	[17]
2	Synthesis and characterization of nano bentonite and its effect on some properties of sandy soils	2021	Using different amounts of nano bentonite	The results indicated that the available water (AW) and water holding capacity (WHC) was increased by adding bentonite and nano bentonite, compared to the control in pot and field experiments.	[20]
3	Improvement in the strength of salt-rich soft soil reinforced by cement	2018	Using different amounts of cement and metakaolin	By increasing the amount of metakaolin, the compressive strength of the sample increased.	[22]
4	Uniaxial compressive strength of soil containing sulfate salt with different amounts of salt and lime	2016	Using different amounts of lime	The value of the maximum uniaxial compressive strength of soil improved with lime is almost 17 times that of The unimproved mode is increased.	[18]
5	Corrosion mechanism for cementitious soils in three different sulfate solutions	2015	Use of cement	The sulfate solution has caused changes in the soil-cement sample, such as reducing the dimensions and creating cracks. The uniaxial compressive strength of the soil-cement sample decreased with the increase of sulfate ions and processing time.	[21]
6	Laboratory investigation of uniaxial compressive strength and hardness of clay improved with cement	2013	Using different amounts of cement	The uniaxial compressive strength of the samples increased by increasing the amount of cement and processing time. By increasing the amount of salt, the maximum axial stress has decreased.	[19]
7	Stabilization of silty sandy soil using lime and microsilica	2012	Use of lime and microsilica	The uniaxial compressive strength of samples stabilized with 2% lime increased by 2.5 times after 5 days. The California bearing ratio (CBR) of soil amended with 2% lime under submerged and non-submerged conditions shows values of 89 and 92.	[23]

available chemical additives designed to stabilize soils and reduce susceptibility to wind and water erosion is widely available [25]. One of the methods that are very important in research is the hydration method of cement and its derivatives [26]. In the diagram of Figure 2, the relationship between cement particles and sand particles is depicted.

According to Figure 2, Hydration is the process by which cement particles are hydrated - that is, they are covered with water and thus form a gel-like film. The reaction between water and cement forms small single crystals. With hydration, single crystals are transformed into each other and form a crystal network. Adjacent crystals are attracted to each other by van der Waals forces [26].

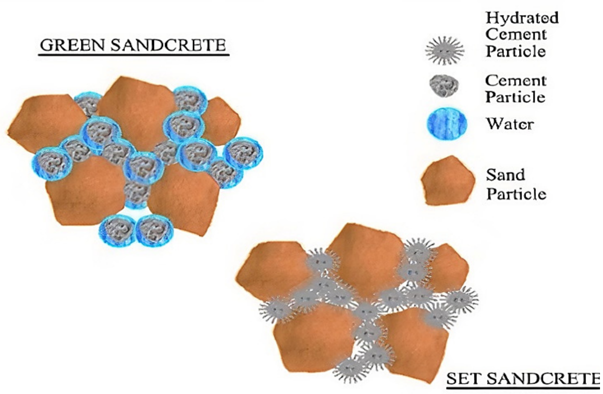

Figure 2) The bonding process between cement particles and sand particles [26]

The most popular techniques for chemical stabilization are the two methods of deep mixing and electroosmosis. The deep mixing method involves soil stabilization at a great depth. It is a land amendment technology in which a wet or dry stabilizer is injected into the ground using a mechanical mixing tool. The goal is to produce a stabilized soil mass that may interact with natural soil [27]. The positive cations on the soil particles can be moved and stabilized using the electroosmosis method, which involves embedding positive and negative electrodes in the soil layer and creating a direct electric current in the atmosphere. The soil environment's washing process, which resulted in the washing of the solutes and the loss of the binding agent between them, has been reversed with the aid of this method, and the establishment of suitable cations in the soil environment has improved the soil environment's shear resistance [28].

The term "soil stabilization" describes systems in which biological processes regulate and manage a network of chemical reactions in soil, and the end products of these processes alter the engineering properties of the soil. The time, speed, and spatial distribution of chemical reactions in the soil should be under the control of biological activity to stabilize soils [29]. Cellulose, starch, chitosan, beta-glucan, xanthan gum, agar gum, gellan gum, and polyacrylamide are among the most widely used biorepositories in geotechnology and soil stabilization processes.

Discussion

Cement

One of the most widely used substances for soil stabilization is Portland cement. Most soil types can be stabilized using cement. About 5 percent to 10 percent of cement is needed for each type of soil: sand, 12 percent to 15 percent for silt, and 12 percent to 20 percent for clay. Cement is widely used today to stabilize soil, enhance its mechanical and engineering properties, and control soil deformation and swelling behavior [30]. When cement is combined with water and other ingredients for its intended application, the hydration process starts and results in the hardening (cementing) phenomenon [31]. The hardening of cement strengthens the soil but does not change the soil structure. Cement-stabilized soil has outstanding resistance and durability as a base and sub-base material. It is also one of the best stabilizers for soil structure and is low in cost [32,33]. In the research, an extensive test was conducted on three studied soils, including sand, laterite, and clay, and their mechanical properties were investigated after they were

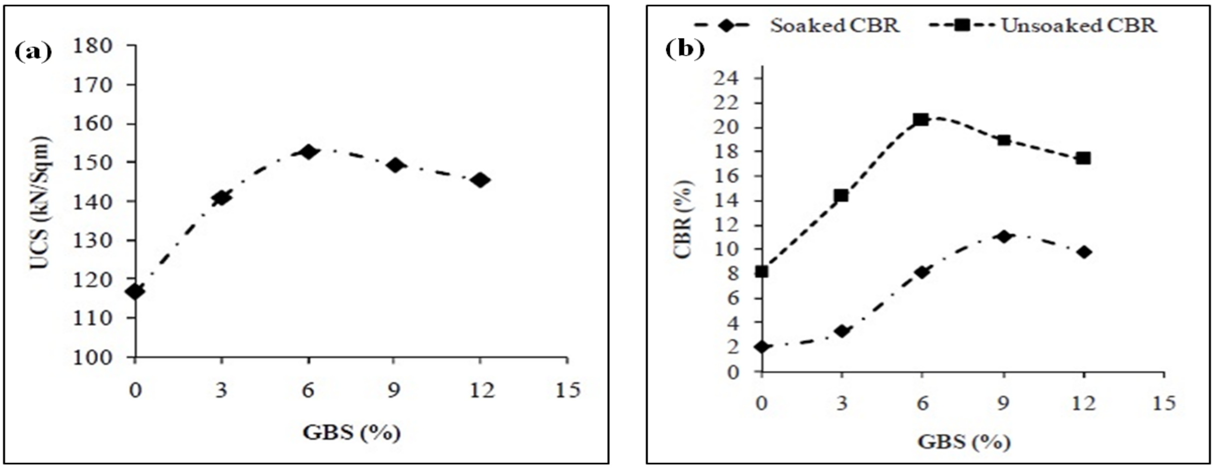

Figure 3) Unconfined compressive strength (a) and California bearing ratio (b) in terms of granulated blast furnace slag percentage [45].

stabilized with cement. The effect of cement content on the strength of soil samples stabilized with it was investigated. Optimum cement content was obtained for sand, laterite soil, and clay at 4%, 6%, and 7.5%, respectively. The ratio of California strength and modulus of rupture increased linearly with unconfined compressive strength. Also, the measured cohesion ($kN.m^{-2}$) shows its increase from 5.1 to 2250. The results showed that with the addition of cement, the dry unit weight ($kN.m^{-3}$) increases from 15.2 to 17.2 and the saturated unit weight ($kN.m^{-3}$) from 16.5 to 19.5 [34]. In another research, the application of nanomaterials in geotechnical engineering was investigated. This study showed that nanoparticles have a significant effect on strength, permeability, and resistance indicators. Different soil nanostructures show different properties due to their smaller dimensions [35].

Nanoclay

Today, the process of stabilization by nanomaterials is expanding. The idea of nanotechnology was first proposed by Richard Feynman in 1959. Many studies show that soils stabilized by nanoclay exhibit excellent hardening behavior and improved strength. Using nanomaterials in soil stabilization causes less permeability, which is very important in the construction of dams [31,33].

In a study, a group of researchers, by adding bentonite as a soil improvement agent, investigated the effect of its presence on the presence of beneficial bacteria that are effective on the growth of corn seeds. Bentonite is an effective soil stabilizer for improving the physical and chemical condition of agricultural sandy soils. It can cause the formation of bulk soil compounds, maintain moisture and increase the concentration of nutrients in the soil. A study investigated the effect of its presence on the presence of beneficial bacteria that are effective in the growth of corn seeds [36]. In one study, different types of ordinary clay and bentonite were used for the construction and stabilization of irrigation canals and dams. The results showed that increasing the wax properties of the improved soil decreases the permeability. Increasing the proportion of bentonite as well as two other clays from 4% to 20% increases the adhesive strength of the soil. In ratios of more than 16%, it reduces the maximum dry density of this soil [37].

In the following study, the addition of nanoclays to sandy wind erosion soil was investigated. The primary mechanism of nano-clay to prevent and increase wind erosion is to dry stable clumps of soil and connect them. As a result, nano-clay can improve the soil in the best way and stabilize

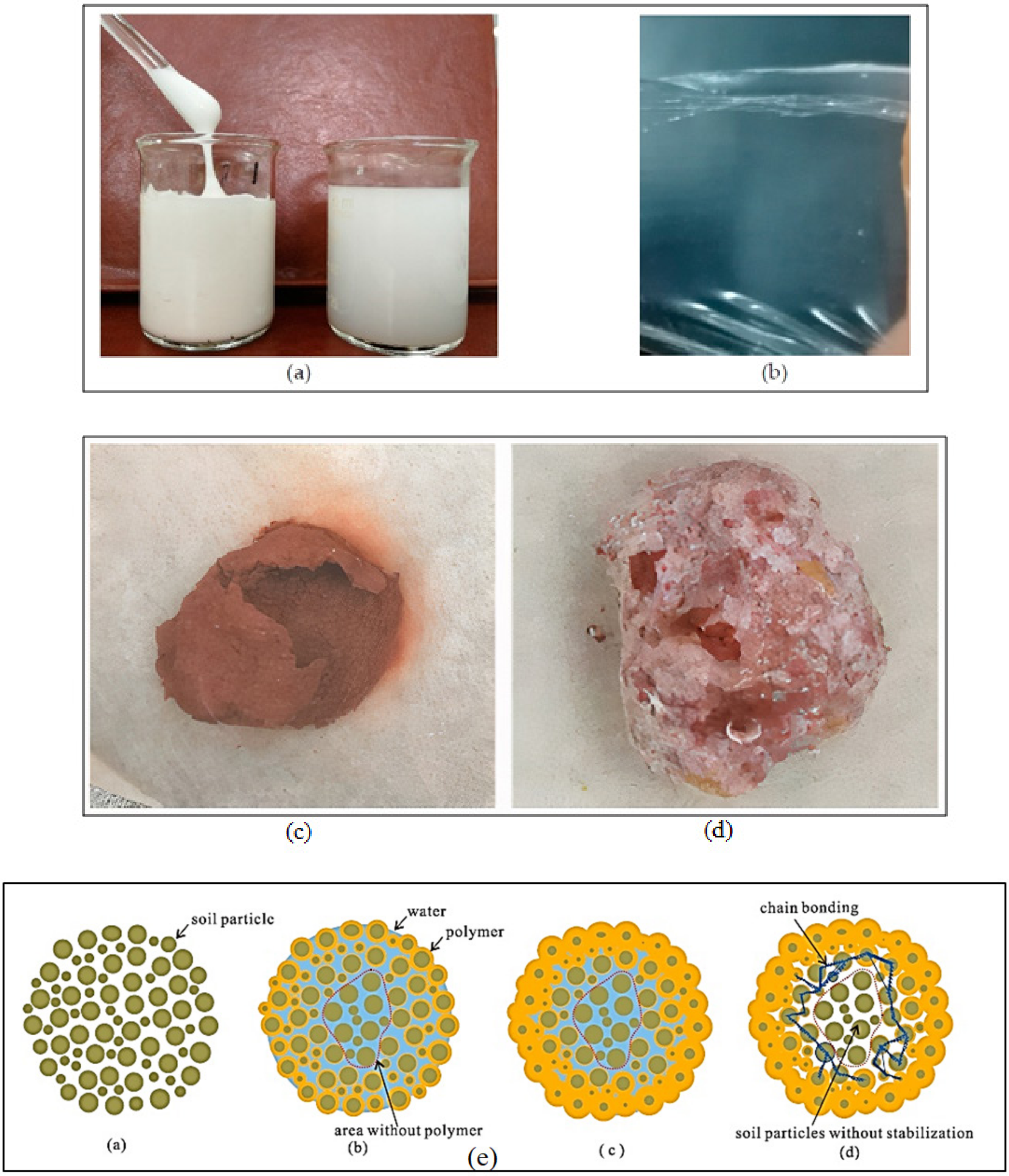

Figure 4) Different modes of dispersion in *Aqua* (a) initial mode and dispersion in water; (b) After water evaporation, in the form of an elastic film, (c) sand amended with 0.5% *ADNB* and (d) 5% *ADNB*, (e) a picture of the mechanism of infiltration and stabilization by polymer emulsion on the soil surface [51].

soil, increase soil mass, and significantly reduce soil erosion. The results showed that the soil moisture content increased by 18.9%. Also, the amount of soil wind erosion decreased by 99%. The Proportion in the 0.25-2 mm fraction increased by 2.5% and the Proportion in the 0-0.25 mm fraction decreased by 74% [38].

Lime

Lime addition is an effective strategy for

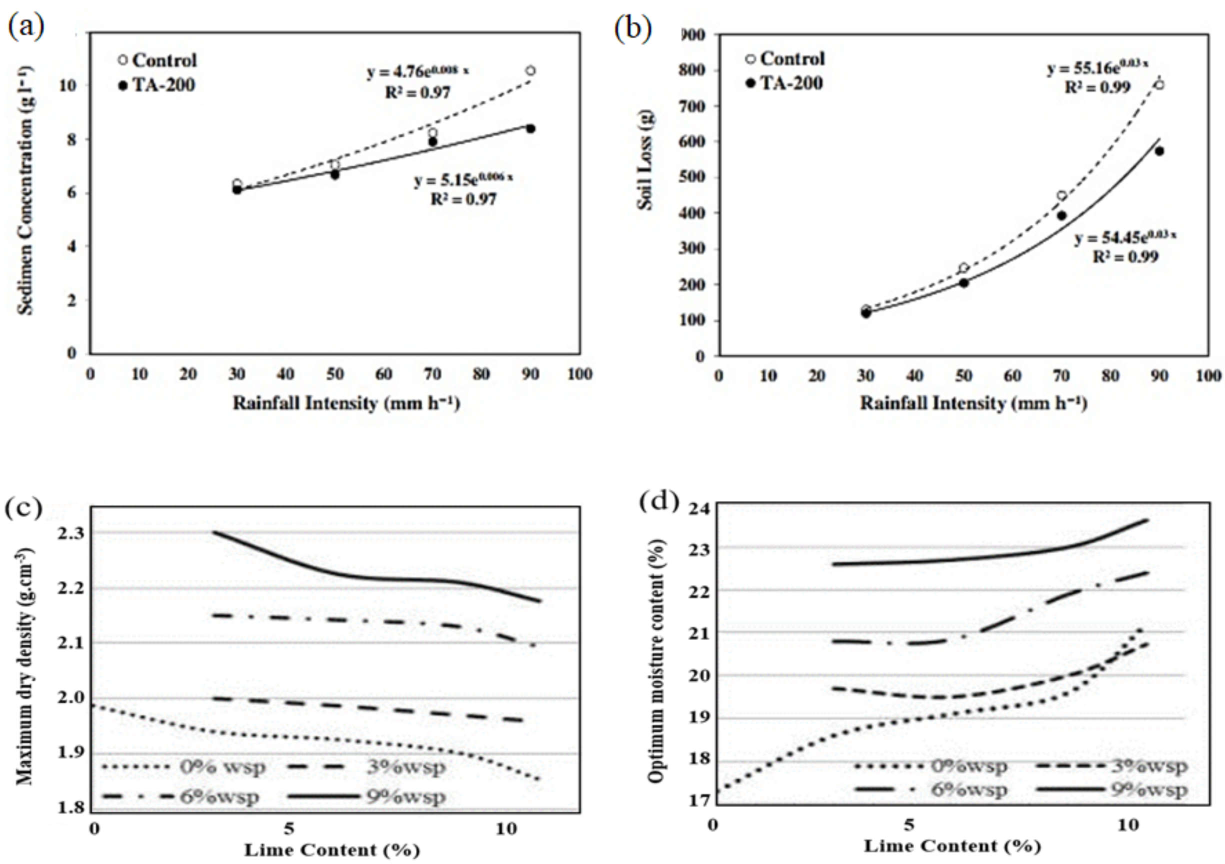

Figure 5) Relationships between rainfall intensity and organic and inorganic treatments on average sediment concentration (a), soil loss (c) *T-A 200 polyacrylamide* and Variation of maximum dry density (c) and optimum moisture content(d) with varying percentages of lime and WSP [55, 56].

stabilizing fine-grained soils. Different types of lime, such as calcitic quicklime or monohydrated dolomitic lime, may be used. Lime stabilization enhances the material's resistance to fracture, erosion, and permanent deformation in addition to strengthening it. Lime stabilization may refer to the pozzolanic reaction, in which water-soluble pozzolanic substances combine with lime to form cementitious compounds. Quicklime, CaO, or hydrated lime, $Ca(OH)_2$, can both produce this effect [40].

A study looked into how different amounts of lime and natural pozzolan affected the geotechnical characteristics of sandy soil. 20 improved soils were created by adding five different amounts of lime. 15, 14, and 28 days of curing were used to achieve the highest-compressive strength. The compressive strength of the soil can be increased by as much as 16 times by adding lime when compared to the unaltered soil. Additionally, compared to unamended soil, the addition of lime and pozzolan raises California's tolerance ratio under ideal water circumstances by up to 9 times and under saturated conditions by up to 12 times [42]. Another study was conducted using copper, lime, and cement slag industrial waste as raw materials to stabilize the soils on highway infrastructure. The maximum dry density and optimal moisture content for the soil amended with industrial waste were found to have significantly improved. Economically, the use of these additives is low-cost and can also reduce the amount of industrial waste used. Also, the measured unconfined compressive strength shows an increase from 66 to 157 ($kN.m^{-2}$) [43]

Blast furnace slag

Blast furnace slag is one of the by-products in the production of pig iron, which has the same chemical composition as cement. However, this composition is not a cement composition by itself, but it has latent hydraulic properties that can be revealed by adding lime or alkaline materials. Blast furnace slag can be divided into three forms [27]:

Air-cooled blast furnace slag (crystallized)

1. Granular or ball blast furnace slag (glass)
2. Blast furnace slag expanded

In a study, researchers worked on extensive soil stabilization using steel slag. They measured consistency limits, swelling index, compaction parameters, and unconfined compressive strength of natural and stabilized soils by adding 0, 5, 10, 15, 20, and 30% steel slat. Adding slag to the soil reduces the liquid limit of natural soil by about 33%, and the plastic index reduction is about 75%. The value of unconfined compressive strength in the composition of 10% slag is approximately 1.5 times higher than that of unamended soil [44].

In the paper, the potential of granulated blast furnace slag for soft soil stabilization was evaluated. Soft soil samples were obtained from a village in India. Different types of granulated blast furnace slag, i.e., 3%, 6%, 9%, and 12%, were used to stabilize soft soil. Based on resistance performance tests, the optimal amount of granulated blast furnace slag was 9%. The results show that including granulated blast furnace slag increases the strength of soft soils. For example, with unconfined compressive strength, the modified soil with 9% granulated blast furnace slag was approximately 28% higher than the bare soil. This phenomenon causes a reaction between cement and soil hydration and granulated blast furnace slag and causes a reduction [45]. Figure 3 shows the changes in the unconfined compressive strength (a) and California bearing ratio (b) in terms of granulated blast furnace slag percentage.

Fly ash

One of the four byproducts of coal combustion, fly ash is created when coal is burned. Class C and class F fly ash are the two main types of fly ash that are typically produced. Fly ash in class C is produced when burning lignite and coal. Anthracite, also known as bituminous coal, produces Class F fly ash when it is burned. Fly ash particles typically consist of hollow spheres of Silicon, Aluminum, Unoxidized iron, and Carbon Dioxide, though other chemical additives may also be present. Class F fly ash is rarely used because it lacks latent cementitious properties and needs an activator, such as lime or cement, to create stabilized pozzolanic mixtures. [26]

Researchers evaluated the wind erosion resistance of the soil layer using an indoor wind tunnel under simulated wind erosion conditions. Fly ash particles fill soil layers and Polyacrylamide, after dissolving in water, causes a flocculation effect. The lowest wind erosion at a speed of 8 m/s was related to the sample containing 10% fly ash and 0.1% Polyacrylamide. The wind erosion of soil is 81%-100% for improved soil and 57%-93% for non-stabilized soil [46].

In other research, a study was carried out on the stabilization of dunes using a combination of fly ash and biopolymers. There is a strong correlation between the strength and the porosity of the earthen materials. Results show the formation of a silica-rich surface layer between sand particles and their matrix. This indicates chemical interactions between silica aggregates and highly alkaline solutions. When river sand is replaced by dune sand, the amount of reduction in resistance is directly related to the rise in excess air content, and this shows that the decrease in resistance is due to the increase in air voids in the dune mortars. The compressive strength of geopolymer mortars exhibits a high association with their water sorptivity regardless of the type of sand used. This suggests that the porosity of the matching geopolymer matrix determines the strength of mortars primarily [47].

Bitumens and petroleum products

Petroleum-based materials have long been used for soil stabilization, but recently their use has been reduced, even banned in some areas. For example, petroleum products such as bitumen, asphalt, asphalt emulsion, or mineral oils, the adhesive and waterproof properties of these products make it possible to use them for soil stabilization and dust control in case of restrictions [25]. Since bitumen is an oil product, it cannot be mixed with water. Therefore, an emulsifier is added before bitumen with water. An emulsifier with water before adding the bitumen to the soil particles disperses it into suspension [33]. Bitumen requirements typically range from 4 to 7 percent. Inadequate bitumen use will result in a weak reduction, decreased strength, and negative effects on the compaction of the stabilized soil because it will only fill the gaps between the soil and rock particles. A group of researchers worked on soil stabilization with foamed bitumen for road paving in Western Australia. Foamed bitumen is a mixture of bitumen, air, and water. It was found to be successful due to its ease and speed of manufacture, compatibility with a wide range of aggregate types, and its relative immunity to weathering [48].

Polymers and Biopolymers

Polymers are large, long-chain molecules with high charge density composed of small repeating units (monomers). Due to the size and structure of the Polymers, they can affect the physical and chemical properties of the soil. Polymers can be cationic, anionic, or non-ionic. Anionic Polymers are the most commonly used form of soil amendment and can promote the formation of larger flocs that are released from solution by cations [25]and due to the dry climate setting, and the long half-life of radioactive isotopes, soil erosion poses a long-term health risk at the NNSS. The objective of this literature review is to present a survey of current stabilization methods used for minimizing soil erosion, both by water and wind. The review focuses on in situ uses of fundamental chemical and physical mechanisms for soil stabilization. A basic overview of the physical and chemical properties of soil is also presented to provide a basis for assessing stabilization methods. Some criteria for stabilization evaluation are identified based on previous studies at the NNSS. Although no specific recommendations are presented as no stabilization method, alone or in combination, will be appropriate in all circumstances, discussions of past and current stabilization procedures and specific soil tests that may aid in current or future soil stabilization activities at the NNSS are presented. However, not all Soils Corrective Action Sites (CASs. Biopolymers are synthetic polymers with natural starting materials like amino acids, sugars, natural fats, or oil. They can be degraded without harming the environment because they are made from naturally occurring, renewable resources. Their distinctive qualities and high stability have increased their popularity in numerous industrial applications [49]. These types of resins are environmentally friendly materials that are produced from biomass components and therefore can be considered sustainable sources [50].

Researchers introduced a soil stabilizer containing an organic polymer named *Aqua Dispersed Nanoparticles* (*ADNB*) They sprayed it on the soil surface to stabilize clay on sloping surfaces. *ADNB* can be dispersed in water at the nanoscale and always maintain its polymer chains. *ADNB* can quickly accumulate pores in the soil surface layer due to the high ratio of its polymer materials. This layer can then guard against immersion-related decomposition loss. Figure 4(a-d), shows the mechanism, function, and form of *ADNB* polymer emulsion [51].

In a study, a chitosan solution made from shrimp shell waste was used to examine the possibility of stabilizing clay. Chitosan has the potential to improve the mechanical properties of soil by increasing the interaction between soil particles.

Wet conditions promote greater particle interaction during the initial stages of processing. The interaction is strongly influenced by time and soil moisture. The combination of materials increases the compressive strength of the soil sample in the wet state under various durations of 1, 3, 7, and 28 days. Increasing the concentration of chitosan led to an increase in mechanical strength in the early stages but at high concentrations, it lost effectiveness. While it loses its effectiveness over time, increasing the moisture content increased adhesion in wet conditions [52].

Other Stabilizers

Pozzolans are siliceous and aluminum compounds that, by themselves, have little to no cementitious value but, when exposed to moisture and calcium hydroxide at room temperature, chemically react to produce cementitious compounds (ASTM C595). Pozzolan and lime can enhance efficiency, compaction, strength, and other soil engineering properties. The bearing strength of soil that has been stabilized with lime is improved by the addition of natural pozzolans [53]. Because they are less expensive than other traditional stabilization materials, fibers have been used in soil stabilization projects. These materials resist biological and chemical deterioration well and stop water erosion [26]. The use of fibers is one of the main methods of improving the engineering properties of soils. Polypropylene, polyester, and glass fibers are commonly used for soil reinforcement. The strength and elasticity of fiber-reinforced soils are useful for earthquake-resistant structures [54].

The soil can also be stabilized using a variety of chemicals, including Calcium Chloride, Sodium Chloride, hydrofluoric acid, Sodium Silicate, Phosphoric Acids, etc. These materials absorb moisture by increasing the surface tension between the particles, which slows down evaporation [25]. To stop or lessen water's damaging attack on the soil, waterproofing agents like Alkyl Chlorosilanes, Silicones, Amines, and quaternary ammonium can be used. The electrical attraction between the fine soil particles is heightened by organic salts like Calcium Chloride and iron Chloride, and this results in the accumulation or coagulation of a soil mass. For soil conservation, a variety of organic and inorganic mulches are used, and their effectiveness on the characteristics of the soil has been thoroughly examined from various angles (Figure 5a-b) [55]. Marble slab waste is taken in the form of stone powders. By reusing and recycling these waste materials as an additive in the soil to improve the geotechnical properties of the soil, we can minimize the effects of pollution caused by stone mines and make significant contributions to the economy and environment (Figure 5c-d) [56].

Organic non-petroleum products have also been used in soil stabilization. Lignin, the substance that binds wood fibers together in trees, and its derivatives have been proven soil binders. Oily wastes (e.g., food industry wastes and soybean oil) have many of the properties of light petroleum oils [25].

5. Conclusion

In this article, various techniques for stabilizing soil are discussed. The properties and applications of some well-known and frequently utilized chemical stabilizers are described. Desert dune stabilization typically offers some temporary primary protection against the movement of sand and gravel under the desert landscape. Mulching, soaking, chemical stabilizing, biological encrusting, and covering the ground with any other material are all methods of prior stabilization. For instance, only 15% of vegetation might be necessary to stabilize a sand surface. Sand and soil can be stabilized by stabilizing agents like cement, lime, nano clay, polymer, biopolymer, and others. The deterioration of flowing sands and desert dust is a serious and concerning issue in Iran's and the Middle East's geographic location. Researchers can examine this as an intriguing and significant research area because many studies fail to consider the factors mentioned above. Additional crucial factors are cost-effectiveness, availability, and non-toxicity of the substance or compound introduced. The primary goal of this work has been to investigate soil stabilizing methods and materials. Chemical soil stabilizers have been thoroughly investigated in terms of their mechanism and intended use. The main hypothesis of this study was to analyze previous studies and research in the areas of dust stabilization and desertification, weigh their benefits and drawbacks, and then provide appropriate solutions and ideas for how to overcome this problem. We conclude that a green stabilizer with a fair price is required to stabilize desert dust in light of the research conducted and analysis of the articles offered in this part. Future development of new and appropriate compounds is crucial due to the examined stabilizers' shortcomings and drawbacks, which include curing conditions, high cost, environmental issues, and other drawbacks.

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Conflict of interest
The authors declare no conflict of interest.

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