Assessment of efficiency of windbreak and dust suppression walls for coal terminals

I V Moskovaya, A T Olishevskiy, L P Lazareva

Far Eastern Federal University, 8, Sukhanov St., Vladivostok, 690091, Russia

E-mail: moskovaya.92@gmail.com

Abstract. This paper analyzes the methods for measuring atmospheric concentrations of coal dust and assesses the impact of operating activities of the coal terminal at the port of Vanino on the atmospheric air. The authors suggest an installation diagram of windbreak and dust suppression walls for the coal terminal at the port of Vanino; analyze the efficiency of such walls with regard to coal storage conditions, coal characteristics, and storage area; and put forward measures to further reduce the environmental impact of the terminal.

1. Introduction

In the modern world, energy security plays a major role in the economic development of any nation. This is especially true for the developing countries of the Asia-Pacific region.

The Russian Federation is one of the world leaders in coal mining and is one of the largest coal exporters. Considering the present situation in the world and in order to expand into the international coal markets, as well as to enhance economic stability, the country's government made a decision to build a number of solid fuel shipping terminals in Russia’s Far East. Implementation of these geopolitical projects brings about the problem of preventing destructive anthropogenic impact of the operating terminals and those planned for construction and lives of the population on the territories involved. One of the problems arising in the construction and operation of coal terminals is the contamination of atmospheric air with coal dust.

The aim and purpose of this paper is to assess the ecological impact of coal terminals on the atmospheric air, specifically, to consider the related problems and ways to address them via a case study of the coal terminal at the port of Vanino.

The tasks of the paper are as follows:

1. To study the environmental impact of coal terminals and to analyze the methods of measuring atmospheric concentrations of coal dust coming from coal storage facilities, as well as dust suppression techniques
2. To assess the impact of the Vanino coal terminal operated by Daltransugol JSC on the atmospheric air
3. To develop an installation diagram of windbreak walls and dust suppression walls for by Daltransugol JSC coal terminal
4. To study the influence of windbreak walls on wind velocity and to assess a change in air quality in the area of the coal terminal after installation of windbreak and dust suppression walls.

2. Methods and objectives of research
Research works of windbreak walls installing consequence prediction are carried out in the Asia-Pacific Region, for example, in China [1–5]. Nowadays, there are currently two recommended methods for determining the quantity of coal dust produced during transshipment of bulk loads in Russia: the Novorossiysk method and the Perm method. In case of the Vanino coal terminal, the authors chose the Novorossiysk method. This choice is caused by the fact that formulas of both methods take into account through coefficients the following: moisture, particle size distribution, storage surface area and flowability.

However, the Perm method does not presuppose any connection between wind velocity and flowability, the latter being constant. On the other hand, the Novorossiysk method accounts for changes in flowability depending on wind velocity, which is more reasonable from a physical viewpoint.

Figure 1 shows the curve of flowability in relation to increasing wind velocity.

As shown in Fig. 1, flowability significantly increases even with a slight change in wind velocity.

![Flowability vs. wind velocity](image)

**Figure 1.** The curve of flowability in relation to increasing wind velocity.

Formula (1) shows that such sharp increase of flowability is explained by power law relationship between flowability and wind velocity:

$$ q = a \times v^b, \quad (1) $$

where $q$ is the dust flowability, mg/(m$^2$ s); $v$ the wind velocity, m/s; and $a$ and $b$ the empirical coefficients depending on the type of material being transshipped. For coal, the coefficients are 0.1085 and 2.9195, respectively.

Let us now proceed to the case study of the Vanino coal terminal. As shown in the map, the nearest residential area is relatively close to the boundary of the terminal (approx. 200 m), but it is almost 1.5 km away from the dust emission source (coal storage).

Figure 2 shows the measured atmospheric concentrations of coal dust in the area of the coal terminal. As shown in the map, safe reference level of impact (SRLI) exceeds both in the residential area (1.65 SRLI) and on the boundaries of the 500-m sanitary protection zone and even the 1,000-m sanitary protection zone. Permissible levels are observed only at a distance of approximately 2 km
from the dust emission source (coal storage). This situation is unacceptable. Based on the analysis of the calculation procedures, the authors suggested reducing wind velocity to decrease the quantity of the material blown off.

It is known from the literature that wind velocity can be changed by installing windbreak walls [6–8]. The operating principle of a windbreak wall is as follows. Wind partially reflects from, partially envelopes the perforated windbreak, and partially passes through it, thereby losing its velocity.

The curve of wind flow transformation ratio in relation to the distance to the wall was plotted in works of Dyunin [6] and Serebrovsky [8] (see Fig. 3).

Figure 2. Atmospheric concentrations of coal dust in the area of the Vanino coal terminal.

To change the wind velocity in the whole area of the coal storage, let us suggested windbreak walls with a height of 20 m and porosity of 30% along the perimeter of the storage according to the following scheme (green lines in Fig. 4). To calculate the average wind velocities for each of the five coal piles, the authors chose six wind velocity control points located along each pile.

The authors used the curve above to determine wind flow transformation ratios at certain distances to the installed walls.
Figure 3. Curve of wind flow transformation ratio in relation to distance to wall.
1, porosity 0.3 (30%); 2, porosity 0.2 (20%); wind flow transformation ratio ($\tau$) shows the wind velocity change in front of and behind a windbreak wall of certain porosity; $x$, ratio between distance to a windbreak wall and its height.

Figure 4. Configuration of windbreak and dust suppression walls and locations of wind velocity measurement points in dust sources.

Figure 5. Average wind velocities at the coal storage before and after installation of the walls.

3. Results and discussion
The calculation showed that wind velocity changes in all wind directions for each coal pile (Fig. 5). Analysis of the chart showed that decrease in wind velocity would constitute from 24% to 60%. Considering the power law relationship between flowability and velocity, such a decrease is rather significant. For illustrative purposes, we plotted a chart showing average wind velocity in the whole
storage area. As shown in the chart in Fig. 5, northeast and southwest directions are unfavorable from the viewpoint of reducing wind velocity. A slight change in wind velocity determines a small reduction in the quantity of the material blown off, and this is depicted in Fig. 6, which shows the reduction in the quantity of the material blown off in different wind directions.

The least changes in wind velocity and, consequently, in the quantity of the material blown off by northeast and southwest winds may be explained by big length of the storage in these directions and insufficient wind shadow.

For further analysis of the efficiency of the windbreak walls, the authors chose north-east and southwest directions as unfavorable from the viewpoint of reducing wind velocity and emission load, and also southeast wind, as it is directed toward the residential area. Let us consider the unfavorable wind directions.

Figures 7 and 8 show concentrations of coal dust in northeast and southwest winds after installation of windbreak walls. As shown in these figures, permissible levels of dust are not reached even on the boundary of the 1,000-m sanitary protection zone. This is connected with big length of the storage in northeast and southwest directions. In this case, wind shadow is insufficient.

**Figure 7.** Concentrations of coal dust in northeast wind after installation of the walls.
This situation is explained by the fact that the longer is the distance from the wall, the weaker is its capability to reduce wind velocity, and wind velocity gradually increases.

Figure 9 shows the curve of wind velocity in relation to distance to the wall. The curve shows that the least velocity of the wind broken by the 20-m wall is observed at a distance of 100 m. Then the velocity gradually increases and reaches its initial value at a distance of 800 m. For these particular conditions, it is reasonable to install the wall in such a way that it divides the coal pile into two parts, as it will not interfere with the storage operations and will reduce the desired reduction in wind velocity, as reduction of velocity by just 20% will reduce flowability by two times.
Figure 9. Curve of wind velocity in relation to distance to the wall.

Figure 10. Concentrations of coal dust in southeast winds after installation of the walls.
Let us now proceed to the second type of wind directions – directions toward the residential area. As shown in Fig. 10, the walls installed according to the initial plan will be sufficient to reach the SRLI in the residential area. This may be explained by the fact that the residential area is located at a distance of 1.5 km from the dust emission source.

Figure 11 shows the relation between dust concentration and distance to the emission source before and after installation of the walls.

The figure shows that without walls, dust concentration on the boundary of the coal terminal is 2.4 SRLI, and in the nearest residential area, it is 1.65 SRLI. Permissible concentration is reached only in the 1,000-m sanitary protection zone at a distance of 2.5 km from the emission source.

Figure 11. Curve of coal dust concentration in southeast wind.

With the walls installed, permissible concentration is reached at a distance of as near as 500 m from the emission source. On the boundary of the coal terminal, it is 0.5 SRLI; in the nearest residential area, it is 0.3 SRLI.

4. Conclusion
In the present paper, the authors analyzed the methods for measuring concentrations of coal dust blown off from open storage surfaces and assessed the impact of the coal terminal at the port of Vanino on the atmospheric air.

The authors also developed an installation diagram of windbreak and dust suppression walls for the Vanino coal terminal, analyzed the efficiency of the walls with consideration for coal storage conditions, coal characteristics, and storage area with different wind directions, and suggested measures to further reduce the environmental impact of the coal terminal.

The work presented in the paper leads us to arrive at the following conclusions:
1. Large terminals that transship and store coal in open piles are sources of severe pollution of the atmosphere with coal dust.
2. As a result of the analysis of existing procedures, the authors chose the one that most closely corresponds to the processes related to coal storage.
3. Based on the analysis of executed calculations, the authors suggested measures for protection.
4. The calculations made after installation of the windbreak and dust suppression walls showed
that their installation resulted in reducing coal dust concentrations by 58.6–81.3% depending on wind direction.

5. The calculations also showed that when setting boundaries of sanitary protection zones around large coal terminals, it is necessary to take into account the location of emission sources on their territories.

5. Acknowledgment
This work was supported by the Far Eastern Federal University, project no. 14-08-02-24_i.

References
[1] Cong X C, Cao S Q, Chen Z L, Peng S T & Yang S L 2011 Impact of the installation scenario of porous fences on wind-blown particle emission in open coal yards. *Atmospheric Environment* Journal. 45 5247–5253
[2] Cong X C, Du H B, Peng S T & Dai M X 2013 Field measurements of shelter efficacy for installed wind fences in the open coal yard. *Journal of Wind Engineering and Industrial Aerodynamics* 117 18–24
[3] Jinrui S 2013 Study on the application results of “dry cleaning” mode in port dust control.
[4] Yang Y, Sun X, Zhao J, Sun J & Yang Q 2012 Environmental protection in the port construction and operation in China. *Advanced Materials Research* 524–527, 3298–3301
[5] Se-Woon Hong, In-Bok Lee, Il-Hwan Seo 2015 Modelling and predicting wind velocity patterns for windbreak fence design. *Journal of Wind Engineering and Industrial Aerodynamics* 53-64
[6] Dyunin A K 1963 *Mekhanika metelevi* [Mechanics of Snowstorms]. (Novosibirsk: Publishing House of the Siberian Branch of the USSR Academy of Sciences) p 380
[7] Chenzyan C & Shuifen X 2010 Study and Application of Dust-Proof Technologies and Windbreak Grids at Port Warehouses of Package Cargo *Electronic Publishing House of the Chinese Academic Journal*
[8] Serebrovskiy F L 1985 *Aeration of Populated Areas* (Moscow: Stroyizdat Publication) p 170