

EFFECT OF NANOCCLAY ON SOIL EROSION CONTROL

Marjan Padidar¹, Ahmad Jalalian², Majid Abdouss³, Payam Najafi², Naser Honarjoo², Jaber Fallahzade¹

1. *Young Researchers and Elite Club, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran*

2. *Department of Soil Science, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran*

3. *Department of Chemistry, Amirkabir University of Technology, Tehran, Iran*

E-mail: M25padidar@gmail.com

Abstract

Wind erosion is a widespread phenomenon in arid region. The purpose of this study was assessed the capacity of nanoclay to control soil erosion in wind tunnel experiment. The nanoclay isolated from soils was dominant in montmorillonite. A sandy soil from the Khara desert, nearly 100 km East of Isfahan (Central Iran) was used. The soils of this area are structurally unstable and sandy texture makes these soils highly erodible for most seasons. After packing the soil samples in the trays and before setting them in the wind tunnel, the samples were treated with distilled water as control and nanoclay at a rate of 2 g L⁻¹ were uniformly spread on the soil surface. The volume of water and nanoclay solutions was 0.5 L. The treatments were performed in the condition with wind velocity of 8.60, 15.34. Every experiment lasted 5.0 min. The results reveal that the soil erosion amount decreased with the usage of nanoclay. The effect of nanoclay with 2 g L⁻¹ on controlling wind erosion was significantly better than distilled water as control treatment. Consequently Nanoclay able to fixate the sand and it has ability to stabilize the soil structure, increase aggregation and of course decrease soil erosion.

Keywords: Central Iran; Nanoclay; Sandy Soil

1. INTRODUCTION

Arid and semi-arid regions are the principal domains of wind erosion throughout the world (Gomes et al., 2003). About 90 % of land in Iran is arid or semiarid (Qadir et al., 2008). In these regions, soils (especially desert soils) with low precipitation, very low organic matter and structure less or week structure are prevalent (Fallahzade and Hajabbasi, 2012). So these soils are prone to wind erosion during the windy period. Wind erosion results in destruction of soil structure and land production potential (Lopez, 1998) and health risk (Zobeck and van Pelt, 2006). There are different strategies to control wind erosion. The most widely applied control measures is mulched with crop residues (Sterk, 2003), gravel mulch and petroleum mulch (Hashemimanesha and Matinfar, 2012) and during recent decades polyacrylamide (Mamedov et al., 2009; Yang and Tang, 2012). Nanotechnology could have several applications in soil science (Lal, 2007). Montmorillonite nanoclays are unique clays having a platy structure with a unit thickness of one nanometer or less. However, no information is available regarding the effectiveness of nanoclay for preventing soil loss through wind erosion. So the application of nanoclay maybe is an effective and viable alternative method to prevent wind erosion. Thus, the objective of this study was to use wind tunnel to examine the effect of nanoclay on soil wind erosion control, especially in the arid regions, such as central Iran, where surface sandy soils cannot supply sufficient resistance for wind erosion control during the windy period.

2. MATERIALS AND METHODS

2.1. Description of soil samples

The soil samples of our experiments were provided from Khara desert in Varzaneh area, with a flat topography and nearly 100 km East of Isfahan, Central Iran (32° 23' N, 52° 40' E). The climate of this area is arid and the mean annual precipitation and evaporation are 68 and 2800 mm, respectively. The Khara desert is characterized by soils that generally have sandy texture, low fertility and organic matter, being the most limiting soil nutrient for planting growth and crop production. The mentioned lands are covered by a low coverage of *Haloxylon* and *Calligonum*. The soils are structurally unstable and have low water holding capacity. Soil surfaces are mostly bare and without adequate wind erosion controls. Moreover, the dry climatic condition and sandy texture soils without sufficient organic matter have made these soils highly erodible for most seasons of the year.

2.2. 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. 20 g of soil samples 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

2.3. Experimental design

The wind erosion experiment was conducted in a straight line forces wind tunnel with a test section size of 2.5 (L) × 0.3 (W) × 0.3 m (H) in the Laboratory of College of agriculture, Islamic Azad University of Isfahan (Khorasgan). Wind velocity was controlled continuously from 0.2 to 15.34 m S⁻¹. Soil samples were covered on trays which had a length of 30 cm, a width of 100 cm, and a height of 5 cm. After packing the soil samples in the trays and before setting them in the wind tunnel, the samples in the trays were treated with two treatments: (1) distilled water as control and (2) nanoclay at a rate of 2 g L⁻¹ were uniformly spread on the soil surface. The threshold wind speed was investigated by exposing the sample trays to a series of consecutive increasing wind speeds. Starting at 2 m s⁻¹, the speed was increased until sand particles began to be blown away by wind. The volume of water and nanoclay solutions was 0.5 L. The treatments were performed in the condition with wind velocity of 8.60, 15.34 m s⁻¹. Every experiment lasted 5.0 min.

3. RESULTS AND DISCUSSION

SEM images from montmorillonite nanoclays separated from soil are displayed in Figure 1. The SEM images showed that the dimensions of montmorillonite nanoclay were of 50 to 70 nm.

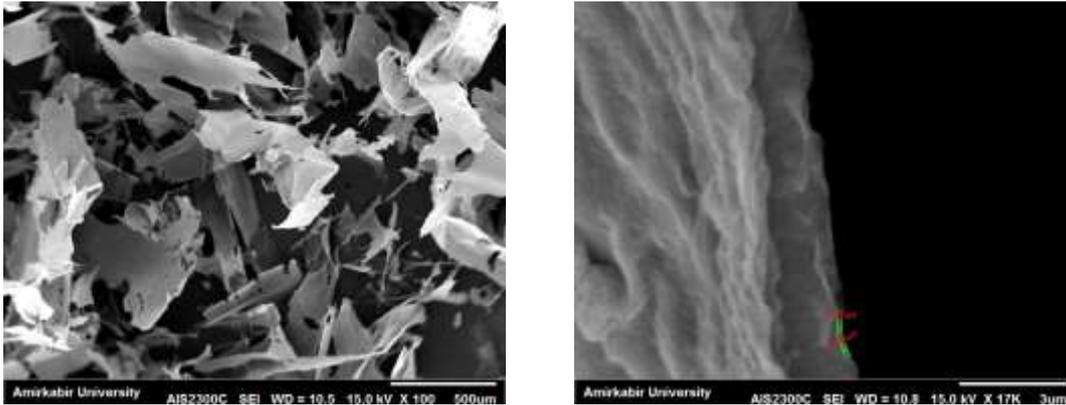


Fig. 1. scanning electron microscopy (SEM) images from montmorillonite nanoclays separated from soil

The result revealed that the threshold wind speed of the untreated soil was 8.6 m s^{-1} . The effect of nanoclay on the wind erosion at a wind speed of 8.6 and 15.34 m s^{-1} for 5 min is listed in Tale 1. Results reveal that the soil erosion amount decreased with the use of nanoclay. In fact, the results stated that the nanoclay using on the soil surface can enhance the capability of soil against the wind erosion. The amount of soil erosion was significantly higher in control treatment compared to the nanoclay treatment.

Table 1 Effect of nanoclay on the wind erosion ($\text{g m}^{-2} \text{ h}^{-1}$) of the experimental soil at three wind speeds

Speed(m s^{-1})	Nanoclay concentration (g L^{-1}) control	2
8.60	60.0 (4.21) A	1.8 (0.5) C
15.34	1183.5 (46.7) A	8.0 (0.6) B

From Table 1, it has seen that the soil erosion decreased with the use of nanoclay at a wind speed of 15.34 m s^{-1} for 5 min. The results showed that the application of nanoclay led to significant reduction of soil erosion in two treated wind speeds. Also, the soil erosion amount decreased with the use of nanoclay. The studied soil is structure-less or structurally unstable. 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. All these indicate that nanoclay has a cementation action on the unstable aggregates in soil. The clay in soil has more effect on the aggregates; generally, soil with higher clay has more aggregates, which could increase the capacity of soil resisting wind erosion (Chen, 1991; He et al., 2008). Ćirić et al. (2012) reported that clay particle is a cementation substance. They observed that a highly significant correlation between clay content and aggregate stability. Probably, the nanoclay solution in the soil forms network structures that bind the sand particles together and consequently, this solution is able to offer positive adhesion of the soil. Therefore, addition of nanoclay solution in soil is able to improve the capability of soil against wind erosion. Also the test results of applying nanoclay in sandy soil in Egypt showed that nanoclay could lead to decrease of wind erosion and produce aggregates in the soil (Olesen, 2010).

CONCLUSIONS

In this study, positive influences of utilization of nanoclay on soil wind erosion control were acquired. The nanoclay works as a binder and generate aggregates in the soil. In fact, the mechanisms of erosion control by nanoclay are increasing dry aggregate stability and their connections are resistant to wind erosion. Covering of deserts by nanoclay could lead to the mitigation of wind erosion. These conclusions are only based on laboratory experiment, further field tests are required to verify these conclusions.

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