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Characteristics and Concentration of White Dust and The Particulate Matter (PM_{10}) in Erdenet city, Mongolia

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Abstract

The purpose of this research was to determine characteristics and composition of white dust in the tailings pond of Erdenet Copper Mining (ECM) and to identify mass concentration of the particulate matter (PM_{10}) around Erdenet city. Based on these goals, we determined critical level of flaring speed for white dust and how to reduce this speed. Meteorological data and particulate matter (PM_{10}) were collected from the Research Institute of Meteorology, Hydrology and Environment (IRIMHE) and Air Quality Monitoring Station (AQMS) in Erdenet city. The mass concentration of par-ticulate matter (PM_{10}) were analyzed and compared with WHO guidelines and Mongolian air quality standard (MNS4585:2016). Critical speed of flaring was tested in the laboratory condition and based on that we had estimated total number of days that white dust released into the air. In addi-tion, in order to reduce flaring white dust, watering method was tested in the laboratory and based on that the moisture amount to avoid flaring of white dusts had estimated. Results were shown that spring and autumn have a significantly higher level of mass concentration of PM_{10} in Erdenet city. It was caused by the stagnant atmosphere which leads to pollution's cumulative effect and white dust from the storage of tailings pond during spring and autumn. Particle size of white dust had two types, 2-0.05 mm sandy and 0.05-0.002 mm dusty; yet it had a high concentration of As, Pb, Zn and Cu that were higher than the Mongolian national standard of heavy metals for soil. The critical level of flaring speed was about 4-5 m/s. Based on this critical level of flaring speed for white dust, on average 25 days per month had flaring white dust. The test result in the laboratory was shown that 5 percent of moisture would reduce the flaring of white dust. Therefore, it is possible to use wastewater reserve for watering to reduce white dust flaring.

Key words: PM_{10}, white dust, characteristics, heavy metal, tailings pond

1. Introduction

Erdenet is definitely one of the most polluted cities and it might be the second polluted city in Mongolia in terms of annual mass con-centration of particulate matter (PM_{10}). The population is increas-ing and due to manufacturing and its' pollution of city air quality has been above the standard limit for the last years (METM, 2015). One of the main pollution source of heavy metals and trace elements within the Erdenet Mining Corporation environment is the white dust from the storage of tailings pond. Erdenet Mining Corporation is one of the biggest ore mining and ore processing factory in Asia. The main mineral deposit, extracted by the Corporation was the Erdenetiin-Ovoo area which locates 400 kilometers northwest from Ulaanbaatar city, 180 kilometers east from Dar-khan city, 60 kilometers northern from the center of Bulgan aimag (Ziadat et al., 2015). In 2006, there are 500 million tons' sands, 25 million m^3 wastewater accumulated in tailings pond (Khukhuu et al., 2008). Moreover, white dust and heavy metals in it in ECM tailings are becoming problem for population of around Erdenet city in recent decades. Many researcher was studied the about it. For example; the result obtained from this research indicated that the area surrounding the copper mine in Erdenet, Mongolia is polluted with heavy metals especially with copper. This is attributed to the dust emission from mining activities in addition to vehicle emission in the area. This reflects the fact that mining activities had a direct impact on atmospheric pollution with heavy metals in Erdenet, Mongolia (Baljinnyam et al., 2009). The general and mi-cro mode of country wind, humidity and, cold and warm air of the area effects for dissipation and disperse of white dust of tailings pond. The white dust distribution depends from the wind mode (Khukhuu et al., 2008). 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 (Khukhuu et al., 2008; Bayalag, 2012).

In May and October, white dust dispersion would increase up to 38-68 km also these months are the most spread months among all other months. During this time, mass concentration of PM_{10} was measured the highest in the air. Thereby, it's possible that white dust is the source of PM10. White dust dispersion 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 (Lkhagvajargal et al., 2018).

2. (Materials &) Methods

2.1. Study area, materials and field study

Erdenet city, the second largest industrial city, is located in Western Mongolia at an elevation of 1580 meters above sea level character-ized by high annual sunshine exposure, short dry summer months and

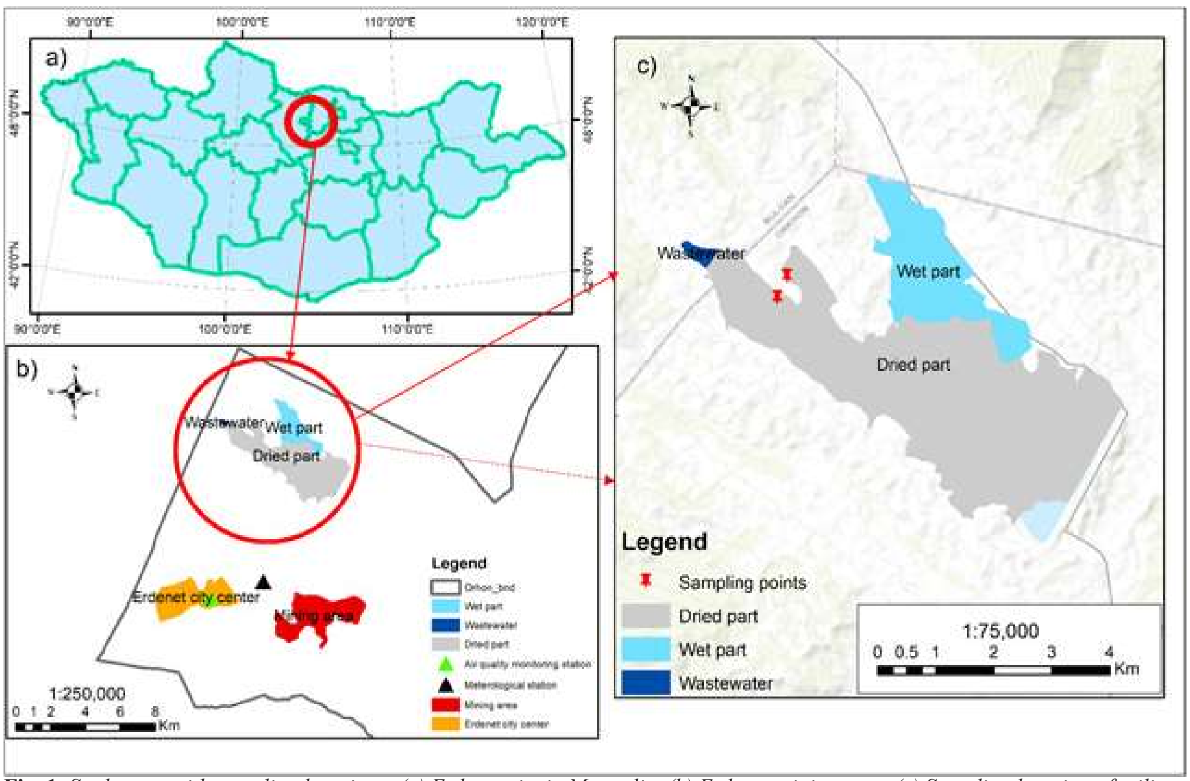

Fig. 1. *Study area with sampling locations; (a) Erdenet city in Mongolia, (b) Erdenet mining area, (c) Sampling location of tailings pond area in Erdenet Copper Mining*

long cold winter season climatic conditions (Badarch, 1971). Erdenet copper molybdenum mine and tailings pond is located northeast of Erdenet city (Fig. 1).

The mine area is a semiarid region with a typical continental cli-mate of a short summer, long winter, and a vast temperature fluc-tuation. The coldest season is in January with a mean temperature of -22.2 ɵC, while the warmest season in July has a mean tempera-ture of 16.5°C. The dominant wind direction is from the west and northwest, and the velocity reaches 20 m/s in spring. The maxi-mum annual precipitation in the area is 355 mm, with 90 % falling between May and September. Average snow cover ranges from 5 to 8 cm (Tsegmid, 1969; Jambaajamts, 2009).

The study was conducted a field study, a laboratory analysis, testing, experiments and statistical processing. Changes of the tailings pond area between 1985 and 2014 were used by measurement data of ECM and tailings pond area of 2017 was calculated on satellite image. Meteorological data including precipitation, wind velocity, wind direction, air humidity and temperature was collected from a weather station in Erdenet, which is attached to the IRIMHE. The data of particulate matter (PM_{10}) was collected from AQMS in the Erdenet city (Tab. 1).

Tab. 1. The data used in the survey

№	Name of data, unit	Year	Time duration
1	Average wind velocity, m/s	2014-2015	Monthly average
2	Max wind velocity, m/s	2012-2015	Daily average
3	Wind direction	2014-2015	Monthly average
4	Precipitation, mm	2014-2015	Monthly average
6	Humidity, %	2014-2015	Monthly average
7	Temperature, °C	2014-2015	Monthly average
8	PM_{10}, μg/m3	2014-2016	Monthly average
9	PM_{10}, μg/m3	2014-2016	Daily average

We conducted a field survey of white dust sampling at tailings pond of Erdenet Copper Mining in August 2016 at Erdenet city (Fig. 2).

Fig. 2. *White dust sampling /03 August 2016, 49^{0}07'17" N 104^{0}04'28" E/*

2.2. Laboratory analysis

Laboratory analyzes were used for 300 g sample that taken from the dried part in the tailings pond. We have separated the sample that more than lowest 45 micrometers and between from 45 micrometers to 125 micrometers, prepared a use composition, worked on the inductively coupled plasma mass spectrometry (ICP-MS). Ultra-pure deionized water (18MΩcm-1) from a mille-Q analytical reagent-grad water purification system (mille pore) and ultrapure HNO3 60% (Lot-No B0157318 Merck) were used. In order to validate the method for determining the concentration of heavy metals, NCB ZC 73006 Certified Reference Material was used. For digestion of this reference material, an acid mixture 3 ml HNO_3 ultrapure 60% and 2 ml HF 40% was added to 0.1 g of sam-ple in a Teflon receptacle, tightly closed. Six such receptacles were inserted into a device made of six stainless steel cylinders mount-ed between two flanges, to confer pressure resistance. The whole system was put in an oven at 200°C for 12 hours. A colorless solution resulted and ultrapure water was added up to 50 ml. Calibration standard solutions and internal standard were prepared by successive dilution of a high purity ICP-multi element calibration standard (10 μg/l from nineteen elements ICP-MS standard, 5% HNO_3, matrix, item N9300233, PerkinElmer Life and Analytical Sciences).

All plastic lab ware used for the sample treatment were new or cleaned by soaking 24 h first in 10 % HNO_3 then in ultrapure water (Voica et al., 2012).

2.3. Laboratory testing and experiments

We have developed some methodology in laboratory conditions. Here in:

- To determine a critical level of flaring speed for white dust by artificial wind
- To determine the moisture amount to avoid flaring of white dust
- To determine which of the sandy and dusty white dust are most likely to occur.

2.3.1. Method of critical level of flaring speed for white dust

Estimating critical level of flaring speed for white dust by artificial wind is between a wind speed of 1-2 m/s, 2-3 m/s, 3-4 m/s, 4-5 m/s and 5-6 m/s each time with 20 times and calculated the white dust emission threshold. The volume of emitted dust from the unit was measured by volume method and wind speed, air temperature, pressure and relative humidity were measured by Silva instrument (Fig. 3).

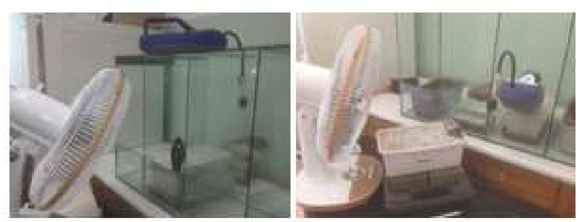

Fig. 3. *Laboratory experiments process*

2.3.2. Method of determination of moisture content

The moisture content of white dust was determined according to the method of A.N. Kachinski, which determines the moisture content of the soil. To determine moisture content, we weighed the sample and then dried at 104°C for six hours. Each 500 g of two types of samples were used for laboratory experiments. First, we measured the mass concentration of white dust with moisture con-tent of 20 percent by Dust Trak TSI instrument. Then we reduced the moisture content of white dust by 2 percent step until 0 percent of moisture content is reached. Each moisture content of white dust was measured 20 times in the laboratory testing.

Moisture content,%=((original weight-dry weight)/(original weight))·100 (1)

3. Results

3.1. Pollution of PM10 in around Erdenet city

First part of this study result was compared with last three years' daily and monthly average mass concentration of PM_{10} between 2014 and 2016. Mass concentration of PM_{10} was exceeded from the WHO AQG for all months other than in February, March and December 2014 and is 1.04-3.5 times higher in concentrations. The highest average concentrations per month were in October 2014, reached 142 µg/m^3 and 1.4 times higher than the Mongolian AQS (MNS 4585:2016), 2.8 times higher than the WHO AQG. In October 2015, mass concentration of PM_{10} reached 130 µg/m^3, 1.3 times higher than the Mongolian AQS (MNS 4585:2016), 2.6 times higher than WHO AQG. But in 2016, the highest concentration of PM_{10} was 105.6 µg/m^3, which was 1.06 times higher than Mongo-lian AQS (MNS 4585:2016), 2.12 times higher than the WHO AQG (Fig. 4).

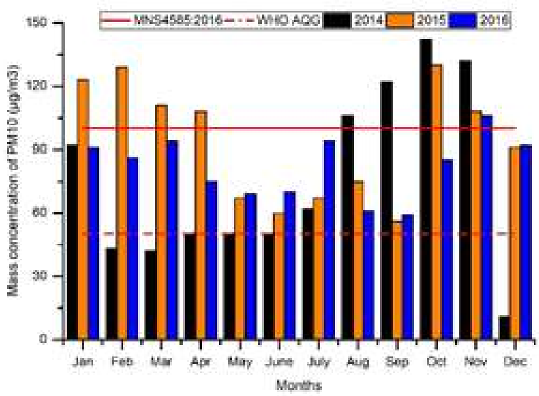

Fig. 4. *Monthly mass concentration of PM10 between 2014 and 2016*

In October and April mass concentration of PM_{10} have increased dramatically. The average maximum concentration of PM_{10} reached 321 µg/m^3 on 14 October 2014, 249 µg/m^3 on 14 April 2015, 261 µg/m^3 on 3 October, 266 µg/m^3 on 21 April 2016 and 265 µg/m^3 on 18 November 2016, respectively. During these days PM_{10} was 2.5-3.2 times higher than Mongolian AQS (MNS 4585:2016) and 5-6.4 times higher than the WHO AQG (Fig. 5).

Particulate matter spread in the air depending on precipitation and wind. Due to the fact that the average monthly mass concentration of PM_{10} in recent years has been compared with meteorological indicators. Fig. 6 has shown that the local monthly average mass concentrations of PM_{10}, combined

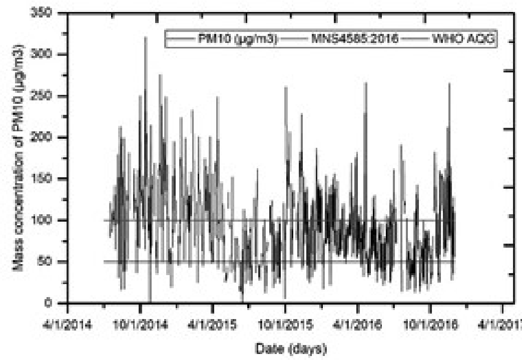

Fig. 5. *Daily mass concentration of PM_{10}*

with monthly precipitation and wind between 2014 and 2016. Fig. 6 reveals the trend of monthly average mass concentration of PM_{10} from February to October, is consistent and takes a concave parabolic form, which is approximatively opposite to the trend of precipitation. The peak value of the monthly average mass concentration of PM_{10} appears in February and October, reaching 113.3 µg/m^3, 119 µg/m^3, respectively, while the trough value is in June, reaching 65 µg/m^3. On the contrary, the monthly total precipitation in August 149.5 mm, while those in January are both less than 3.3 mm. It is observed that mass concentrations of PM_{10} in January, February, March, October and November exceed the daily average PM_{10} upper limit of 100 µg/m^3 as defined by the ambient Mongolian AQS (MNS 4585:2016), illustrating the severity of PM_{10} pollution in the Erdenet area during late autumn, early spring, and winter (Fig. 6).

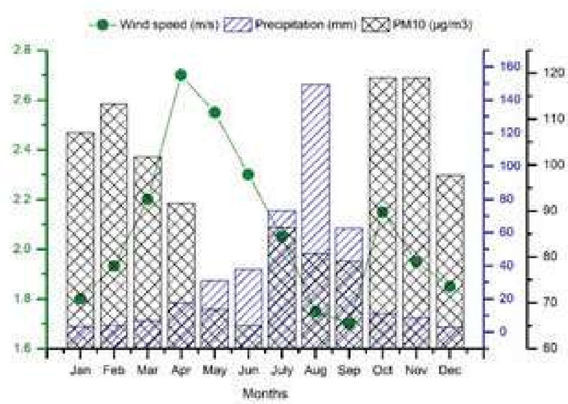

Fig. 6. *Monthly variations of mass concentration of PM_{10} with monthly total precipitation between 2014 and 2016*

Fig. 7 illustrates local seasonal characteristics in the seasonal average mass concentration of PM_{10}. In this study, spring consists February, March and April; summer refers to May, June and July; autumn includes August, September and October; winter includes November, December and January.

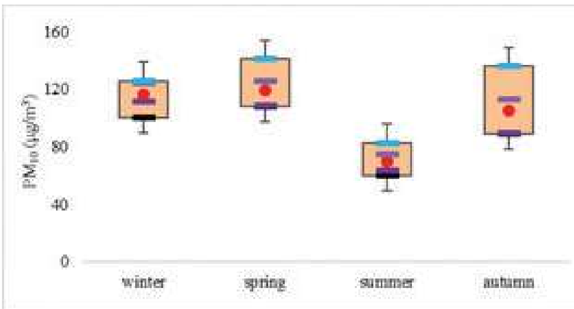

Fig. 7. *Seasonal characteristics of mass concentration of PM_{10}*

A red dot represents the mean value of PM_{10} in each season and a purple horizontal line and a yellow horizontal line represents the twentyfifth and seventyfifth percentiles (upper and lower edges of the box); a blue horizontal line represents the maximum; a black line represents the minimum value of PM_{10} in each season.

Fig. 7 indicates that regardless of particle size, summer has the lowest PM_{10} mass concentration. In contrast, spring has a significantly higher level of PM_{10} mass concentration, probably caused by the stagnant atmosphere which leads to pollution's cumulative effect and white dust from the storage of tailings pond in spring. From the figures above, based on the boxplot, which graphically depict numerical data via quartiles, it is demonstrated that there was a tiny minority of large values in summer, since the mean and median values are below the middle position between maximum and minimum, which could result from longstanding high temperature and low pressure with occasional precipitation in summer.

3.2. Changing tailings pond area and composition of white dust

The ECM produces flotation concentrate in the ore containing copper minerals, and the wastewater is collected into the tailings pond. This wastewater is drying up and spreading in the wind by the environmental climate, drying up over time (Fig. 8). Tailings pond has accounted for 1712.8 hectares of land. Sand, slimes and wastewater area are expanding at disposal every year. In 2017, there are 333.1 hectares of a wet part, 1345.7 hectares of dried part in tailings pond (Fig. 9).

Fig. 8. *White dust externality (a) white dust accumulation in the tailings pond (b) white dust is spreading by the wind from the tailings pond*

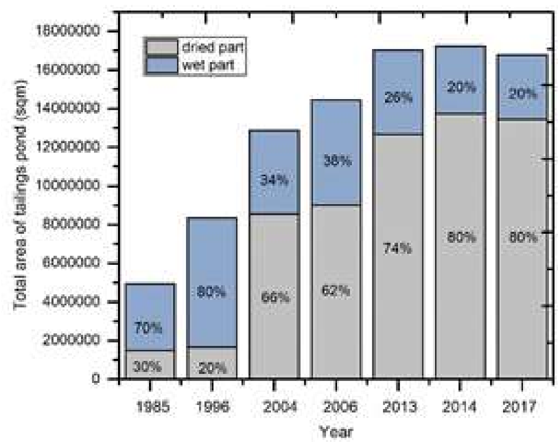

Fig. 9. *Changing area of dry and wet parts of the tailings pond*

According to the expansion of the tailings foundation, the tailings pond area covered 494 ha in 1985 and it has increased 1.7 times that 834 hectares in 1998, 1287 hectares in 2004, 1445 hectares in 2006, 1704 hectares in 2013, 1722 hectares in 2014 and 1713 in 2017, respectively. This result has shown that the tailings storage area is increasing year by year. From 2006 to 2017, the wet area of the tailings area is decreasing and the sand area has increased (Fig. 9). Changes in these areas form the basis for increasing dryness of white dust and expanding the distribution range.

White dust samples taken from tailings ponds were different in particle size. First sample of white dust were 75% of dust, 18% of clay and 7.4% of sand, and second sample were 43% of sand, 41% of dust and 17% of clay (Tab. 2). In laboratory testing and exper-iment, we named that first sample is dusty, second sample is sandy (Fig. 10).

Tab. 2. Particle size of white dust

Sample number	Particle size, %		
	Sand /2-0.05mm/	Dust /0.05-0.002mm/	Clay /<0.002mm/
Sample №1	7.4	74.6	18.0
Sample №2	42.5	41.0	16.5

Fig. 10. *Different white dust sample (by particle size a) dusty sample and b) sandy sample)*

3.1. Heavy metals study in the white dust

The samples were analyzed according to size distribution (fine<45µm and 45 ≤ coarse ≤125 µm). Concentration of 19 heavy metals (Cu, Pb, Zn, and Ni et al.,) for both fine and coarse grain sizes were collected from the Erdenet mining tailing pond (Tab. 3).

Tab. 3. The concentration of heavy metals in fine and coarse dust

№	Metals name	Concentration (mg/kg)	
		Fine	Coarse
1	Cr	1.2	1.1
2	Co	1.3	1.3
3	Cd	2.5	2.7
4	As	18.7	25.7
5	Ni	27.1	28.2
6	Se	88.4	89.0
7	Pb	119.7	118.0
8	Zn	353.3	363.7
9	Sr	498.6	490.4
10	Cu	2815.7	2746.0
11	V	0.5	0.5
12	Rb	5.8	5.2
13	Cs	1.5	1.5
14	Th	13.5	13.1
15	U	6.4	6.3
16	Ga	25.8	24.1
17	Tl	1.0	1.0
18	Bi	12.2	12.0
19	Ba	1375.6	1352.5

The concentration of copper (Cu) were the highest and the concentration of vanadium (V) was the lowest in fine and coarse dust in Tab. 3. That concentration of copper (Cu) were the highest this result is due to the fact that such elements could be directly associated with emission from the mining activities.

We have selected the 10 heavy metals (Cu, Zn, Ni, Cd, and As et al.,) that have in the Mongolian national standard (MNS) for soil from these 19 elements and compared these elements with Mongolian National Standard for soil. The concentration of Chromium (Cr), lead (Pb), Selenium (Se), Copper (Cu) in fine were higher than from concentration of coarse dust. Also the concentration of arsenic (As), lead (Pb), zinc (Zn), and copper (Cu) were the high-est from MNS for soil. Also copper was maximum and higher 27.46-28.15 times than MNS for soil. Chromium was the lowest (1.1-1.2mg/kg) from other elements (Fig. 11).

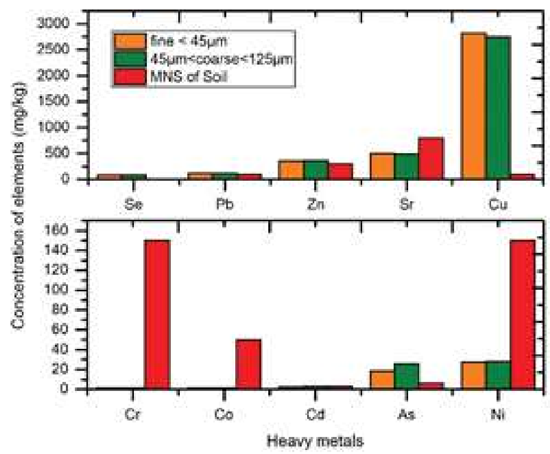

Fig. 11. *Comparison of the concentration of heavy metals and with Mongolian National Standard of Soil*

3.2. White dust experiment

May and October, white dust distribution was the highest (Lkhagvajargal et al., 2018), mass concentration of PM_{10} were the highest in the Erdenet city. Thereby, it's possible that white dust was the source of PM_{10}. We tested the study of how to reduce white dust outbreak. The critical level of flaring speed for white dust is determined at the laboratory conditions (Fig. 12). There was no dusty and sandy samples in the air when the wind speed was between 1 m/s and 4 m/s. Then, to increase wind speed samples were breaking when about 4-5 m/s lost 23 g, about 5-6 m/s lost 30 g of sandy sample. For dusty samples, wind speed was about 4-5 m/s when white dust is a little breaking that lost 0.5 g, about 5-6 m/s lost 0.6 g. For both samples were outbreak to the around when wind speed was 4-5 m/s. Therefore, the critical level of flaring speed for white dust is 4-5 m/s. Sandy sample is more outbreak than dusty sample by the wind (Fig. 12).

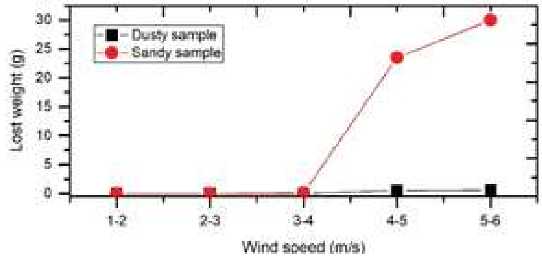

Fig. 12. *Experiment of average value the critical level of flaring speed for white dust*

The critical level of flaring speed is about 4-5 m/s. Based on on this critical level of flaring speed for white dust, we have calculated flaring white dust days from 2012 to 2015. On average 318 days in 2012, 324 days in 2013, 288 days in 2014 and 279 days in 2015 had flaring white dust. Between 2012 and 2015, on average 25 days per month had flaring white dust (Fig. 13).

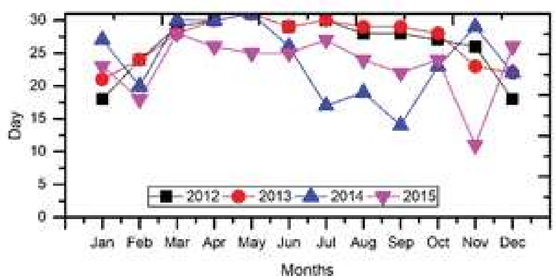

Fig. 13. *Flaring white dust days*

In April and October, the relative air humidity and precipitation were low, the average wind speed was high (Fig. 14). Therefore, these conditions have created better conditions for airborne white dust flaring.

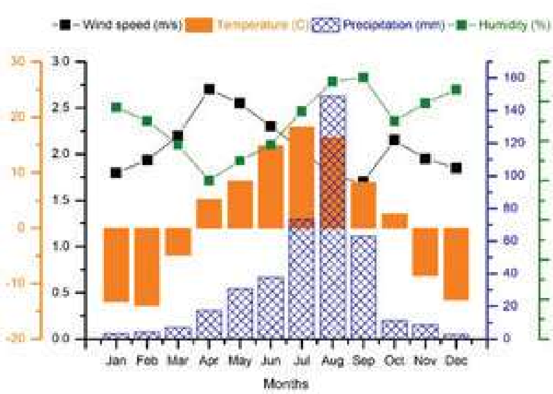

Fig. 14. *Monthly average meteorological condition in Erdenet city*

White Dust Program, Reduce Zeolite, Spray Cuts, Permanent Watercourses or Damps, Water Drainers/ Water Absorbers, Reduce Use of Waste Paper from Millennium, cover with Soil and Gravel, LENKO NW-490 - artificial snow creation, water mist formation, spray engine oil on the surface, covering the surface of the dust with plastic material, recycling of waste (300 technology) side, some of the options were implemented in the tailings area, but were not successful. Due to the fact that we studied the world's most widely recognized copper and molybdenum mine tailings pond and studied the methods of solving the outbreaks of dry dust in the tailings pond. The following table summarizes the ways and means to minimize dust emissions from these works (Tab. 4).

Tab. 4. An international example of reducing the outbreak of tailings dust

№	Name of other mine and experi-ments	Cover with soil	Watering	Reforesta-tion	Polymer spraying	Planting plants
1	Rio Tinto's Ken-necott Utah Copper, USA		+		+	+
2	Giant Mine, Canada		+			+
3	Highland Valley Copper Mine, Canada		+			+
4	Collahuasi copper mine, Chile Total		+			+
Total		0	4	0	1	4

From the international perspective used to reduce dust emissions, watering and planting is more used. It is possible to use the irrigation method to minimize the white dust emissions of the tailings foundation based on the international experience and previous findings of this study.

Therefore, the moisture content of white dust was determined at the laboratory condition and the had tested how may percent of humidity or moisture would reduce the flaring of white dust.

Result have shown that white dust is not flaring that mass concentration of 0 μg/m^3 when dust moisture is from 6 to 17 percent. When moisture content was 5%, white dust was flaring that mass concentration was 14 μg/m^3. In order to reduce the moisture content to 4 percent, the concentration of white dust increased by 9.6 times and 134 μg/m^3. And white dust was measured with mass concentration of 2060 μg/m^3 when no moisture in the white dust (Fig. 15).

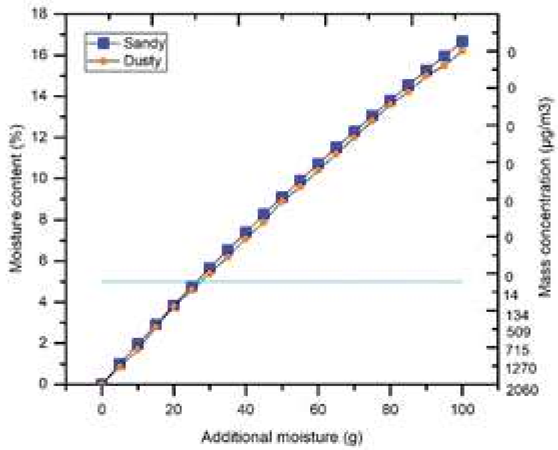

Fig. 15. *The moisture content of white dust*

The test result in the laboratory shown that 5 percent of moisture would reduce the flaring of white dust. Based on this result, the amount of water required for the irrigation was calculated. The area of the dried part is 1347.7 ha. The minimum moisture content of white dust is 5 percent and 23000 m^3 water per day is required to calculate the amount of water required for the total area. The quantity of wastewater for the tailings pond is 25.5 million m^3 and this water can be estimated at 1108 days or 3 years for watering. It is not necessary to conduct irrigation during the days with precipitation and winter season. According to the weather data, it is possible to watering the white dust for 6 years using the wastewater of the tailings pond.

4. Conclusions

Average monthly mass concentrations of PM_{10} were 1.3-1.4 times higher than Mongolian AQS (MNS 4585:2016), 2.6-2.8 times higher than the WHO AQG in most months last three years in Erdenet city. In April and October, average daily mass concentration of PM_{10} reached from 249 μg/m^3 to 321 μg/m^3 that it was 2.5-3.2 times higher than Mongolian AQS (MNS 4585:2016) and 5-6.4 times higher than the WHO AQG. Mass concentration of PM_{10} was low when air humidity and precipitation was high.

The concentration of Chromium (Cr), Lead (Pb), Selenium (Se), Copper (Cu) in fine were higher for fine particles than coarse parti-cles. Also the concentration of arsenic (As), lead (Pb), zinc (Zn), and copper (Cu) were higher than MNS of soil. The copper (Cu) was determined 2746 mg/kg in the coarse particles and 2815.7 mg/kg in the fine particles. It was 27.46-28.15 times higher than the Mongolian national standard of heavy metals for soil.

White dust had two types of particle size: sandy and dusty, sandy sample white dust is more likely to be windy. The critical level of flaring speed is about 4-5 m/s. Based on this critical level of flaring speed for white dust, on average 25 days per month had flaring white dust. The test result in the laboratory was shown that 5 percent and more of moisture would reduce the flaring of white dust. Due to the fact that it is possible to use wastewater reserve for watering to reduce white dust flaring.

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Author Contributions

L.B., and S.C. designed the fieldwork and analyses for PM10. L.B., S.C., B.By and A.M. took samples and field measurements. B.By. performed ICPMS analysis. L.B., and B.Bo performed laboratory experiment and analysis. L.B. wrote the paper.

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Conflict of Interest

The authors declare no conflict of interest.

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Эрдэнэт хотын агаар дахь том ширхэглэгт тоосонцор (PM_{10}), цагаан тоосны агууламж, шинж чанар

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Хураангуй

Энэхүү судалгааны ажлаар Эрдэнэт хотын агаар дахь том ширхэглэгт (PM_{10}) тоосонцрын агууламж болон Уулын баяжуулах Эрдэнэт үйлдвэрийн хаягдлын сан дахь цагаан тосны шинж чанар, найрлагыг тодорхойлохыг зорьсон. Энэхүү зорилгын хүрээнд цагаан тоос дэгдэх босго хурдыг тодорхойлж дэгдэлтийг сааруулах судалгааг хийлээ. Судалгаанд ашиглагдсан цаг уурын мэдээ, том ширхэглэгт (PM_{10}) тоосонцрын мэдээнд Эрдэнэт хотын УЦУОШГ болон агаарын чанарын автомат станцын мэдээг авч ашигласан. Том ширхэглэгт тоосонцрын (PM_{10}) агууламжийг агаарын чанарын стандарт MNS4585:2016 болон Дэлхийн эрүүл мэндийн байгууллагын зөвлөмжтэй харьцуулсан. Цагаан тоос дэгдэх босго хурдыг лабораторийн нөхцөлд тодорхойлж, цагаан тоос дэгдсэн нийт өдрүүдийн тоог тооцоолсон ба цагаан тоос дэгдэхгүй байх үеийн чийгийн агууламжийг тодорхойлов. Үр дүнгээс харахад Эрдэнэт хотод хавар, намрын улиралд том ширхэглэгт тоосонцрын агууламж өндөр байгаа бөгөөд энэ нь хавар, намрын улиралд хаягдлын сангаас дэгдэх цагаан тоосны дэгдэлтийн үетэй давхцаж буй нь эх үүсвэр нь цагаан тоос болохыг харуулж байна. Цагаан тоос механик бүрэлдэхүүний хувьд элсэрхэг болон тоосорхог гэсэн хоёр өөр хэв шинжтэй байгаа бөгөөд элсэрхэг цагаан тоос салхинд илүү дэгдэмтгий байна. Цагаан тоосон дахь хүнцэл, хар тугалга, цайр, зэсийн агууламж монгол улсын хөрсөнд агуулагдах хүнд металлын зөвшөөрөгдөх агууламжаас давсан байна. Цагаан тоос салхины хурд 4-5 м/с байхад агаарт дэгдэж байна. Дэгдэх хурдыг сааруулах туршилтын дүнгээр цагаан тоосыг 5 хувь болон түүнээс дээш хувийн чийгийн агууламжтай болгоход дэгдэлт нь саарч байна. Иймд цагаан тоосны дэгдэлтийг сааруулахад усалгааны арга ашиглах нь боломжтой болох нь харагдаж байна.

Түлхүүр үг: PM_{10}, цагаан тоос, шинж чанар, хүнд металл, хаягдлын сан