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Research Article
Effects of Nanoclay on Some Physical Properties of Sandy Soil and Wind Erosion

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Abstract
Wind erosion is a widespread phenomenon causing land degradation in arid regions. The capacity of nanoclay in soil erosion control has been assessed in wind tunnel experiments as a novel technology. To study the effect of nanoclay on stability of sandy soils against wind erosion, a laboratory research program was set up in wind tunnel. The soil samples were treated with distilled water as control and nanoclay at a rate of 2000 ppm were uniformly spread on the soil surface. The treatments were performed in the condition with wind velocity of 31.0, 55.2 and 67.3 km h^{-1}. The results showed that soil volumetric water content at 300 kPa increased (about 18.9%) with application of nanoclay. There was a positive function between the erosion amount and soil moisture content in the treatment of soil with nanoclay. The soil erosion amount decreased (more 99%) with the application of nanoclay. The proportion of 0.25-2 mm fraction increased (2.5%) and the proportion of 0-0.25 mm fraction significantly decreased (74%) with use of nanoclay. As a result nanoclay is able to fixate the sand and it has ability to stabilize the soil structure, increase aggregation and of course decrease soil erosion.

Key words: Wind erosion, wind tunnel, sandy soil, nanoclay

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INTRODUCTION

Many arid regions in the world will be experience enhanced desertification in the next decades (Moshki and Lamersdorf, 2011). A variety of natural and human factors are contributing to desertification, including dwindling vegetation cover, overgrazing, over exploitation of water and land resources, deforestation and soil erosion (Irshad *et al*., 2007). The soil erosion recognized in fields has destructive effects on the soil fertility. This adverse impact of the soil erosion is caused by loss of soil nutrients (Li *et al*., 2014). Wind erosion is recognizing as a serious soil degradation process in arid and semiarid regions. It can prevent agricultural productions (Ekhtesasi and Sepehr, 2009), loss of nutrients and reduction of soil fertility, loss of plants, landslide reinforcement and air pollution (Rafahi, 2006), deteriorates the environment (Bakker *et al*., 2007; Rosario-Diaz *et al*., 2013), especially human health (Wilson and Spengler, 1996). In Iran, wind erosion is the prevailing difficulty on 20 million ha of land area and is of specific concern in the central plain of Iran (Azimzadeh *et al*., 2008). There are different numbers of methods for stabilizing; Aeolian soils, such as physical and mechanical (Armbrust *et al*., 1964), biological way (Akbarian, 2010) and chemical (Vaezi, 2010; Movahedan *et al*., 2011). Several control measures have to be adopted in this field by considering account the technical, economic and time criteria through study and identification of optimum problem solving methods. Nanotechnology could have several applications in soil science (Lal, 2007). Nanoscience is of crucial importance to the soil sciences because many natural compounds of the soils are nanoparticulate or have nanoscale features (Mura *et al*., 2013). Montmorillonite nanoclays are hydrophilic and having a platy structure with a unit thickness of one nanometer or less (Armstrong and Fortune, 2007).

There is no information about the effectiveness of nanoclay for preventing soil loss through wind erosion. Thus, the effect of additive nanoclay on sandy soils was studied in this research and effect of wind velocity on erodibility of soils and water holding capacity of soil is also aimed to be discussed.

MATERIALS AND METHODS

The wind erosion experiments were conducted in the Laboratory of wind tunnel at College of Soil Science in Islamic Azad University of Isfahan (Khorasgan). Length, width and height of the wind tunnel are 13, 0.5 and 0.5 m, respectively. In order to estimate soil behavior against wing blowing, a $100\times30\times5$ cm^3 tray was used to locate soil samples. A double-walled plastic room is set at the end part of sediment sampler in which, during flowing of wind, sediment particles are collected and cleared air is released. The soil used in the present tests was obtained from the Khara desert, which is located in Isfahan Province in Central of Iran (52°40 E, 32°23 N, elev. 1450 m.a.s.l). In the experimental area, the mean annual precipitation is 68.55 mm and, the mean annual air temperature is 15.5°C. Soil texture in this area is sandy. These soils are loosely structured and vegetative cover on land is low due to soil dryness, thus, they are susceptible to wind erosion. The texture of soil is a main factor that influences the capability of soil avoiding wind erosion.

The experimental soils air-dried and were packed in trays and were treated with different treatments. In order to mitigate soil erosion under-wind conditions, nanoclay has to be added to the soil surface. Uniformly spray of nanoclay solution (500 cc) at concentration of 2000 ppm and distilled water (the same volume) as control were treated on the soil surface. The threshold wind speed was investigated exposing the untreated sample trays and increasing wind speeds. The wind speed at which soil particles begin to move in the wind stream is called the threshold velocity (Chepil and Woodruff, 1963). The treatments were carried out in the condition with wind velocity of 31.0, 55.2 and 67.3 km. Every experiment lasted after 5.0 min.

Separation of nanoclay: The selected soil for nanoclay separation was a Vertisol taken from Central Zagros. After air-drying soil samples were sieved through 2 mm sieve size and treated with 30% hydrogen peroxide to remove soil organic matter. Then, soils were suspended in 100 mL of 1 M NaCl in a bottle, stirred well and were heated at about 80°C. The suspensions were dispersed using 214 J by ultrasonic dispersion. Separation of particle-size <2 µm fractions was performed by sedimentation procedures based on Stoke's law. The clay suspension was centrifuged at 3000 rpm for 40 min. The pellet was collected. These were moderately stirred for 40 min and nine-fold washed with distilled water (Li and Hu, 2003). Montmorillonite nanoclay was characterized through Scanning Electron Microscopy (SEM) (Seron model AIS-2100) in Amirkabir University, Tehran, Iran. Also, a Bruker D8 model XRD machine at the central laboratory of Shahrkord University, Shahrkord Iran was used for identification of the minerals.

Aggregate size distribution: The size distribution of soil aggregates was measured by drying sieving through a series of sieves (2, 1, 0.425, 0.25, 0.106 and 0.053 mm). For each treatment, the three replicate of soil samples were used. Briefly, 50 g of air-dried soil samples were spread uniformly on the top of a 2 mm sieve. A portable flat-sieve shaker was used to shake for 1 min. The material is passing from each sieve was separately weighed.

Water retention: Soil samples in the small core samplers (still adhered) were gently wet by capillary. To measure the water retention at 300 kPa, we were imposed using a pressure plate apparatus (Dane and Hopmans, 2002).

Statistical procedures: Statistical procedures were analyzed using the software package SPSS 19 for Windows. The effect of nanoclay on wind erosion control was determined by one-way analysis of variance (ANOVA). Mean differences were considered significant when $p<0.05$ Duncan's Multiple Range (DMR) Test.

RESULTS AND DISCUSSION

The effect of nanoclay on wind erosion at three wind speed (31.0, 55.2 and 67.3 km h^{-1} for 5 min) is presented in Table 1. The threshold wind speed for the untreated soil was 31 km h^{-1}. The results stated that use of nanoclay on the soil surface can enhance the capability of soil against the wind erosion and amount of soil erosion was significantly higher in control treatment compared to the nanoclay treatment (Table 1). Using nanoclay on the soil surface could enhance the capability of avoiding the wind erosion (Padidar *et al*., 2014; Olesen, 2010) and reduced the amount of loose erodible material. The content of clay in soil has more impact on soil aggregation; therefore, soil with higher clay has more stable aggregates, which may increase the capacity of soil against wind erosion (He *et al*., 2008).

Application of FA (Fly Ash) and PAM (Polyacrylamide), advance the formation of stable soil structure and reduce the content of eroded particles on the surface (Yang and Tang, 2012), however, the persistence to wind erosion of the soil treated with FA was finite.

He *et al.* (2008) showed that application of 2 gm^{-2} PAM to the surface of a sandy loam and loam soils could control the wind erosion efficiently.

Hazirei and Zare (2013) found that utilization of the clay-lime mulch was an appropriate treatment for temporary stabilization of sand dune until the establishment of the plant.

Spray of nanoclay produces a layer on the soil surface that contains the aggregates and particles. Nanoclay binds the surface particles together to form a crust. In fact, nanoclay increases the soil resistance to wind, by producing this thin layer. The surface layer of nanoclay samples of sandy soil is completely homogenous, relatively hard and without crack after drying and it is penetrate easily by water.

The SEM images of montmorillonite nanoclay separated from the soils are displayed in Fig. 1. Scanning electron microscopy images showed that produced nanoclay has dimension of 90 nm thick and the structure of this nanoclay is platy. Nanoparticles having a diameter at least one dimension in the order of 100 nm or less (Auffan *et al*., 2009).

Table 1: Effect of nanoclay on the soil erosion (g) at three wind speeds

	Nanoclay concentration (ppm)	
Speed (km h^{-1})	0	2000
31.0	1.67 (0.11)^{a}	0.05 (0.013)^{b}
55.2	32.87 (1.29)^{a}	0.22 (0.017)^{b}
67.3	1071.82 (8.68)^{a}	1.52 (0.08)^{b}
Mean	368.79	0.60

^{a,b}In each row, means followed by the same letters are not significantly different at $p<0.05$. Each value represents Means±SE (n = 4)

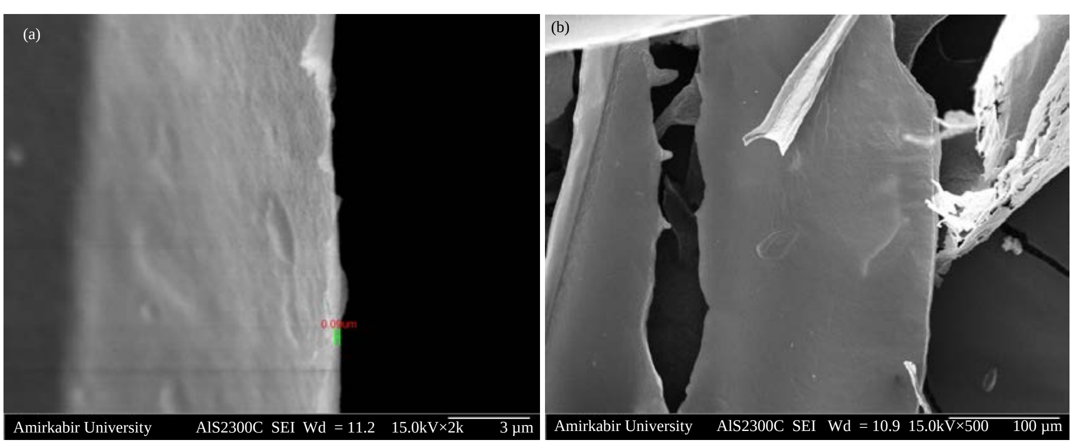

Fig. 1(a-b): Scanning Electron Microscopy (SEM) images from montmorillonite nanoclays separated from soil

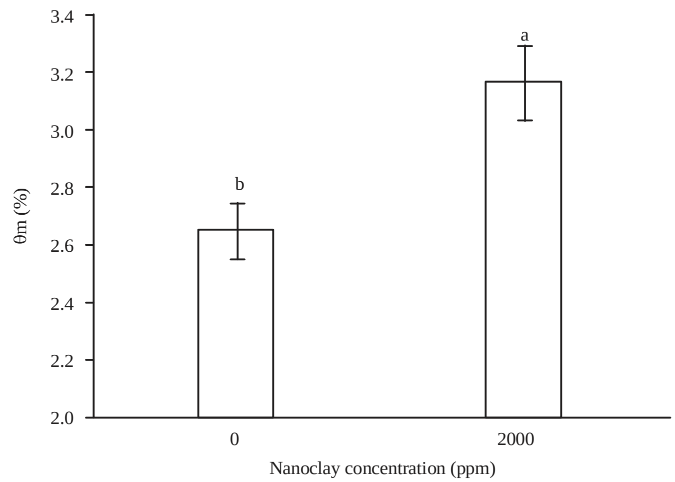

Fig. 2: Effect of nanoclay on water retention in sandy soil. [a,b]Means followed by the same letters are not significantly different at $p<0.05$

Table 2: Effect of nanoclay on proportion of aggregate size classes

	0.25-2.0 (mm)	0.05-0.25 (mm)
Treatments	------------(%)------------	
0	48.38[b]	1.61[a]
2000 ppm	49.59[a]	0.42[b]

[a,b]In each column, means followed by the same letters are not significantly different at $p<0.05$

Effect nanoclay on soil aggregation: Aggregate stability is a measure of the structural stability of soils. One of the most important aspects of nanoclay is their ability to cement the particles to each other and therefore leads to more stability of aggregates. The effect of nanoclay on the proportion of aggregate size is represented in Table 2. The results revealed that the proportion of 0.25-2 mm fraction significantly increased with use of nanoclay, whereas, the proportion of 0.05-0.25 mm fraction significantly decreased with application of nanoclay. Many researches show the effect of aggregates in soil on wind erosion is quite important, the structure of dry aggregates and clod in the soil were very sensitive to the wind erosion, the higher the dry aggregate is in soil, the less the amount of wind erosion is (Chepil, 1950). Chen (1991) discovered that soil with higher clay particle content had more stable aggregates against wind erosion. Nanoclay can generate aggregates in the soil (Olesen, 2010). An increase in soil aggregate stability implies a decrease in soil degradation; hence aggregate stability and soil degradation are interlocking.

Water retention: The soils with low water content and low organic matter content are prone to wind erosion during the dry and windy fallow period (He *et al*., 2008). Soil volumetric water content at 300 kPa increased by nanoclay (Fig. 2). The amount of soil water retention treated with nanoclay was observed higher than in control. Using of nanoclay causes increase storage moisture soil in sandy soil. The use of nanoclay may change the soil surface area and balance proportion of pore size distributions. Nanoclay to having hydrophilic properties, leading to the creation of changes in soil properties such as increases soil moisture and micro porosity. Increasing the content of clay in the soil vouches the increment of the water retention. These results agreed with the findings of Olesen (2010) who showed that nanoclay could lead to increase the amount of soil water available in desert lands. Karbout *et al*. (2015) stated that addition of clay ameliorates the water retention capability of the sandy soil. The erosion amount of soil with nanoclay was less notable than the erosion amount of control treatment. All these indicate that nanoclay using could enhance the capability of sandy soil avoiding the wind erosion remarkably.

CONCLUSION

In this study positive influences of nanoclay on soil wind erosion control were acquired. The use of nanoclay in the soil can more enhance the capability of soils avoiding the wind erosion. The effect of nanoclay with 2000 ppm on controlling wind soil erosion was better than water. In fact, the mechanisms of erosion control by nanoclay are increasing dry aggregates stability and their connections are resistances to wind erosion. Nanoclay seems to have some advantageous effect in forming and maintaining the aggregate structure. As a result it has high aggregate stability when used in soils, which is a major reason to control wind erosion by application of nanoclay. Also results showed that nanoclay causes increasing water retention in sandy texture comparison with control of soil. Water holding capacities of nanoclay and its control release have the main significant role in arid land. These conclusions are only based on laboratory wind tunnel tests, further experiments and field observations and tests are needed to verify these conclusions.

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