



WHITE DUST SIMULATION FOR TAILINGS POND OF ERDENET COPPER MINING USING HYSPLIT

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Abstract: The purpose of this research was to identify dispersion and transporting of white dust for tailings pond of Erdenet copper mining in Mongolia. Spring and autumn have a significantly higher level of PM10 mass concentration in Erdenet city. Probably caused by the stagnant atmosphere which leads to pollution's cumulative effect and 'white dust' from the storage of tailings pond in spring and autumn. We used meteorological data for 2015 gathered from Information and Research Institute of Meteorology, Hydrology and Environment (IRIMHE) in Erdenet city and GDAS meteorological data provided by U.S NOAA. In the present study, white dust simulation by using the ArcGIS, HYSPLIT program modeling. The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model is used to identify the white dust dispersion and transportation trends. According to the simulation from model HYSPLIT, white dust was spread between 14 and 65 km in 2015. The main month of white dust distribution was May and October when mass concentration of PM10 was high due to white dust. White dust distribution was four times lower when the rainy day.

Keywords: white dust; trajectories; dispersion; HYSPLIT; tailings pond; Erdenet copper mining;

INTRODUCTION

The rapid industrialization, urbanization and increasing population bring major environmental pollution problems associated with air pollution. The scientific interest has been driven by the diverse effects mineral dust has on climate and the environment. Crustal aerosols have an influence on the atmospheric radiation balance through scattering and absorption processes [14, 23] and acting as cloud condensation nuclei [29]. Moreover, mineral dust can also make an important contribution to the levels of suspended particulate matter (SPM) recorded in air quality monitoring networks. Dust particles can also act as reaction surfaces for reactive gas species [6, 16 and 24].

There are many drawbacks with the dust phenomenon such as environmental, socio-economic, human health, climate and microclimate problems [12]. Some of these issues are discussed as follows. Wind-blown dust is an effective factor for the transport of pathogens and pollutants [22, 26] and also can influence air quality downwind of dust source regions by reducing visibility, soiling property and causing illnesses [4, 19].

Inhalation of dust particles can cause heart beat irregularities, heart attacks and respiratory problems, severe and chronic headaches, severe allergies and skin diseases [13]. Particles such as mineral dust, by absorbing ultraviolet radiation can inhibit smog production, having

profound implications in the control of air pollution in urban areas [7]. Furthermore, the interactions between windblown dust and anthropogenic pollutants aggravate the generation of secondary aerosols [2].

Different Techniques have been developed to identify dust hotspots and pathways.

Numerical modeling, trajectory analysis, Remote sensing and satellite imagery, dust observations and metrological data analysis, mineral tracers and geological models can be applied as the principal tools used to research dust events [8, 11, 12 and 28].

Erdenet, one of the biggest cities in Mongolia and has several mining and industrial companies. By 2015 statistics, population within the city was counted at 100731 inhabitants in Erdenet city [21]. The population is increasing, and due to manufacturing and its' pollution of city air quality has been above the standard limit for the last three years [20]. In October 2015, mass concentration of PM10 was reached 321 $\mu\text{g}/\text{m}^3$ in Erdenet city. It's about 3.2 times higher than the Mongolian ambient air quality standard (AQS). In May 2015, mass concentration of PM10 was reached 266 $\mu\text{g}/\text{m}^3$ and it's about 4.1 times higher than Mongolian AQS [17].

Spring and autumn have a significantly

higher level of PM10 mass concentration in Erdenet city. Probably caused by the stagnant atmosphere which leads to pollution's cumulative effect and 'white dust' from the storage of tailings pond in spring and autumn.

One of the main pollution sources of heavy metals and trace elements within the Erdenet Mining Corporation environment is the white dust from the storage of tailings pond. In 2006, there are 500 million tons sands, 25 million m^3 wastewater accumulated in tailings pond [15]. Chromium (Cr) from 6.9 to 13.1 mg/kg, arsenic (As) from 9.3 to 10.7 mg/kg, lead (Pb) from 0.2 to 2.3 mg/kg, and copper (Cu) from 61.4 to 96.1 mg/kg were detected in tailings and filtration pond sediment samples [5].

The White dust resulted from the mining process of Erdenet Mining Corporation is a fine dust, moves around when the wind speed is 5.4 m/sec or more landing on soil. Households, animals, plant near the industrial area is faced with the risk of being exposed to heavy metal and negative effect upon their health in the long run has been proven [15].

Some studies have been conducted on white dust characteristics, but there is no study on transport and distribution. Therefore, it is necessary to estimate the distribution of white dust.

MATERIALS AND METHODS

Study area

Erdenet copper molybdenum mine tailings pond is located northeast of Erdenet city (Fig.1). Tailings pond has accounted for 1712.8 hectares of land. Area of sands, slimes and wastewater are expanding at Disposal every year. In 2017, there are 331.1 hectares of wet part, 1345.7 hectares of dried part in tailings pond (Fig.2).

HYSPLIT model description

The HYSPLIT model uses puff or particle approaches to compute trajectories, complex dispersion and deposition. The model computation method is a combination of Eulerian (concentrations are calculated for each

grid cell using integration of pollutant fluxes at every grid cell interface due to advection and diffusion) and Lagrangian (concentrations are computed by summing the contribution of each pollutant "puff" that is advocated through the grid cell as represented by its trajectory) approaches.

The model utilizes meshed meteorological data on one of three conformal map projections (Polar, Lambert and Mercator). The dispersion model requires meteorological data fields that can be obtained from archives or from forecast model outputs and the datasets should be formatted for input to HYSPLIT [9, 10].

The accuracy of the model is considerably

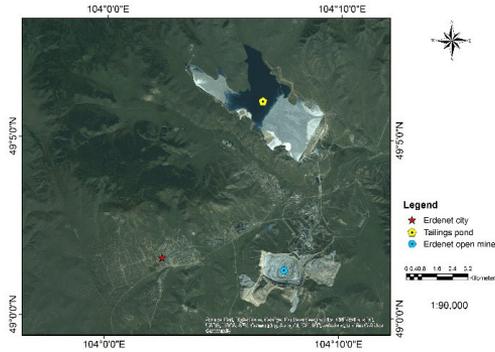


Fig. 1. Study area

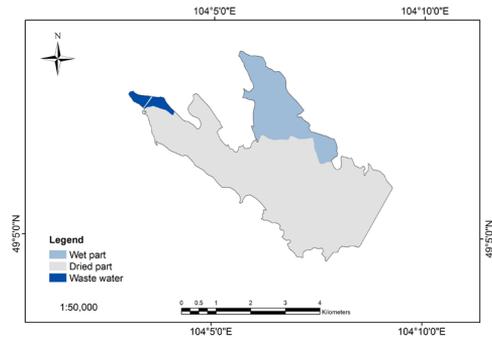


Fig. 2. The classification of the tailings pond

dependent on the meteorological data resolution [3]. For this study, we used daily meteorological data, including precipitation, wind velocity, humidity and temperature, was gleaned from a weather station in Erdenet, which is attached to the Information and

Research Institute of Meteorology, Hydrology and Environment (IRIMHE) and GDAS meteorological data provided by U.S. NOAA. We chose the windiest day during the month and then modeled in those days.

Table 1. Windiest days

Month	Jan	Feb	Mar	Apr	May	Jun
Days	22	14	20	22	12	29
Max wind speed, m/s	13	10	14	16	17	10
Average wind speed, m/s	6.9	5.5	7.6	9.3	8.8	8.3
Month	Jul	Aug	Sep	Oct	Nov	Dec
Days	8	11	5	1	3	14
Max wind speed, m/s	17	20	13	14	10	12
Average wind speed, m/s	9.2	7.7	7.4	7.4	4.3	6.3

In HYSPLIT dust module, PM_{10} dust injections are estimated using as mass source algorithm [18].

$$F = K \frac{\rho}{g} u_* (u_*^2 - u_{*t}^2) \quad (1)$$

where F is the vertical mass flux of dust that is obtained from the friction velocity u_* , a threshold friction velocity u_{*t} , (required for initiation of dust emission), and a coefficient K (s/m) that depends on the surface soil texture. The friction velocity varies in space and time. However, the threshold velocity and soil texture coefficient vary only in space and related to the soil, land-use characteristics and surface roughness. In this study, the model

is used over domain where detailed soil characteristics are not available and revised version of the dust module for vertical mass flux is replaced as Equation (1) [27].

$$F = 0.01u_*^4 \quad (2)$$

The trajectory calculation in any Lagrangian model is based on the following the particle or puff. Therefore, once the basic meteorological data (U, V and W) has been processed and interpolated to the model grid. Trajectories can be computed to test the advection components of the model. The advection is computed from the average of the 3-D velocity vectors for the initial position $P(t)$ and the first-guess position

$P'(t + \Delta t)$.

The velocity vectors are linearly interpolated in both space and time [9, 10].

The first guess position is

$$P'(t + \Delta t) = P(t) + V(P, t)\Delta t \quad (3)$$

and the final position is

$$P(t + \Delta t) = P(t) + 0.5 [V(P, t) + V(P', t + \Delta t)]\Delta t \quad (4)$$

RESULTS AND DISCUSSION

Erdenet city's mainstream wind is from the west and south west. White dust aligned with the average wind direction when it is dry it blows with the wind spreads the whole area which pollutes the soil. Therefore, in Fig.3 has information about wind speed also wind direction.

White dust dispersion shown by HYSPLIT-Dispersion model. Fig. 4, 5 shown the white dust dispersion between January and December in 2015. Dispersion border has drawn on HYSPLIT model with step measurement of 10 to 10 km.

From the result, white dust has spread with 21 to 65 km from tailings pond to the east and southeast and it simulated on these days (on January 22nd, May 12th, March 20th, October 1st and December 14th). Even so, on February 14th, April 22nd and November 3rd it has spread with 15 to 31 km on west also to the southwest. During on June 29th and July 8th it has spread with 14 to 16 km to the north from the tailings pond. On August 11th from tailings pond to the west and northwest it has spread with 16 km. Furthermore, on September 5th it has spread to the northeast with 18 km. From the simulation with HYSPLIT-Dispersion, it shows that white dust has spread far away and for most of the

In this study forward trajectory simulations were used for determining the dispersion of white dust and motion direction of the dust plume over tailings pond. Forward trajectories started from tailings pond (49.09°N, 104.13°E). For HYSPLIT trajectory setting, trajectory tracking levels, including 500, 1000 and 1500 m is considered and also the top of the model assumed to be 10,000 m. Turbulence, wind fields and mixing depth values are used as inputs for dispersion model.

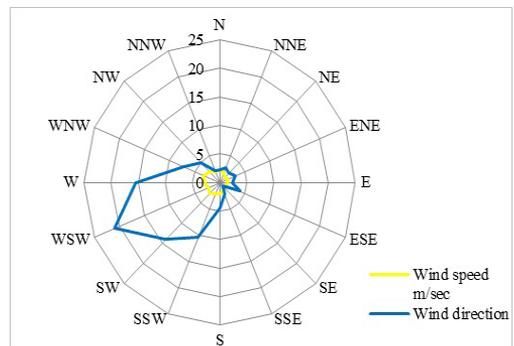


Fig. 3. Polar graph showing the relative impact of the wind, according to azimuth

months to the east and southeast are distributed (Fig.4, 5).

In figure 6, we can see the graphic of some data of white dust dispersion, air humidity, precipitation and wind speed. For building this graph, we used the data of those days in which the highest wind speed of each month during 2015. In October, white dust has spread far from the tailings pond where no precipitation, low air humidity and wind speed is 14 m/s. Also in August was windy day (wind speed is 20 m/s), but air humidity was with 66% due to rain (22mm). Therefore, white dust has spread near from the tailings pond.

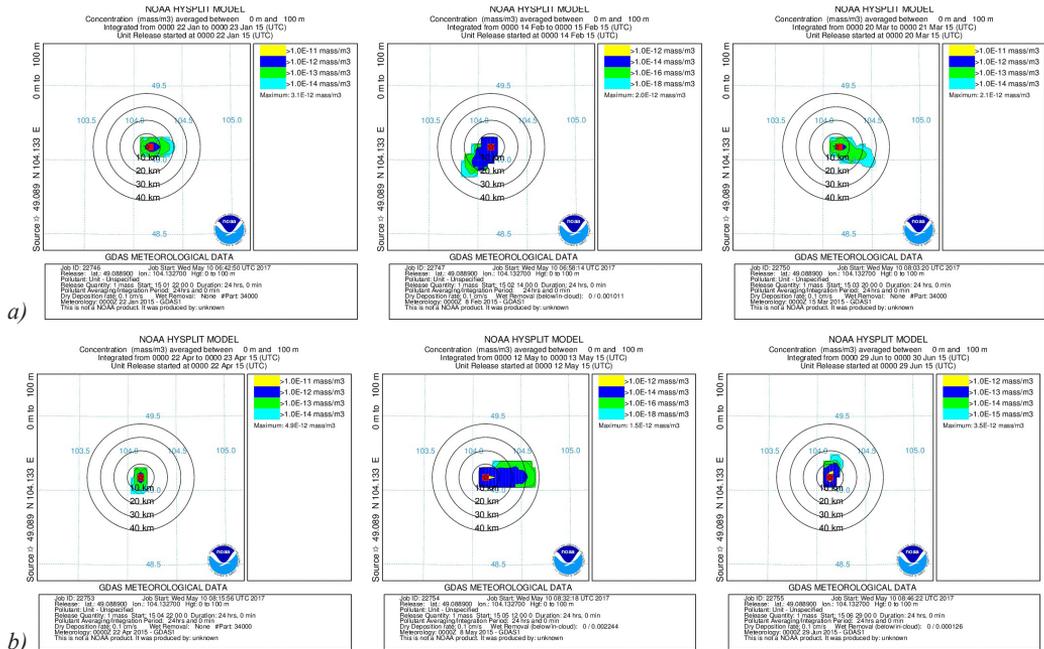


Fig. 4. HYSPLIT-Dispersion generated dust deposition ($\mu\text{g m}^{-2}$) averaged between 0 and 100 m levels and integrated for 24-h period between 0900 UTC of 22 January 2015 and 0900 UTC of 29 June 2015 sourced from tailings pond (49.09N 104.13E), (a) January-March; b) April-June)

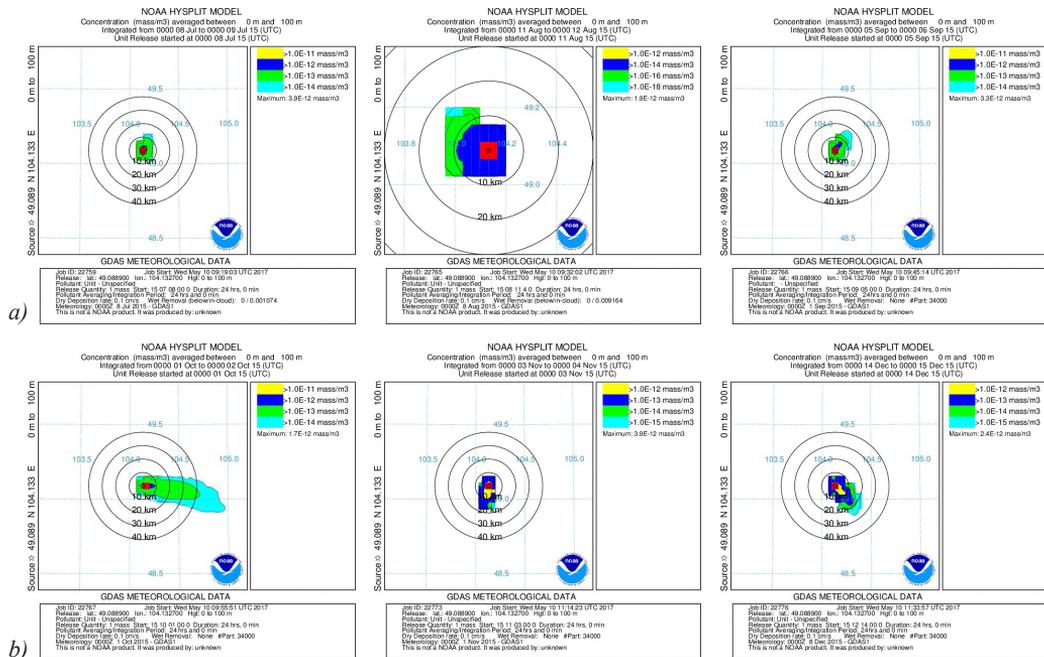


Fig. 5. HYSPLIT-Dispersion generated dust deposition ($\mu\text{g m}^{-2}$) averaged between 0 and 100 m levels and integrated for 24-h period between 0900 UTC of 01 July 2015 and 0900 UTC of 01 December 2015 sourced from tailings pond (49.09N 104.13E), (a) July-September; b) October-December)

In figure 7 we can see HYSPLIT-Dispersion and HYSPLIT-Trajectory modeling it showed the white dust possible spread directions and a long distance (Fig.7). On October 1st white dust which erupts into air was reached up 2000 m. It shows that the dust particle size up to 20 μm in the air mass has been transferred to the air for a long time. Also on August 11th 08 UTC when white dust which erupts into air has been landing on soil sharply, and it shows that it is raining.

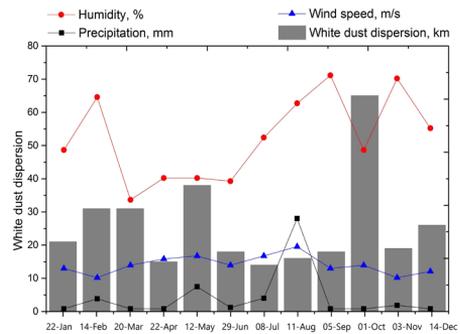


Fig. 6. White dust dispersion

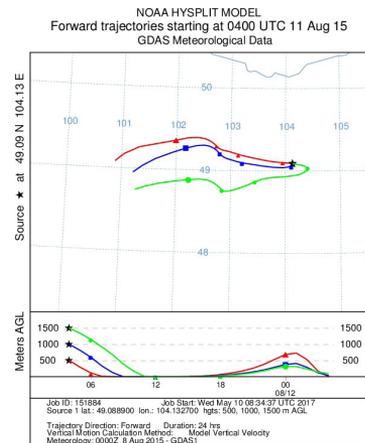
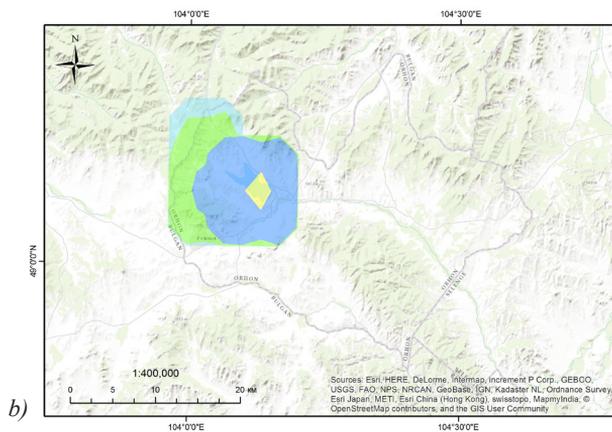
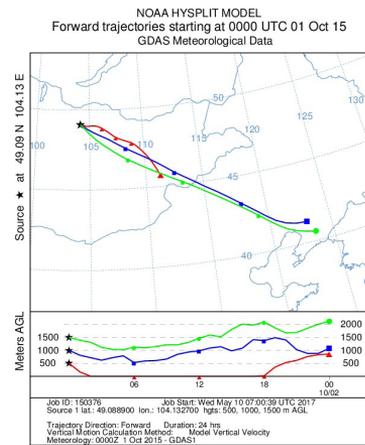
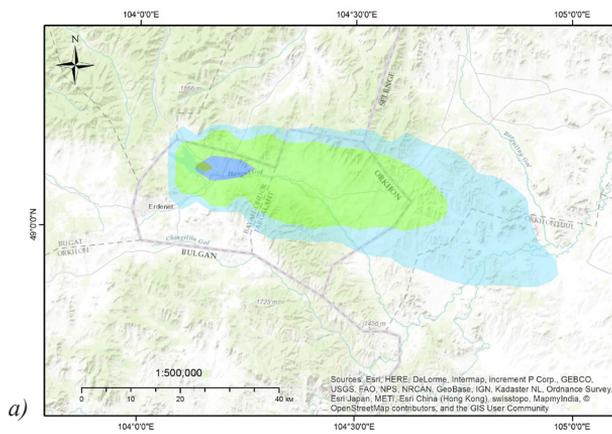


Fig. 7. HYSPLIT-Dispersion and Forward trajectory simulations. Integrated for 24-h period 0000 UTC of 01 October and 0400 UTC of 11 April 2015 sourced from the tailings pond (49.09N 104.13E) (a) dry day; b) rainy day



CONCLUSION

According to the simulation from model HYSPLIT, white dust was spread between 14 and 65 km in 2015. During May and October, white dust distribution would increase up to 38-68 km also these months are the most spread months among all other months.

In May and October are the main months of white dust distribution. During this time, mass concentration of PM_{10} was measured the highest in ambient air quality. Thereby, it's possible that white dust is the source of PM_{10} .

Comparing the white dust dispersion to

weather factor, it is related to precipitation, relative humidity and wind speed. From the analysis between rainy day and normal day, white dust distribution was four times lower when the rainy day. Therefore, precipitation is an important indicator that white dust spread.

From this simulation and analysis we studied, that the rainfall might be one of the solutions also improving researching on this subject and using it for decreasing the distribution of white dust.

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