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Experimental study of dust emission intensity from the surface of the alluvium beach

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Abstract. The paper presents data on the current state of waste storage facilities of mining and processing plants in Kryvyi Rih. They are complex, environmentally hazardous hydraulic structures. When assessing the extent of dust pollution from tailing ponds, it is extremely important to know the intensity of dust emissions from the surface of the alluvium beach. This parameter is the basic one in all prognostic models used to predict environmental pollution. The paper presents the results of experimental studies to determine the wind speed at which the removal of dry dust particles from the surface of the beach of a tailing pond begins, as well as the intensity of dust removal from the surface of the beach for dry sand and wet sand. The experimental studies conducted in the laboratory allowed obtaining data on the intensity of dust emission from the surface of the tailing dump beach. The results obtained by the authors make it possible to more accurately assess the degree of environmental dustiness using predictive models. The data on determining the intensity of dust formation for sand of different moisture content will be useful for determining the effectiveness of dust suppression by supplying water to the beach surface.

1. Introduction

Mining and processing plants (MPPs) are enterprises that ensure the sustainable development of not only the Kryvyi Rih iron ore basin, but also Zaporizhzhia, Donbas and the Dnipro regions. Therefore, the stability of these MPPs is an important component of the country's national security. However, iron ore mining in Kryvyi Rih is accompanied by the creation of artificial storage facilities (SF), the size of which is increasing over time (table 1) [1-3].

Table 1. Geometric characteristics of the SF [4-6].

Name of the SF	Height of the dam, m	Area, hectares
"Obiednane"	50	450
"Myroliubivske"	55	324
"Voikove"	62	250
Pivnichnyi MPP	76	1750



One of the factors of the threat is wind erosion, which leads to dust formation on dry areas of the SF surface and the removal of dust into the atmosphere. In order to predict dust pollution from the SF, it is extremely important to know the intensity of dust emission from the surface of the alluvium beach at different wind speeds and to determine the wind speed near the surface of the beach, exceeding of which leads the dust formation process. These parameters are basic and are used in all prognostic models [7-9]. Intensive wind blowing of dust from the surfaces of the SF leads to large-scale pollution of both the atmospheric air and the underlying surface in the areas of iron ore mining. It should be noted that the risk of dust formation on the surfaces of the SF increases with the growth of the sealing dyke, as the height of the sealing dyke increases, the beaches fall into the area of increasing wind speeds. Therefore, in order to assess the risk of dust formation, it is very important to determine at what wind speeds the process of dust formation on the surface of the beach V_{su} begins. To solve this urgent problem, experimental studies are very important to determine the value of this wind speed for specific types of dust material, i.e., size and density, on a particular beach, i.e., height, humidity, angle of inclination, length. The use of such data in prognostic models makes it possible to obtain adequate information on the assessment of the risk of dust formation at the SF.

Thus, the purpose of the study is to experimentally determine the intensity of dust emission from the surface of the beach at different wind speeds and wind speeds at which the process of dust formation on the surface of the beach for Central MPP beneficiation waste of different humidity begins.

2. Methods

For the study, the Central MPPs [10] specialists took samples of enrichment waste at the outlet of the enrichment production, which were dewatered and dried in a regulated manner. In the dry state, this waste is a fine-grained material (table 2) of brown color with a bulk porosity of 0.46 and a density of 3000 kg/m³.

Table 2. Granulometric composition of Central MPPs beneficiation waste [11].

Class of size, mm		Weight part, %.
from	to	
0.000	0.056	63.1
0.056	0.071	27.7
0.071	0.160	2.4
0.160	0.250	5.5
0.250	0.450	1.1
0.450	0.630	0.2

The study of the intensity of dust formation from the surface of the SF of alluvium beach was carried out experimentally in the laboratory at the experimental installation (figure 1). The experimental study consisted of two stages. At the first stage, the air flow velocity at which the process of movement of dust particles along the emission source began (V_{cr}) and the rate of "detachment" of dust particles and their removal from the emission source (V_{su}) were studied. At the second stage, the intensity of dust particle removal from a unit area of the alluvium beach was determined at different wind speeds and material humidity.

Two approaches were used to model the "source" of the emission:

1. The dust was placed in a container in the shape of a "circle" with a diameter of 95 mm. The height of the sides of the container was 5 mm (option 1, figure 2).

2. The dust was placed on the table in the form of a "surface of the beach"; the shape of this source is shown in figure 3, maximum length 15 cm, maximum width 13 cm (variant No. 2).

The arrow in each figure shows the direction of the air flow.

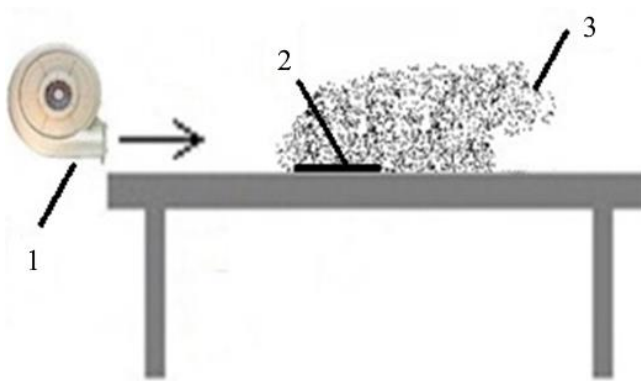


Figure 1. Schematic of the experimental setup: 1 – blower, 2 – emission source, 3 – dust plume.

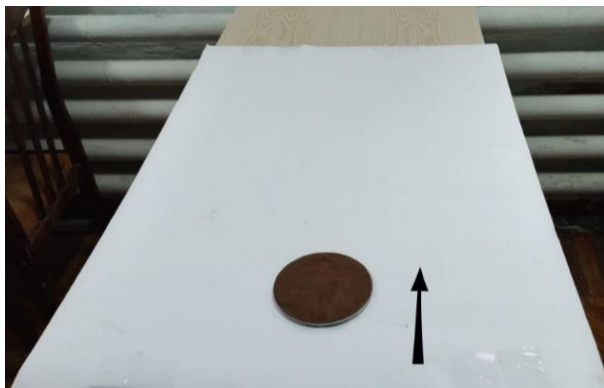


Figure 2. Source of dust emission of the "circle" type (option No. 1). The arrow indicates the direction of air flow.

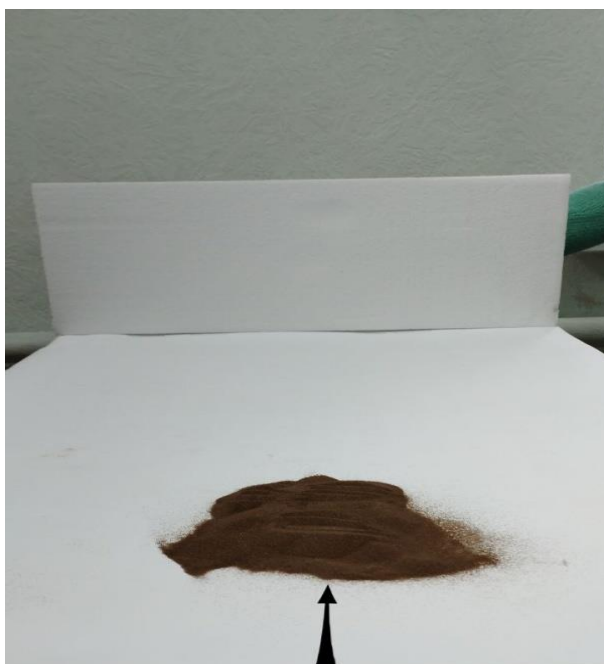


Figure 3. Source of dust emissions of the "surface of the beach" type (option 2). The arrow indicates the direction of air flow.

The air flow was generated using a wind blower. The airflow velocity was measured using a GM 8908 anemometer. Since the measurement was carried out in a turbulent flow, the speed shown by the anemometer is within a certain range. The air temperature during the experiment was 19°C. For the experiment, the sand samples were kept in a drying cabinet, model 2B-151, for 40 minutes. The dust samples were kept in the oven at a temperature of +40°C. This was done in order to obtain dry sand. During the experiment, the process of detachment of dust particles from the surface of the surface of the beach model was videoed and the "creep" V_{cr} and "suspension" speeds V_{su} were visually determined.

At the second stage of the study, the intensity of dust particle emission from a unit area of the surface of the beach was determined at different air flow rates or at different sand humidity. To model the "source" of emissions, a "circle" surface of the beach was formed with a diameter of 4 cm. The blowing took place for 60 seconds. After that, the mass of sand that was "blown" from the surface during this time was determined by measuring on the scales. Next, the intensity of sand emission from a unit area of the surface was calculated at the selected air flow rate:

$$Q_i = \frac{M_i}{tS}, \quad (1)$$

M_i – is the mass of dust blown off the surface of the beach model in time t at air speed V_i , gr/s/sm²; t – time, s; S – surface of the beach area, sm².

For the experiment, the dust samples were also placed in an oven for 40 minutes at a temperature of +40 C. After that, water was added to the sample to form sand with a specific moisture content. The moisture content of the sand was determined by the formula (2):

$$P = 100 \frac{M_w - M_0}{M_0}, \quad (2)$$

P – humidity, %; M_0 – weight of dry sand, g; M_w – weight of wet sand, g.

After blowing, the mass of sand that was "blown off" the surface of the wet sand was determined. Further, based on dependence (1), the intensity of wet sand removal was determined.

3. Results

During the experiment, the air flow velocity at which the process of dust particle movement along the emission source begins (this is the "creep" velocity V_{cr}) and the velocity of dust particles "detachment" and their removal from the emission source (the "suspension" velocity V_{su}) were visually recorded.

The measurement results for the first stage of the experiment are as follows:

1. Option 1, source of the "circle" type: $V_{cr} = 5.4$ m/s – 6.3 m/s; $V_{su} = 7.4$ m/s – 8.2 m/s.
2. Option 2, a source of the "surface of the beach" type: $V_{cr} = 5.2$ m/s – 5.8 m/s; $V_{su} = 6.5$ m/s – 7.1 m/s.

As can be seen from the results, the values of speed V_{cr} and V_{su} for each scenario are of the same order. But it can also be seen that for scenario 1, the values of these parameters are slightly higher than for scenario 2. This can be explained by the influence of the container sides on the aerodynamics of the flow: the sides create an obstacle to the flow path, which is absent in the "surface of the beach" scenario, so only at a higher value of the flow velocity is the separation of dust particles behind these sides. In general, it can be taken into account that at an air velocity of about $V_{cr} = 5$ m/s, the movement of dust particles on the surface of the beach begins, and at an air flow velocity of about $V_{su} = 6$ m/s, the removal of dust particles into the atmospheric air begins.

At the beginning of the second stage of the experiment, the speed was determined for sand with different humidity, namely $P=5\%$, $P=7\%$, and $P=10\%$. The processing of the experimental data showed that the values of this parameter were: $V_{su} = 8.7$ m/s for $P=5\%$; $V_{su} = 9.3$ m/s for $P=7\%$; $V_{su} = 10.5$ m/s for $P=10\%$.

Figure 4 shows the dependence of the sand emission intensity on the dry surface of the beach. Figure 5 shows the dependence of the sand emission intensity on the surface of the beach model for different sand moisture content. The determination of the emission intensity for this case was carried out for the corresponding velocity V_{su} , which was determined earlier.

The results of processing the experiments to determine the parameter Q_i are shown in figure 2, where the dependence of the dust emission intensity on the unit area of the surface of the beach at different air flow rates is shown.

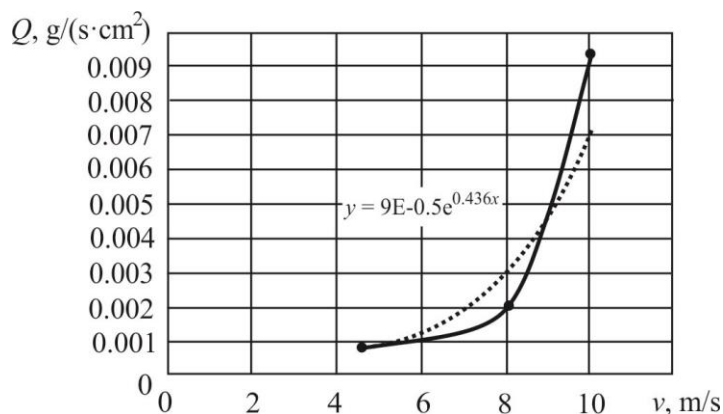


Figure 4. Intensity of dust emission from the surface of the beach at different air flow rates (dry sand).

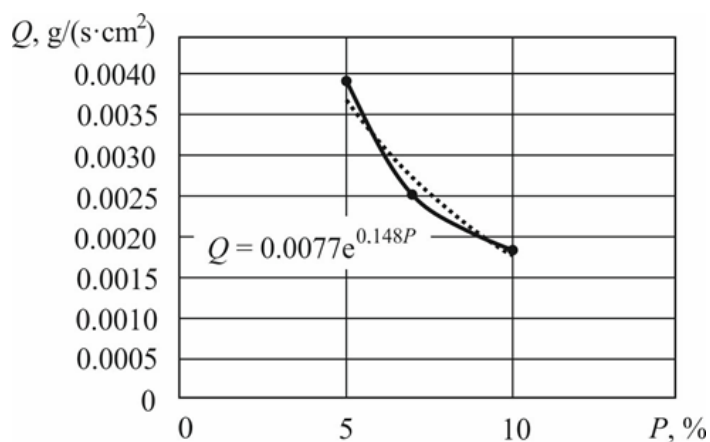


Figure 5. Intensity of dust emission from the surface of the beach for sand with different humidity.

It should be noted that at a sand moisture content of 20%, there is a "swamp" – there is no removal.

4. Conclusions

The experimental studies made it possible to obtain data on the intensity of dust emission from the surface of the beach of the tailing pond. The studies were conducted for both dry sand and sand of different moisture content. These results make it possible to more accurately assess the extent of dust pollution in the environment using predictive models. In addition, the data on determining the intensity of dust formation for sand of different moisture content will be useful in determining the effectiveness of dust suppression by supplying water to the surface of the beach.

The wind speed at which dry or wet dust particles are detached from the surface of the beach and carried into the air was determined experimentally. The value of this parameter makes it possible to determine the zones of dust formation on the surface of the tailing pond based on the aerodynamics model alone.

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