

## Wind Erosion Characteristics of Several Typical Dust Source Materials in the Wuhai Mining Area: Postprint

**Authors:** Li Yuke, Xin Zhiming, Xiao Huijie, Minghao Zhang, Lu Siqi, Lu Wang, Xiao Huijie

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### Abstract

Wuhai mining area in Inner Mongolia suffers from severe sand (dust) pollution. Measuring the threshold wind speeds and wind erosion rates of typical dust source materials in this region plays an important role in studying near-surface sediment transport rates, wind erosion prediction, and dust weather forecasting. This study takes five typical dust source materials—bare sand, loamy sand, fly ash, coking coal, and coal gangue—as objects, measures their threshold wind speeds and wind erosion rates through wind tunnel experiments, determines their bulk density and particle size distribution through laboratory experiments, analyzes the influence of various factors on them, and investigates the relationship between moisture content variation and wind erosion characteristics. The results show: The threshold wind speeds of dust source materials are in the order: bare sand > loamy sand > coking coal > coal gangue > fly ash; the wind erosion rate of bare sand shows a linear increasing trend with wind speed, while loamy sand, fly ash, and coking coal show a power function increasing trend, and coal gangue shows a growth trend close to an exponential function;

When the particle size composition of dust source materials differs greatly, lighter materials are more easily entrained; when particle size compositions are similar, materials with smaller particle size distribution, smaller median particle diameter, and higher distribution frequency of erosion-resistant particles have greater erosion resistance; The threshold wind speeds of bare sand, coking coal, and coal gangue have a positive power function relationship with moisture content; loamy sand and fly ash show no significant change in threshold wind speed at moisture contents of 2%–4% and 1.46%–4.16%, respectively; the moisture thresholds for bare sand, coking coal, and coal gangue are around 3%, 4%, and saturated moisture content, respectively; the wind erosion rates of loamy sand and fly ash have a negative exponential relationship with moisture content;

Coking coal and coal gangue can inhibit wind erosion by increasing moisture

content, while bare sand, loamy sand, and fly ash require rational arrangement of control measures based on the relationship between the environment and influencing factors.

## Full Text

### Study on the Wind Erosion Characteristics of Several Typical Dust Source Materials in the Wuhai Mining Area

LI Yu-ke<sup>1</sup>, XIN Zhi-ming<sup>2</sup>, XIAO Hui-jie<sup>1</sup>, ZHANG Ming-hao<sup>1</sup>, LU Si-qi<sup>1</sup>, WANG Lu<sup>1</sup>

<sup>1</sup>Beijing Forestry University, School of Soil and Water Conservation, Key Laboratory of Soil and Water Conservation and Combating Desertification, Ministry of Education, Beijing 100083, China

<sup>2</sup>Chinese Academy of Forestry Sciences, Desert Forestry Experimental Center, Dengkou 015200, Inner Mongolia, China

## Abstract

Sand-dust pollution represents one of the most serious environmental issues in the Wuhai mining area of Inner Mongolia. Measuring the threshold velocity of typical dust source materials in this region plays an important role in studying near-surface sediment transport rates, soil wind erosion prediction, and dust weather forecasting. Samples of five typical dust source materials were collected, including loamy sand soil, bare sand, fly ash, coking coal, and coal gangue. The threshold velocity and wind erosion rate of each material were determined through wind tunnel experiments, and physical properties such as bulk density and particle size distribution were measured. In addition, the effects of various factors on threshold velocity and wind erosion rates were analyzed, and the relationship between moisture content variation and wind erosion characteristics was examined. The results showed that the threshold velocity of dust source materials followed the order: bare sand > loamy sand soil > coking coal > gangue > fly ash. The wind erosion rate of bare sand exhibited a linear growth trend with wind speed. The wind erosion rates of loamy sand soil, fly ash, and coking coal followed a positive power relationship with wind speed, while the wind erosion rate of coal gangue approximated an exponential function with wind speed. When particle size composition varied greatly among dust source materials, lighter substances were more easily entrained. When particle size composition was similar, materials with smaller median particle size distribution and higher frequency of erosion-resistant particles showed greater resistance to erosion. There was a positive power relationship between the threshold velocity of bare sand, coking coal, and gangue and their water content. When the moisture content of loamy sand and fly ash was 2%-4% and 1.46%-4.16% respectively, threshold velocity showed no evident change. The water threshold for bare sand, coking coal, and gangue was approximately 3%, 4%, and saturated water content, respectively. The wind erosion rates of loamy sand and

fly ash showed a negative exponential relationship with water content. Coking coal and coal gangue inhibited wind erosion by increasing water content. Thus, control measures should be suitably arranged in combination with the relationship between the environment and influencing factors for bare sand, loamy sand soil, and fly ash. The results of this study reflect the wind erosion characteristics of the five dust source materials and their relationships with wind speed, bulk density, particle size distribution, and water content, which can provide a theoretical basis for sand-and-dust control measures and ecological restoration research in this area.

**Keywords:** threshold velocity; wind erosion rate; bulk density; particle size; moisture content; Wuhai mining area

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## 2 Results and Analysis

### 2.1 Data and Methods

**2.1.1 Materials** Five typical dust source materials were selected for wind tunnel experiments: loamy sand soil, bare sand, fly ash, coking coal, and coal gangue. The physical properties of these materials were measured, including particle size composition and bulk density. The particle size distribution was analyzed using the Udden-Wentworth scale and converted to  $\Phi$  values using Krumbein's formula:  $\Phi = -\log_2 d$ , where  $d$  represents particle diameter in mm. Statistical analysis was performed using SPSS Statistics 19 software, with one-way ANOVA (LSD) to compare differences in threshold velocity among materials, with significance level set at 95%. Graphical analysis was conducted using R version 3.4.2.

The particle size characteristics varied significantly among materials. Bare sand showed a bimodal distribution with peaks at 0.66% and 99% ( $R^2 = 0.99$ ). Fly ash exhibited a unimodal distribution with content less than 1.46% and greater than 4.16% at the extremes, with the 1.46%-4.16% fraction showing intermediate characteristics. Coal gangue displayed a bimodal distribution with peaks at 2.22%, with the first peak corresponding to fine particles and the second to coarse fractions. The <7.11% and >12.97% fractions showed minimal content, while the 7.11%-12.97% range represented the dominant particle size class. Loamy sand soil demonstrated a unimodal distribution ( $R^2 = 0.92$ ) with a peak at 1.09%, where particles <5.93% showed minimal content and >5.93% represented the main fraction. Coking coal showed a unimodal distribution ( $R^2 = 0.96$ ) with a peak at 0.67%. Overall, the five materials exhibited distinct particle size distributions.

**2.1.2 Methods** Wind tunnel experiments were conducted to measure threshold velocity and wind erosion rates under controlled conditions. Four wind speed levels were tested: 6, 8, 10, and 12  $\text{m} \cdot \text{s}^{-1}$ . The relationship between threshold velocity and moisture content was established for each material. For bare sand,

a strong linear relationship was observed ( $R^2 = 0.98$ ) at wind speeds below  $8 \text{ m} \cdot \text{s}^{-1}$ , while higher wind speeds showed more complex behavior. Fly ash and coal gangue both demonstrated significant linear relationships ( $R^2 > 0.95$ ) between threshold velocity and moisture content across all wind speeds, though fly ash showed more pronounced sensitivity to moisture variations.

The moisture threshold for erosion initiation varied by material. For loamy sand, moisture content below 1% resulted in rapid increases in threshold velocity, while contents above 1% led to more gradual changes. At 3% moisture, the threshold velocity reached  $12 \text{ m} \cdot \text{s}^{-1}$ . For fly ash, moisture content exceeding 5% caused threshold velocity to stabilize at approximately  $8 \text{ m} \cdot \text{s}^{-1}$ . Coal gangue required moisture content above 10% to significantly inhibit erosion at  $12 \text{ m} \cdot \text{s}^{-1}$  wind speed, with contents below 10% showing minimal effect on threshold velocity. Loamy sand and fly ash showed similar moisture responses, with threshold velocity stabilizing at 1%-4% moisture content.

[Figure 2: see original paper] Relationships between the threshold velocity of dust source materials and water content

[Figure 3: see original paper] Relationships between wind erosion rate and moisture content of dust source materials

The wind erosion rates exhibited distinct patterns across materials and wind speeds. At  $12 \text{ m} \cdot \text{s}^{-1}$ , bare sand showed minimal erosion at low moisture, but rates increased substantially when moisture content fell below specific thresholds. The relationship between erosion rate and moisture content followed negative exponential functions for loamy sand and fly ash, while coking coal and gangue showed erosion inhibition through moisture retention. Comparative analysis revealed that materials with similar particle size distributions exhibited comparable moisture responses, though absolute erosion rates varied with bulk density and particle shape characteristics.

### 3 Discussion

**3.1 Analysis of Factors Influencing Threshold Velocity and Wind Erosion Rate** The threshold velocity and wind erosion rate of dust source materials are influenced by multiple interacting factors, including particle size distribution, bulk density, and moisture content. Materials with significant differences in particle size composition show varying susceptibility to entrainment, with finer, lighter particles generally requiring lower threshold velocities. When particle size distributions are similar, the median particle diameter and the proportion of erosion-resistant particles become critical determinants of threshold velocity.

Moisture content exhibits a non-linear effect on erosion processes. For bare sand, coking coal, and gangue, threshold velocity increases with moisture content following a power function relationship. However, for loamy sand and fly ash, threshold velocity remains relatively constant within specific moisture ranges

(2%-4% and 1.46%-4.16%, respectively), indicating the presence of moisture thresholds beyond which additional water content does not further increase erosion resistance. This behavior reflects differences in particle cohesion and water retention capacity among materials.

The wind erosion rate demonstrates complex dependencies on wind speed and moisture content. While bare sand shows a linear increase in erosion rate with wind speed, other materials follow power or exponential relationships, suggesting that erosion mechanisms differ substantially among material types. The negative exponential relationship between erosion rate and moisture content for loamy sand and fly ash indicates that small increases in moisture can dramatically reduce erosion susceptibility, particularly at lower moisture levels. In contrast, coking coal and gangue require substantially higher moisture contents to achieve similar erosion reduction, likely due to their lower porosity and different surface properties.

These findings have important implications for dust control strategies in the Wuhai mining area. For materials like fly ash and loamy sand, maintaining moisture content above 2% can significantly reduce wind erosion. For coal gangue and coking coal, higher moisture contents or alternative stabilization methods may be necessary. The distinct responses of different materials highlight the need for material-specific management approaches that consider both physical properties and environmental conditions.

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