Structural Differences in Aeolian Sand Flow on Dunes along Both Banks of the Yellow River in Wuhai City and Characteristics of Aeolian Sand on Ice Surfaces: Postprint

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Abstract

To investigate the structural differences in dune aeolian sand flow and ice surface aeolian characteristics along both banks of the Yellow River in Wuhai City, aeolian sand observation experiments were conducted along a path from the west bank of the Yellow River—Yellow River ice surface—east bank of the Yellow River, providing a theoretical basis for Yellow River dust prevention and control through comparative analysis of the aeolian sand flow structure and dust particle size characteristics of dunes along both banks. The research indicates: the total sand transport rate of dunes on both banks decreases with increasing height; the goodness-of-fit for vertical distribution of sand transport rate is poorer on the east bank than on the west bank, and the aeolian sand flow more readily reaches unsaturated states than on the west bank. Dust particles retained in cracks on the Yellow River ice surface are larger than 0.19 mm, while smaller particles are transported to the east bank; dunes on the east bank are affected by dust from mining areas, with increased content of very fine sand particles (0.05~0.1 mm), the average content of very fine sand on the east bank is less than that on the west bank, and the average particle size of dust on the east bank is less than that on the west bank. The grain size parameter kurtosis of dunes along both banks of the Yellow River and dust on the ice surface are both platykurtic, indicating similar sources of sand material.

Full Text

Study Area

The study was conducted at three distinct sites along the Yellow River in Wuhai City. **Area I** is located on the west bank of the Yellow River, with coordinates

ranging from 39°39 14.31 to 39°39 3.68 N and 106°41 2.79 to 106°42 8.67 E. This area features a dune surface with sparse vegetation cover. **Area II** is situated on the ice surface of the Yellow River, characterized by a smooth, hard surface with cracks. Its coordinates range from 39°46 29.14 to 39°46 13.39 N and 106°49 56.26 to 106°52 12.13 E. **Area III** lies on the east bank of the Yellow River, approximately 2.6 km from the river channel, with an average dune height of about 1 m. The coordinates for this area range from 39°32 51.73 to 39°40 26.48 N and 106°41 40.09 to 106°42 8.67 E.

Wind-Sand Flow Structure

The sediment transport rate in Areas I and II exhibited a decreasing trend with height. In Area I, the relationship between sediment transport rate (Q) and height (H) followed the equation $Q = 40.871H - 2.583$ ($R^2 = 0.972$). The transport rate at 0–6 cm was $30.330\,\mathrm{g \cdot cm^{-1} \cdot min^{-1}}$, accounting for 60.19% of the total transport, while the 0–30 cm layer accounted for 95.59% of the total transport. In Area II, the relationship was $Q = 25.983H - 2.493$ ($R^2 = 0.884$), with a transport rate of $18.260\,\mathrm{g \cdot cm^{-1} \cdot min^{-1}}$ at 0–6 cm, representing 61.32% of the total, and the 0–30 cm layer accounting for 98.36% of the total transport.

At lower wind speeds (5.73–7.60 $\mathrm{m \cdot s^{-1}}$), Area I showed a saturated wind-sand flow structure, while Area II exhibited an unsaturated structure. At wind speeds below 7.60 $\mathrm{m \cdot s^{-1}}$, the wind-sand flow structure remained unsaturated, but became saturated at speeds exceeding 7.60 $\mathrm{m \cdot s^{-1}}$. The critical wind speed for saturation was lower in Area II than in Area I. In both areas, the 0–30 cm layer accounted for over 90% of the total sediment transport, consistent with previous studies [23, 34, 38–40].

Characteristic Values of Wind-Sand Flow Structure Parameter λ

The parameter λ, defined as the ratio $\lambda = Q_{6\text{–}30}/Q_{0\text{–}3}$ (where $Q_{0\text{–}3}$ is the sediment transport rate in the 0–3 cm layer and $Q_{6\text{–}30}$ is the rate in the 6–30 cm layer), varied with wind speed conditions . In Area I, λ values were generally higher than in Area II. At wind speeds of 10.70 $\mathrm{m \cdot s^{-1}}$ and 10.40 $\mathrm{m \cdot s^{-1}}$, Area I showed $\lambda > 1$, indicating greater transport in the upper layer. At 11.20 $\mathrm{m \cdot s^{-1}}$, the relationship changed. In Area II, $\lambda < 1$ at wind speeds below 6.72 $\mathrm{m \cdot s^{-1}}$, but exceeded 1 at speeds between 6.72–8.80 $\mathrm{m \cdot s^{-1}}$, with a maximum increase of approximately 12%.

Particle Size Characteristics

The particle size parameters for the three areas showed broad peaks, indicating similar sand sources . The mean grain size (MZ), standard deviation ($\delta\phi$), skewness (SKϕ), and kurtosis (Kϕ) were calculated using the following formulas:

$$SK\phi = \frac{\phi_{84} - \phi_{16}}{\phi_{84} - \phi_{16}}$$

$$K\phi = \frac{\phi_{95} - \phi_5}{2(\phi_{95} - \phi_5)}$$

where $\phi_5, \phi_{16}, \phi_{25}, \phi_{50}, \phi_{75}, \phi_{84}, \phi_{95}$ represent the grain sizes at 5%, 16%, 25%, 50%, 75%, 84%, and 95% cumulative frequency, respectively.

The mean grain size ranged from 0.13–0.24 mm, with standard deviation values of 1.71, 1.65, and 1.01–1.52 for the three areas. Skewness values were 0.13, 0.11, and -0.02 to 0.25, while kurtosis values were 1.12, 1.11, and 1.06–1.10, respectively. The particle size distribution was relatively coarse, with the 0.05–0.1 mm fraction being significantly affected by dust from mining activities. The average content of very fine sand on the east bank (Area III) was lower than that on the west bank (Area I), and the overall particle size on the east bank was finer than on the west bank.

Discussion

The vertical distribution of wind-sand flow demonstrated that over 90% of sediment transport occurred within the 0–30 cm layer, confirming that this near-surface zone is the primary region of aeolian activity [23, 34, 38–40]. At low wind speeds (5.73–7.60 $\mathrm{m \cdot s^{-1}}$), Area I maintained a saturated flow structure while Area II did not, indicating differences in surface conditions between the dune and ice surfaces. The ice surface cracks retained sand particles larger than 0.19 mm, while finer particles were transported to the east bank.

The particle size characteristics revealed that the sand source for all three areas was similar, as evidenced by the broad peaks in the distribution curves. However, the content of very fine sand (0.05–0.1 mm) in the east bank dunes was influenced by dust from the mining area, resulting in lower average contents compared to the west bank. The mean particle size on the east bank was consequently smaller than on the west bank. The sorting coefficient ($\delta\phi$) values indicated moderate to good sorting, while the skewness and kurtosis values suggested near-symmetrical distributions with moderate peakedness.

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Abstract: To study the difference of sand dune wind-sand flow structure along the Yellow River and characteristics of wind-sand on the ice surface in Wuhai City, wind-sand observation experiments were conducted on the west bank of the Yellow River, the Yellow River ice surface, and the east bank of the Yellow River, and contrast analysis of sand-sand flow structure and sand particle size characteristics was conducted on the banks of the Yellow River to provide a theoretical basis for solving the dust control of the Yellow River. The results indicated that the total sediment transport rate of sand dunes on both banks of the Yellow River decreased with height, although the goodness-of-fit of the east bank sediment transport rate and height were worse than the west bank, as it is easier to reach the unsaturated state on the east bank of the sand flow than the west bank. The grain size of the sand retained in the cracks on the ice surface of the Yellow River was larger than 0.19 mm, and smaller particles were transported to the east bank. The content of the very fine sand, which was 0.05-0.1 mm, in the sand dunes on the east bank was affected by the dust in the mining area, the average content of the very fine sand in the east bank was less than that of the west bank, and the average particle size of the sand on the east bank was smaller than that on the west bank. The parameters of

particles along the banks of the Yellow River and the surface of the ice showed broad peaks, and the source of the sand was found to be similar.

Keywords: Yellow River; wind-sand flow structure; particle characteristics; ice surface; Wuhai City

Note: Figure translations are in progress. See original paper for figures.