Study on the Critical Dynamics of Compound Erosion in the Pisha Sandstone Area

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Abstract: The Pisha sandstone area which was distributed in Ordos of Inner Mongolia was the main source area of Yellow River sediment. The area has a characteristic of serious composite erosion and fragile ecological environment. So it is an important prerequisite to identify the critical force occurrence conditions of compound erosion for prevent and control the multiple composite erosion. Using the method such as field observation, simulation experiments and literature review, this study preliminarily summarizes the dynamic critical conditions and key influencing factors of water erosion, wind erosion and freeze-thaw erosion.

1. Introduction
The main exposed areas of Pisha sandstone was distributed in HuangFuChuan, KuYe River, Ten KongDi River basins and other tributaries of Yellow River, which was located in the border area of Shanxi, Shaanxi and Mongolia in China. This area is located in the main sediment yield area in the middle reaches of Yellow River[1]. During one year, wind erosion, water erosion and freeze-thaw erosion occur alternately, and the multi dynamic action aggravates the regional soil erosion. However, not all rainfall and wind can cause water erosion and wind erosion. When and how does freeze-thaw erosion occur in the year? At present, studies on critical rainfall of erosion are mostly carried out on loess slope, but the standards of erosive rainfall are different in different regions and different site conditions[2]. In view of that, the infiltration performance of arsenic sandstone is different from that of loess[3]; Moreover, previous studies on critical rainfall of erosion mainly focus on hydraulic erosion. There are few studies in this field of involving wind erosion, freeze-thaw and other dynamic forms of erosion. Therefore, it is of great significance to find out the critical law of the occurrence and development of the composite erosion of Pisha sandstone for the prediction, prevention and control of soil erosion. In order to provide theoretical support for the prevention and control of composite erosion, the dynamic criticality of hydraulic, wind and freeze-thaw composite erosion was studied on the basis of field location observation, simulation experiment and data get.

2. Materials and Methods

2.1. Site conditions
The study area is located in Nuanshui Country, Jungar banner, Inner Mongolia Autonomous Region, with geographic coordinates of 110 ° 36 ′ 2.74 ″ E and 39 ° 47 ′ 38.79 ″ N. It belongs to the branch of
GeQiu Gully on the right bank of NaLinChuan Gully, a tributary of HuangFuChuan in the middle reaches of the Yellow River, which is called ErLaoHu valley by local people, with a drainage area of 3.23 km². The climate in the study area is dry, annual precipitation was about 350 mm and which mostly concentrated in summer, and wind usually blows with the speed above 5 m/s in spring and winter. Temperature frequently alternates between above 0 °C and below 0 °C in winter from November to March of the next year. There are multiple dynamic composite erosion such as rainfall, wind, freeze-thaw, etc., in the area, soil erosion is very serious with the resulting of deep and wide gully with area of 7 km²/km², and the underlying surface were broken and few vegetation. The ecological environment local was fragile.

2.2. Data get method
Relying on National Science and Technology Support Plan (2013BAC05B04) and the National Key R & D Program of China (2017YFC0504501), A Kakou observation station and a compound erosion monitoring area were built at the outlet and slope of the ErLaoHu valley basin respectively in 2013 and 2017. The continuous observation parameters include runoff and sediment, wind speed, precipitation, ground temperature and other basic data. The study site was shown in Fig. 1.

The compound erosion device were completed in June 2018, and rainfall - wind and freeze-thaw erosion process can be simulated (Fig. 2). Using this device, 14 experiments under different power control combination were completed, including the single rainfall erosion, single wind erosion, rainfall and freeze-thaw erosion, rainfall, wind and freeze-thaw erosion etc.

![Fig. 1 Study area location diagram](image-url)
3. Critical analysis of compound erosion

3.1. Rainfall erosion critical

According to the analysis of the rainfall and runoff observed in the ErLaoHu valley in 2014, 2016 and 2018. Whether does the runoff occur which is related to the previous soil moisture and rainfall intensity and the amount of rainfall. Rainfall runoff occurs when the rainfall intensity is greater than the infiltration rate. But on the contrary, there is no runoff. The initial infiltration rate and the stable infiltration rate are quite different. Under different water content and bulk density. The physical properties and infiltration performance results of Pisha sandstone are shown in Table 1.

| Data collection          | Sampling location                     | Soil moisture (%) | Soil bulk density (g/cm³) | Initial infiltration rate (cm/min) | Soil saturation permeability coefficient (cm/min) |
|-------------------------|---------------------------------------|-------------------|---------------------------|-----------------------------------|-----------------------------------------------|
| MaWenmei, et.al.2018    | Around Zhungeer Banner, surface soil  | 4%                | 1.40                      | 0.42                              |                                               |
|                         |                                       | 4.3               | 1.40                      | 0.71                              |                                               |
| Chang Ping, et.al.2018  | Zhungeer Banner GeTuodDian valley      | 7.7~8.83          | 1.85~1.96                 | 0.312                             |                                               |
| Liu Aigang, et.al.1998  | an engineering soil material from Inner Mongolia | 18                | 2.65                      | 4.02×10⁻³                         |                                               |
|                         |                                       | 16                | 2.65                      | 3.42×10⁻³                         |                                               |
The greater the porosity, the greater the permeability \[4\]. The soil infiltration rate decreases with increasing bulk density \[3\]. According to the rainfall simulation experiment, when the soil moisture on the disturbed soil slope reaches 40%, the slope runoff begins. Next rainfall and runoff erosion starts. Combined with field observations, when the rainfall intensity exceeds 1.2~1.4mm/min (high soil moisture) or 3.12~4.2 mm/min (low soil moisture), the runoff generates. The critical rainfall condition of runoff is 34mm while estimated from the water storage of limited soil thickness in saturated.

3.2. Wind erosion critical

The conditions under which wind erosion occurs are that the wind force is greater than the sand-ejecting wind speed, which is affected by the sand particle diameter, surface roughness, and soil moisture; The strong winds mainly occur in April and May every year, and the instantaneous strong winds are distributed every month, and spring accounts of the largest proportion, and extreme winds mainly occur in spring (Fig. 3).

The wind velocity causing particles which diameter of the sediment particles \(d < 0.5 \) mm to jump is 4.78 m/s \[4\]. The content of particles with a particle size of less than 0.50 mm is 91.7% to 99.7% in the Pisha sandstone area.

![Fig. 3 Wind speed collection times and spring wind proportion](image)

3.3. Freeze-thaw erosion critical

The freezing process begins in mid and late November, the temperature alternates up and down at 0 ℃, the topsoil layer enters the freezing and thawing alternating process to complete freezing; In December, the surface layer and below the soil layer enters a completely frozen state. It is again in a state of thawing and alternating until it is completely melted; the process of freezing and thawing of other layers alternates less than that of the surface layer. Based on the understanding of the field freeze-thaw process and the effect of freeze-thaw cycles on soil structure destruction, the freezing and thawing environment with alternating high and low temperatures of the soil was simulated.

The effect of freezing and thawing on erosion is manifested in that freezing and thawing accelerates weathering and erosion, and at the same time changes the porosity and infiltration performance of Pisha sandstone. Factors that affect freeze-thaw erosion include soil content and freeze-thaw times. The
freeze-thaw effect increases with the increase of soil water content, and the freeze-thaw rate increases with the times of freeze-thaw cycles.

Studies have shown that when the moisture content is less than 8.56%, the amount of frost heave is very small. When the moisture content is greater than 10.27%, the volume expansion and cracks is obvious. The porosity and permeability coefficient of the topsoil decreases from 3-5times first, then increases, and then stabilizes as the number times $>10$.

4. conclusions

Compound erosion occurs alternately during the year. Freeze-thaw erosion accelerates soil weathering. Weathering products are the main material sources of wind and water erosion. Increasing ground cover can improve the critical dynamic conditions of composite erosion by reducing wind speed, reducing water speed and increasing ground temperature. It is of great significance for controlling the occurrence of erosion to clarify the conditions which erosion occurs.

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