Available online at www.ap.ardabil.iau.ir
Islamic Azad University, Ardabil Branch
Anthropogenic Pollution Journal, Vol 6 (2), 2022: 48-54
ISSN: 2783-1736- E-ISSN: 2588-4646

Original Research Paper

Investigation of wet spraying system to control dust pollution in mines (A case study)

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Article Information

Received: 2022.06.13
Revised: 2022.08.23
Accepted: 2022.10.22
Published online: 2022.12.17

DOI: 10.22034/AP.2022.1960859.1131

Keywords

Air pollution control
Wet spraying system
Spraying for dust suppression
Iron ore mining
Safety

Abstract

Industrial dust has a significant effect on the environment of mines, which leads to an increase in illness among workers. To decrease the impact of dust on the climate, a wet spraying system is useful for controlling dust in mining companies. In this paper, by using the wet (water) spraying system, dust control in the area of the crusher and pellet plant (discharge tower) has been investigated by Goharzamin Iron Ore company. Goharzamin Iron Ore company has an essential role in producing of steel in Iran. There are a 15 million tons gyratory crusher, three iron concentrate plants with an annual capacity of 6 million tons, and a pelletizing plant with annual capacity of 5 million tons. The dust was controlled in the gyratory crusher area of Goharzamin Iron Ore company by using a wetting spraying system. Results showed that the rates of PM10 for the east, west, north and south sides of the gyratory crusher and also the center of this system are equal to 851.2, 647.5, 643.9 and 781.2, and 1116.3 µg/m3, respectively. Furthermore, after turning on the wet spraying system in this area, these values are reduced to 128.3, 112.8, 115.9, 123.7, and 189.9 µg/m3, respectively. The results showed that the water spray system in the gyratory crusher area reduced the PM2.5 (Particulate matter) and PM10 particles by 67% and 80%, respectively.

How to Site: Makkiabadi M., Yaghoobi S., Haj Mohammadi S., Investigation of wet spraying system to control dust pollution in mines (A case study), Anthropogenic Pollution Journal, Vol 6 (2), 2022: 48-54, DOI: 10.22034/AP.2022.1960859.1131.

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1. Introduction

Air is the most valuable resource given to the earth for the survival of all living things (Bruvoll et al., 2003; Sadigh et al., 2021; Sekhavati et al., 2021; Tabari et al., 2021; Hoseini et al., 2022). Also, maintaining of the environment is one of the requirements of having a good life. With the growth of industries, mines, and population, the pollutants released into the environment have increased (Mostofie et al., 2014; Sousa et al., 2018; Makkiabadi et al., 2020;). In Iron ore mines, due to the nature of crushing, material transfer, harvesting and accumulation, dust production is an intrinsic part of mining operations (Soltani et al., 2017; Geissen et al., 2015) . Occupational diseases caused by dust breathing in mines have a very long history and the resulting dust enters the lungs and makes breathing difficult and reasons respiratory diseases such as asthma and stomach cancer (Sekhavati and Jalilzadeh, 2022; Shaikh et al., 2021; Kelleher et al., 2000). To solve this fundamental problem (production of dust in the environment), the use of industrial ventilation systems such as dust collectors (Janusz et al., 2019; Ryzhov et al., 2019), cannon fag and water spray systems (Yang et al., 2019; Wang et al., 2017). The most crucial industrial dust collectors used to trap dust in the mining industry in concentrate, pellet, reduction, and smelting plants include venturi dust collectors (Fesharaki et al., 2012; Shilyaev at el., 2005) and Electrostatic precipitators (Caplan et al., 2021; Zhang at al., 2021).

Due to the existence of iron mines worldwide, research has been done to reduce the dust generated in these mines in recent years around the world (Chang et al., 2021). Prostanski. 2013 studied the utilize of air-wetty spraying systems for enhancing dusts at the KOMAG company which was utilized in long-wall shearers, in road headersand in roadways. The results showed that this system could decrease dust up to 80 percent, it chip in a considerable reduction of dust concentration. The Experimental characterization of multi-nozzle atomization interposition for falling of all dusts between hydraulic supports at a coal mining face was presented by Wang et al. 2019. Their results showed that under the optimazition parameters, the middle total and respirable dusts suppression amounts valued at diffrent measuring parts on the downwind side during support relocation reach 78.93% and 80.53%, respectively. Peng et al. 2019 studied research with the expansion of a recent wind-water centralized spraying dedusting device for controlling all dusts in a fully mechanized mining face. Yin et al. 2019 investigated transient CFD (Computational Fluid Dynamics) modeling of the space-time progress of toal dust pollutants and airgenerator position. This primary purpose was to exmine the effect of air generators on the control of total and respirable dust. Their results showed that if an air curtain generator did not exist, dust diffusion could not be usefully worked and controlled all dusts in tunnels. A study on the dust control effect of the dust extraction system in tunnel boring machine (TBM) construction tunnels based on numerical simulation was studied by Wen Nie et al. 2019. A study of dust elimination outcome of spraying collector for boosting support in coal mining face by Zhou et al. 2020. Han et al. 2020 studied of influence of water pressure on atomization specifications and dust-depletion efficiency of internal mixing air atomizing nozzle. A CFD simulation study on the total and respirable dusts characteristics and optimal dust control air flow were investigated by Xiu at al. 2020.

Irsel in 2020 studied a paper to bring forward the designs needed and methodology of research production to administrate a mechanical-controllable system electronically. Low-cost water-spray control systems (WSCS) chemical losses were reduced by 6% to 20%. Decoupling on the effect of air droplets and canopy performance in the air-assisted spray was reviewed by Xuemei et al. 2021. A study of numerical modeling and experience on the flow field of air-water ultra-low volume sprayers in conveniences was studied by Xinyu Lu et al. 2021. Their results showed that according to the experiment, the water-spray system was found to successfully enhance the witness on the backside of the crop, increment the droplet density, and diminish the testimony amount and factor of variation (below 20%) within and between regions.

In present paper, an experimental study was conducted to control dust in the Goharzamin Iron Ore company. The results showed that it is essential to use a wet spraying system for open areas such as gyratory crushers. Also, a comparison of the efficiency of the current wet spraying system with other systems was made.

2. Materials and Methods

In Iron Ore Goharzamin Company, there are a gyratory crusher with an annual capacity of 15 million tons, three iron concentrate plants with a capacity of 2 million tons, and a pelletizing plant with a total capacity of 5 million tons. By investigating the conditions of the region and also in consultation with HSEE (Healthy, Safety, Environmental, Energy) of Goharzamin Co, two areas of gyratory crusher and pellet drainage are selected as areas that produce dust mainly.

Due to water shortage in Sirjan city, using fresh water is limited. Water consumption in the water spray system is about 15 liter per minute for each pump. To design the water spray system in the gyratory crusher, its equipment was first drawn using Solid Work software (figure 2). As shown in figure 1, six nozzles were considered for the gyratory crusher. Every two nozzles are connected to a high-pressure pump with a pressure of 200 bar. A schematic of the water launch by each nozzle is shown in figure 1.

Four nozzles are placed in the corner, and also two nozzles are located on the east side of the gyratory crusher. As can be seen in figure 2, three high-pressure 200-bar pumps, and two water reservoirs with a capacity of 5000 and 10000 liters were used in water spraying system in gyratory crusher. A schematic of the location of the nozzles on the east wall of the crusher is shown in Figure 3.

Another area that causes a lot of dust in the Goharzamin Iron Ore company is the pellet discharge area (TT04 part)

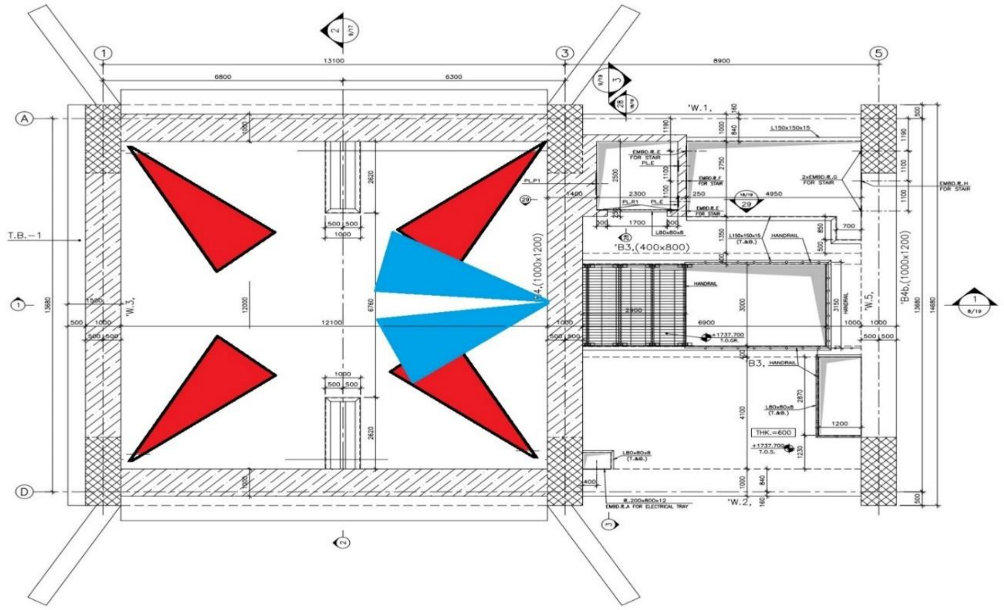

Figure 1. Schematic of the arrangement of the nozzles

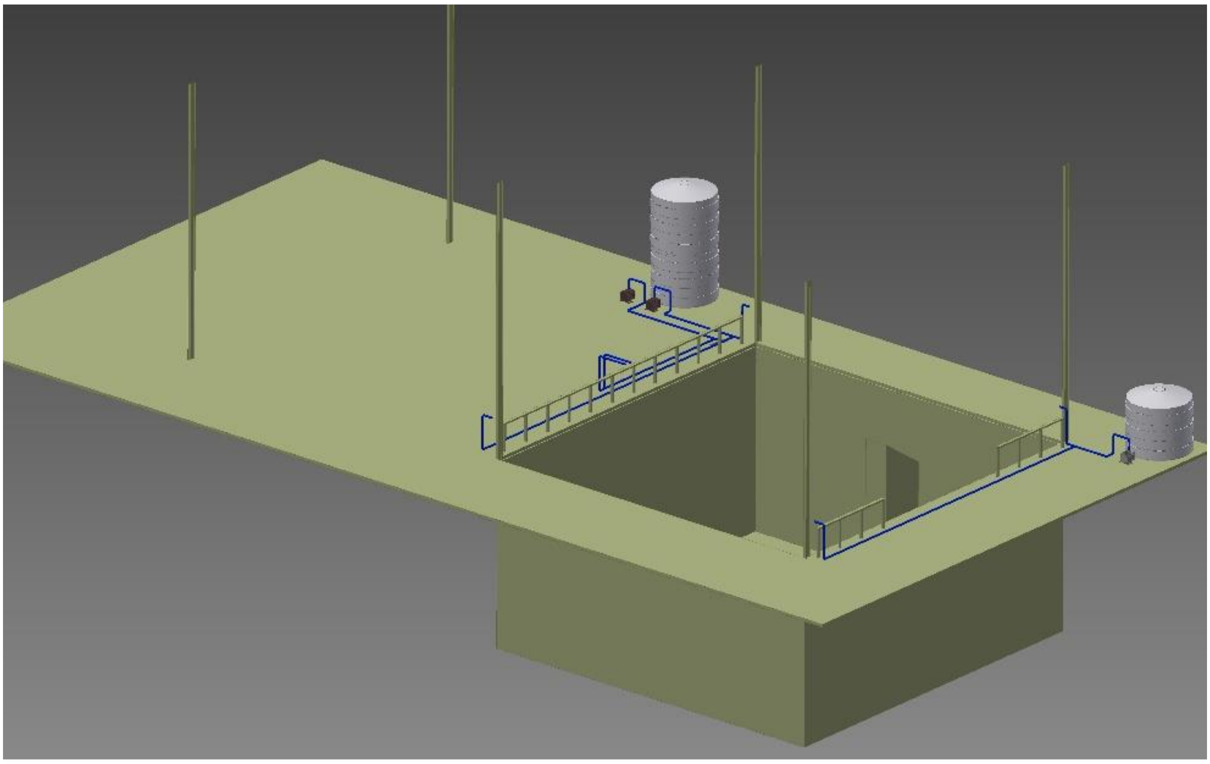

Figure 2. Side view of water spraying system in gyratory crusher

is the end of the pelletizing plant. Two nozzles were used to control dust in this area. Thier nozzles are connected to a 200-bar high-pressure pump.

3. Results and discussion

The world is concentrated on proceeding the fractions of Particulate matter (PM) that include variety of chemical compounds where particles are less than 10 micrometers in diameter (PM10) and less than 2.5 micrometers in diameter (PM2.5) based on the latest evidence on the effects of PM on health.

Control of two environmental parameters PM10 and PM2.5 are of particular importance for the environment and occupational health (the HSEE unit). Goharzamin

HSEE unit calculates parameters PM10 and PM2.5 in different years. These parameters under the management of HSEE unit by using the AEROCET 531S dust calibrator device with calibration approval were measured many times. One of the places where there is a lot of dust is the gyratory crusher area. In each experiment, the parameters PM10 and PM2.5 in the north, south, east, west, and center of the gyratory crusher were tested. Parameters PM10 and PM2.5 for gyratory crusher were reported on 6/8/2018 and 4/5/2021 in figures 3 and 4, respectively. In the first experiment (figure 3), the value of PM10 for the east, west, north and, south sides of the gyratory crusher and also the center of this system is equal to 307.2, 350.5, 277.9 and 1116.3, and 781.2 µg/m^3, respectively. Due to the wind from north to south and south to north, most of the parameters PM10 and PM2.5 are in north and south parts. Also, the center of the crusher is one of the dusty areas. Based on these reports, it was decided that the nozzles

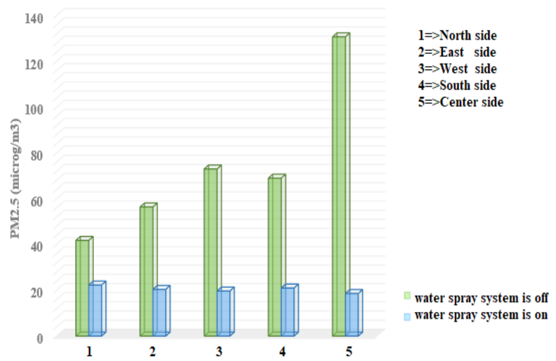

Figure 3. PM2.5 parameter when water spraying system is off and on

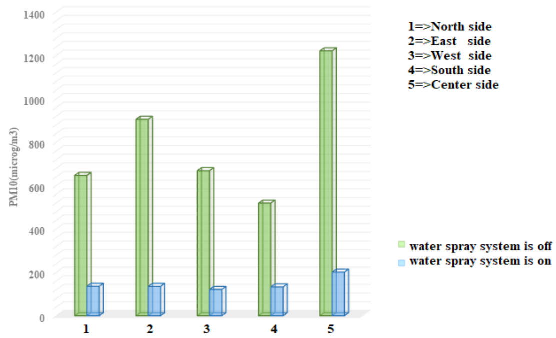

Figure 4. PM10 parameter when water spraying system is off and on

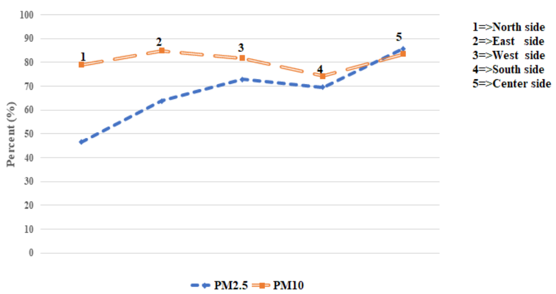

Figure 5. Percentage reduction of parameters PM2.5 and PM10

of the water spraying system should be dusted in such a way as to eliminate dust in the center. For this reason, four nozzles are placed in the four corners and two nozzles are placed on the east side. After installing the dust system, connecting the nozzles and testing the pumps, their dust system was turned on. On 3/3/2022, the dust system was launched and with the coordination of the HSEE unit of Goharzamin company testing of critical environmental parameters such as PM10 and PM2.5 was performed. The study showed that the total level of total dust (PM10) and respirable dust (PM2.5) on the central side of the gyrator crusher in Goharzamin Iron Ore company is 1116.3 and 128 µg/m3 when this system is off, when it was started, the results showed that these parameters have become 189.9 and 18.8 µg/m3. According to the results in the center and average of gyrator crusher, the efficiency of total dust (PM10) for the center of crusher and standard was equal 82 and 83%, and also for respirable dust were equal 84 and 63%.

In a theoretical and emperimental analysis, Wang and Jiang, 2021 showed that by using the gas water system, the real and respirable dust decreased by 86.44 and 68.31%. They reported that when a wetness water spray is used, total dust and resirable dust are reduced by 91.97 and 84.26%. According to their result, the wetting capability of the five surfactants was reconciled and studied by the fransport influence test and tension test. Also, Prostanki, 2013 used a air-wetty spraying systems by KOMAG considerablely decrease dust in the air of the mining company. They used some nozzles that needed just a tiny volume of water among 0.1 and 0.4 dm3/min. In the present study, the six-medium spraying nozzles need a tiny volume of water between 0.3 and 0.4 dm3/min were utilized in the gyratory crusher zone. Prostanki, 2013 reported that the air-wetty spraying fitting expanded at KOMAG company to remove the methane, produced to be a valuable tool in dust reduction. Their results showed that during the long wall cutting act, the total dust decreased by 42% and the respirable dust diminished by 93%. Behshid, 2017 studied a comparison of the performance of different types of nozzles, such as air atomizing nozzles, hydraulic cone nozzles, hollow hydraulic cone nozzles, and hydraulic flat nozzles. According to the results and applications of nozzles, hydraulic flat nozzles have been used for dust control in this study. These nozzles are helpful for wet dust prevention systems, can be used in different volumes between 0.1 and 0.9 dm3/min.

Also, Wang et al. 2019 studied the all flow specifications of several nozzles by CFD simulation and experiment, and determined the optimization atomization dust depletion parameters. They reported that the dust-suppression yield dusts like total and respirable dusts had a tendency of prime increasing and then decreasing with the enhance of the air supply pressure. Wang et al. 2019 have set up the empirical device of air-wetty spray systems and the empirical model of spray. The foremost parameters of the air-water system have been distinguished, and the empirical analysis of total and respirable dust has been performed. Wang et al. 2019 studied the spray pressure and the installation angle of the water system with simulation and experimental methods to reduce the total and respirable dusts. According to the study by Wang et al. 2019, in the present article, Bertolnie pumps with a pressure of 200 bar were selected to pulverize the water properly. The consumption of each pump is 15 liters per minute used for three pumps in the gyratory crusher zone. In 2018, Ma et al. used the particle image velocimetry (PIV) system to check out the effect of gas and water pressure on the spray angle and wind speed. According to this paper, the angle of the nozzles relative to the horizon was considered to be -20 degrees. In this paper, it was determined that when wind speed is less than 4 m/s, the pressure of pumps should be 100 bar, when it was between 4 to 8 m/s the pump pressure should be 140 to 150 bar and finally when the wind speed was above 8 m/s, their pressure should reach 200 bar. Hua et al. 2018 studied the numerical modeling of the total and respirable dusts of the multi-radial air membrane producing machine. Ansart et al. 2009 analyzed an empirical model of water spray to control to the total and respirable dusts. Uchiyama et al. 2006 analyzed the influnces of mixed instable airflow effected by the velocity of particles on airflow and forestall the entrainment flow of particles to the ambient.

4. Conclusions

There are areas such as gyrator crusher and pelletizing plants that cause dust in Goharzamin Iron Ore company. Dust control is one of the most important ends of engineering office management and HSEE management. Due to the openness of the crusher area, it is better to use a water spray system in these areas. The result showed that the value of PM10 for the east, west, north, and south sides of the gyratory crusher and also the center of this system is equal to 307.2, 350.5, 277.9, and 1116.3 and 781.2 μg/m^3, respectively. Also, the results showed that the water spray system in the gyratory crusher area reduced the PM2.5 and PM10 particles by 67% and 80%, respectively. When the water spray system is on, it removes about 80% of the dust. When the system is off, there is a lot of dust in the environment and even for several minutes, this dust is in the air. But when the dust detection system is turned on, after 30 seconds, direct spraying on the dust makes the environment clean. it was determined that when the wind speed is less than 4 m/s, the pressure of pumps should be 100 bar, when it was between 4 to 8 m/s, the pump pressure should be 140 to 150 bar, and finally when the wind speed was above 8 m/s, their pressure should reach 200 bar.

Conflict of interest

The authors declare that they have no conflict of interest.

Additional Information And Declarations

Funding

We thank Goharzamin Iron Ore Company for funding.

Grant Disclosures

There was no grant funder for this study.

Competing Interests

The authors declare there is no competing interests, regarding the publication of this manuscript

Author Contributions

Mahmoud Makkiabadi: Proposed the plan, conceived the experiments, analyzed the data, main writer, authored or revised drafts of the paper.

Sara Yaghoobi: Analyzed the data, authored or revised drafts of the paper.

Mohammad Saleh Haj Mohammadi: Prposed the plan, approved the final draft.

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