Study on the uncertainty of TSP emissions in dry bulk terminals

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Abstract. Aiming at the problem that TSP emissions in dry bulk terminals are uncertain due to the selection of parameters, the influence of different parameters on the uncertainty of particulate emissions in dry bulk terminals was studied. The study established the TSP emission system dynamics model for dry bulk terminals, and quantitatively calculated the TSP emission uncertainties of four parameters, namely "Water action coefficient, homework divide", "Water in material", "Operation TSP up to the maximum TSP up to half of the wind speed", under the normal distribution. The results show that the wharf TSP emission is greatly influenced by parameters, and the maximum emission fluctuates as high as 122% compared with the expected value. The ship loading and Translation operations are greatly influenced by the value of the discharge parameters, and the TSP emission stored in the yard is hardly affected.

1. Introduction
China's rapid economic growth has boosted domestic demand for minerals, coal and other raw materials. As the transportation hub of bulk commodities, the port undertakes the transportation, transshipment and temporary storage of ore and coal. In the process of storage of ore and coal, particulate not only causes the loss of raw materials, but also becomes a serious problem of TSP (Total Suspended Particulate) pollution in port and surrounding environment[1].

Particulate pollution is one of the key problems of urban air pollution in China. The migration and diffusion of port particulate in atmospheric environment constitutes one of the main components of total suspended matter pollution in coastal cities in China, and the diffusion of particulate sources in the loading, unloading and storage of coal and ore often constitutes the main body of port particulate pollution. At present, the prevention and control measures tend to be prevention-based, supplemented by removal, and strive to fundamentally control the generation and diffusion of particulate.

The biggest source of bulk particulate from ports is the small particles that dot the surface of coal and ore piles. Due to the large area of the yard and all open space, when coal and ore are dry and windy, a large area of pollution will be caused. The critical conditions of particulate formation and the amount of dust formation are mainly determined by the water content, wind force and mineral weight ratio of coal and ore.

According to the way of particulate removal, the particulate removal in port bulk storage yard can be divided into static particulate removal and dynamic particulate removal. Static dusting means that the bulk cargoes in the yard and scattered in the road and the clearance between the yard are changed from static state to suspended state under the direct action of the wind. The dynamic particulate is mainly caused by the diffusion of the cargo under the action of the wind when the cargo passes through the air during the operation of the storage yard, such as the loading and unloading operation.
between the ship and the shore, the loading and unloading truck operation on the storage yard, and the pollution caused by the combination of vibration and wind force when the belt conveyor starts.

Due to the early development of international heavy industry and other fields, the problem of environmental pollution appears. The phenomenon of particulate diffusion in the environment has attracted wide attention. The research on particulate matter particulate in foreign countries started earlier and the research process mainly went through two stages. At first, wind-sand particles were taken as a breakthrough point to carry out qualitative research on the behavior process of particulate matter and the evaluation of environmental effects. At this stage, scientists in the United States, Germany, France, Japan and other countries have carried out a lot of work, such as the typical form of particle movement[2], wind and particle interaction[3], particulate amount and its influencing factors[4].

Chinese domestic researchers have successively carried out the changing rules of starting wind speed, particle size and water content of coal pile surface particles [5],[6],[7].In the specific work, a more general authoritative algorithm has been formed, but in the process of calculation, there is little research on the influence of parameter uncertainty on the results.

In this study, a model of particulate emissions from dry bulk cargo terminals was established by means of the system dynamics model, and on this basis, the influence of different parameters on the uncertainty of particulate emissions was quantitatively discussed.

2. Research method

2.1. Research objective

This study takes a coal wharf as an example. The specific parameters of the wharf are as follows:

Table 1 The study selected coal wharf informations

| The type of goods | Way of shipment | In the cart | Yard area |
|------------------|----------------|-------------|-----------|
| coal             | grab           | 10000       | 1000      |

2.2. Calculation method for TSP emissions

The calculation formula of coal, ore and other dry bulk particulate emission in China's "Environmental Impact Assessment Standard for Port Construction Projects" [8] is used to calculate the loading and unloading of dry bulk cargo and the static particulate emission amount in the yard.

Formula for source strength of TSP atmospheric particulate in dry bulk wharf loading:

$$Q_H = a\beta H e^{a(d-a)} y / \left[1 + e^{0.25(d-a)}\right]$$  \hspace{1cm} (1)

Formula of TSP source strength of atmospheric particulate in dry bulk wharf yard:

$$Q_1 = 0.5a(U - U_o)^3 S$$  \hspace{1cm} (2)

$$U_o = 0.03e^{0.5y} + 3.2$$  \hspace{1cm} (3)

$Q$ is the emission amount of particulate matter in operation, kg. $Q1$ is the amount of particulate caused by wind erosion in bulk cargo yard (kg); $a$ is the particulate regulation coefficient of cargo type; $\beta$ is the operating mode coefficient, 1 when loading or stowing, 2 when loading; $H$ is the operating head, m. The coefficient of water action is 2, which is related to bulk cargo property. The value is 0.4~0.45. $d$ is the critical value of water effect, that is, when the moisture content is higher than this value, the effect of water effect is not obvious, and bulk properties, coal take 6%, ore take 5%. For water in material, %. $Y$ is the amount of work. $y$ for homework particulate to do big amount 50% yes wind speed of particulate, m/s. $U$ is the wind speed in the operation area, m/s. 89% of the surface wind speed of the multi-yard to single reactor. $U_o$ is the starting wind speed of mixed particle size. $S$ is the surface area of pilings, m$^2$. 

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2.3. System dynamics model construction

According to the function relationship and parameter setting in Section 2.2, this paper uses Vensim PLE software to establish the dynamic model of TSP emission system. The flow chart of system dynamics model is shown in Figure 1.

![Flow chart of system dynamics model](image)

The model made of 2 level variables, 2 rate variables, 6 auxiliary variables and 5 intermediate auxiliary variables. The two 2 level variables respectively represent “The amount of TSP stored in the yard”, “Dynamic TSP emission in Material piling and taking operation” and “TSP emission from ship loading and unloading operations”; the 3 rate variables were “TSP of storage emission per unit time”, “TSP of Material piling and taking per unit time” and “TSP emission per unit time from ship loading and unloading operations”, respectively.

The initial conditions of the system dynamics model and the initial values of the model auxiliary variables are shown in Table 2.

| Parameter                                                                 | Initial value | Unit  |
|--------------------------------------------------------------------------|---------------|-------|
| water in material                                                        | 0.05          | %     |
| Real-time wind speed in the yard                                          | By real-time data | m/s   |
| Real-time wind speed in port area                                         | By real-time data | m/s   |
| homework divide                                                          | 1.5           | m     |
| Water action coefficient                                                  | 0.45          | -     |
| Particulate regulation factor                                             | 0.6           | -     |
| Critical value of water action effect                                     | 0.06          | -     |
| Operation TSP up to the maximum TSP up to half of the wind speed         | 16            | m/s   |
| coefficient of feeding operation mode                                     | 2             | -     |
| quantity of homework                                                     | 10000         | t     |
| coefficient of Stacking (ship) operation mode                            | 1             | -     |
| Surface area of yard                                                     | 10000         | m²    |
| TSP of storage emission per unit time                                     | 0             | kg/h  |
| TSP of Material piling and taking per unit time                          | 0             | kg/h  |
| TSP emission per unit time from ship loading and unloading operations    | 0             | kg/h  |
| The amount TSP from wharf per unit time                                  | 0             | kg/h  |
| The amount of TSP stored in the yard                                      | 0             | kg    |
| TSP emission from ship loading and unloading operations                  | 0             | kg    |
| Dynamic TSP emission in Material piling and                              | 0             | kg    |

Figure 1 The flow chart of system dynamics model
3. Results and analysis

In this study, real-time meteorological conditions and wind speed were used to simulate the TSP emissions in three links: stockpiling, ship loading and unloading, and loading and unloading from the yard. In terms of parameter uncertainty, the study discussed the uncertainty of four parameters: "Water action coefficient, homework divide", "Water in material", "Operation TSP up to the maximum TSP up to half of the wind speed" under normal distribution.

The simulation result of the uncertainty of total TSP emissions from the wharf was shown in Figure 2 and cumulative emissions of wharf TSP at different times are shown in Figure 3.

![Figure 2 Simulation results of uncertainty of TSP cumulative emissions at different time of wharf](image)

![Figure 3 Distribution of total TSP emissions at wharf](image)

The simulation results show that the expected value of total TSP emissions at the wharf is $4.65 \times 10^7$~$4.8 \times 10^7$ kg, the minimum value is $4.35 \times 10^7$~$4.5 \times 10^7$ kg, and the maximum value is $5.7 \times 10^7$~$5.85 \times 10^7$ kg. The expected value of the minimum value and the maximum value fluctuates between -6% and 122%.

![Figure 4 Real-time TSP emission from ship loading and unloading operations](image)
Figure 5 Real-time dynamic TSP emission in Material piling and taking operation

It can be seen from FIG. 4 and FIG. 5 that loading and unloading vessels are greatly affected by parameters, and the variation of minimum value and maximum value compared with expected value ranges from -100% to 240%. The stack-reaping is also greatly affected by the parameters, and the change of the minimum value and the maximum value compared with the expected value fluctuates within the range of -100%~200%.

Figure 6 Real-time the amount of TSP stored in the yard

It can be seen from Figure 4, Figure 5 and Figure 6 that ship loading and Translation operations are greatly influenced by the four main parameters. TSP emissions from storage sites are almost unaffected.

4. Conclusion

The system dynamics method can be used to calculate TSP particulate emissions from dry bulk terminals and carry out quantitative uncertainty analysis.

The ship loading and Translation operations are greatly influenced by the value of the emission parameters, and the TSP emission stored in the yard is hardly affected.

In terms of total emissions, the maximum emission fluctuates by as much as 122% compared to expected emissions.

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