Journal of Air Pollution and Health (Spring 2020); 5(2): 121-134

**Original Article**

Available online at http://japh.tums.ac.ir

# Investigation of morphological and mineralogy characteristics of dust around the lead and zinc mine in Mehdiabad, Yazd, Iran, using the SEM and XRD analyzes

***Saeed Shojaee Barjoee[1,*], Hadi Farokhi[2], Saeed Zarei Mahmoud Abadi[3], Saeede Sedghi[4]***

[1] Department of Environment, School of Natural Resources and Desert Studies, Yazd University, Yazd, Iran

[2] Department of Environment, School of Natural Resources, Science and Research Branch, Islamic Azad University, Qeshm, Iran

[3] Department of Environment, School of Natural Resources, Payame Noor University, Tehran, Iran

[4] Department of Rangeland, School of Natural Resources, Sari Agricultural Sciences and Natural Resources University, Sari, Iran

**ARTICLE INFORMATION**

*Article Chronology:*
Received 3 April 2020
Revised 10 May 2020
Accepted 15 June 2020
Published 29 June 2020

*Keywords:*
Morphological and mineralogy characteristics; X-ray diffraction (XRD); Scanning electron microscopy (SEM); Quartz and calcite; Mehdiabad lead and zinc mine

**CORRESPONDING AUTHOR:**

said.shojaee71@gmail.com
Tel: (+98 91) 38368436
Fax: (+98 35) 38261722

**ABSTRACT:**

**Introduction:** Dust created by mining activities is one of the most important concerns regarding human health and the environment protection. The aim of this study was to identify the mineralogical and morphological characteristics of dust particles found around the lead and zinc mine of Mehdiabad.

**Materials and methods:** First of all, dust samples were collected around the mine by installing eight passive marble dust collectors using a combined systematic random method during February, March and April in 2020. Then, using two methods of X-ray diffraction (XRD) and scanning electron microscopy (SEM) mineralogy, shape and distribution of the particles of dust samples were investigated.

**Results:** The highest frequency of particles with sizes less than 10, 10-60, and 60-100 µm were determined and observed in S1 station in the northwest, and S5 and S2 stations in the southwest of the mine, respectively. The results of SEM analysis revealed that the appearance of dust particles is mostly Spherical, Irregular, Elongated, Prismatic, and Rhombic. The results of XRD analysis showed that the minerals anorthite (Ca ($Al_2Si_2O_8$)), dolomite (Ca Mg $(CO_3)_2$), albite ($NaAlSi_3O_8$), calcite ($CaCO_3$), quartz ($SiO_2$) and muscovite ($KAl_2$ ($Si_3AlO_{10}$)) ($OH_2$) have the highest frequency in dust samples.

**Conclusion:** The findings show that the predominant mineralogical composition of dust particles includes carbonates (dominant mineral: calcite) and silicates (dominant mineral: quartz) which are found in all stations. Thus, dust particles, with high frequency of quartz, have a high potential to result in respiratory diseases in the inhabitants living around the mine.

## Introduction

Mining has a long history in human history. Since the ancient times, human beings have supplied their needs in different ways from the earth, and mining has evolved along with the development of human societies. Mining is an advanced science today, and the amount of annual extraction of mineral material from the earth is greater than the total amount of sediment carried by the rivers. Taking out this huge amount of material has

Please cite this article as: Shojaee Barjoee S, Farokhi H, Zarei Mahmoud Abadi S, Sadeghi S. Investigation of morphological and mineralogy characteristics of dust around the lead and zinc mine in Mehdiabad, Yazd, Iran, using the SEM and XRD analyzes. Journal of Air Pollution and Health. 2020; 5(2): 121-134.

many consequences in the environment and this can cause some problems if protections are not taken in account carefully [1]. Despite the value of mining activities in terms of creating sustainable job opportunities, and creating and completing the infrastructure such as transportation and social development in countries, it has always been considered in terms of environmental damages. With the extraction of more and more open pit mines, the expansion of operational space and land degradation, and the creation of tailings ponds, the environmental problems associated with the mines are increasing every day [2]. The release of toxic heavy metals in nature, degradation of soil quality, surface and groundwater pollution, acidic drainage, air pollution, noise pollution, visual pollution, ecological effects (negative effects on biodiversity, vegetation, and wildlife species) and finally, health effects in humans are among the environmental problems associated with mining activities [3].

Dust created by mining activities is one of the most important concerns regarding the protection of human health and the environment protection. This is due to the fact that dust plays an important role in the transfer of non-degradable pollutants such as heavy metals to sensitive population centers [4]. Various activities conducted in mines such as excavation, blasting, and natural erosion of tailings can cause dust production. In arid and semi-arid areas, mineral tailings are vulnerable to erosive factors due to their poor construction; therefore, they are one of the most important sources of dust creation in the areas around the mines [5]. Dust created by the excavation and erosion of waste materials, after a period of suspension in the air, will settle on the surfaces in the form of falling dust. The term "falling dust" refers to aerosols with a diameter equal to or greater than 10 μm that have the ability to settle after temporary suspension [6]. Deposited dust particles can have a significant effect on human health. Airborne particles usually have sizes between 0.0001-500 μm, most of which are the materials in the size range of 0.01-01 μm [7, 8]. It has been reported that each person with an average of 10 h of activity and with 17 breaths per minute and an average of 0.01121 g/m$^3$ of dust the air averagely enters 6.6240 g of dust into the lungs at the time of the dust phenomenon (10 h) [9]. Depending on their origin and direction of motion, dust particles have a high ability to carry heavy metals, or they can be a dangerous contaminant if combined with a special mineralogy or morphology [10]. Today, in addition to determining the chemical indicators of dust particles, it is also important to study their physical properties and their role in environmental pollution. Moreover, the size of the particles, as the most important factor, allows them to have deep access to the respiratory system as well as oxygen exchange areas of the lungs [11]. Complex and irregular shapes of the particles result in an increase in their active reaction surface. In some studies, the effect of the shape of the particles on human health has been investigated. Many researchers examined the minerals and the pattern of dust particle size distribution around Hur al-Azim in Khuzestan province, then they found that the predominant minerals in the dust particles include quartz, calcite, feldspar, halite, dolomite, and palygorskite. In addition, their other results showed that due to the similarity in the pattern of dust particle size distribution with some local soils, some of the particles are of local origin [12]. Using X-ray diffraction (XRD) and scanning electron microscopy (SEM) analyzes, classified by some researchers on Khuzestan dust particles into three groups: carbonate (calcite), silicate (quartz), and clay (kaolin) with different spherical, irregular, prismatic, and rhombic shapes [13]. In another studey in a 6-month study on dust particles in Urumia and Abadan, it was found that most of the particles are calcite, quartz, clay minerals, and a little gypsum. In addition with the decrease in the size of the particles, the amount of quartz reduced and the amount of clay minerals and lead particles increased. They also stated that the predominant shape of the particles was mainly spherical, flat, cubic, cylindrical, and prismatic, and with the occurrence of dust events, the shape and size of the particles changed and the tendency to roundness increased [14]. In recent decades, with the discovery of new mineral veins, the mining activities of the lead and zinc mine in Mehdiabad, Yazd, have increased, and as a result, the falling dust around the mine has created many dangers for the residents. Therefore, this study was carried out by carefully examining the falling dust around the lead and zinc mine in Mehdiabad, Yazd, using SEM analysis of particle morphology and using XRD mineralogy analysis. The information, obtained by this study, will determine the degree of dust hazard on the health of local communities and will provide the necessary measures to reduce the harm caused by this phenomenon in the field of human health and the environment protection.

## Materials and methods

The present descriptive-analytical study was conducted in February, March, and April 2019-2020 in the area around the lead and zinc mine of Mehdiabad, Mehriz, Yazd. The geographical coordinates of the area under investigation are 31° 16′ 31″ to 31° 31′ 31″ North Latitude and 54° 47′ 30 ″ to 55° 08′ 19″ East Longitude. In the following, the geological structure of Mehdiabad lead and zinc mine, the environmental conditions of the study area, Sampler design, and dust sampling method, as well as their analysis using SEM and XRD methods will be described.

### *Geological structure of the lead and zinc mine of Mehdiabad, Yazd*

Mehdiabad zinc and lead deposit is located at a location at 110 km southeast of Yazd in the central part of Central Iran. Mehdiabad lead and zinc mine, with more than 200 million tons of lead and zinc, is the largest mine of this kind in the world. This mine contains oxide and sulfide deposits of lead and zinc and includes seven oxide, sulfide, and composite parts. The Mehdiabad zinc deposit with an average grade of 7% is the second largest non-sulfide deposit in the world. This mine has been exploited intensively for a long time using handmade mining system. Most of the extraction of materials was due to the high grade of zinc (20 to 50%) from the oxide part [15]. Asphalite, galena and barite are common economic minerals and pyrite and chalcopyrite are sub-minerals in the sulfide section. Serosite ($PbCo_3$), Smith Zonite ($ZnCo_3$), Hemorphite ($Zn_4(Si_2O_7)(OH)_2 . H_2O$) and Hydrosensite ($Zn_5(CO_3)_2(OH)_6$) are the main minerals of the oxidized part of the deposit. The host rock of the deposit is Lower Cretaceous carbonate rocks including three formations of Sangestan, Taft, and Abkooh. The Sangestan Formation is mostly composed of shale and siltstone with Arnite limestone layers. This lithological unit is covered with dolomite, dolomitic, and ancritic limestone of Taft Formation. Abkooh Formation is located on the Taft Formation in the up-per part, which includes chert and clay limestone with massive row limestone and Conglomerate between-layers [16].

***Climate conditions***

There are a variety of uses in the area under study, including rangeland vegetation, desert, agricultural lands, pistachio orchards, and rural areas. The study area was topographically a combination of mountainous and flat features. According to the information obtained from the Meteorological Organization in 2020, the prevailing wind direction in the region in February, March, and April was from the northeast to the southwest and the average wind speed in February, March, and April was equal to 2.16, 2.59, and 2.60 m/s (Fig. 1). The average horizontal visibility in February, March, and April was 15662, 15386, and 15516 m, respectively. In addition, dry air temperature in February, March, and April was equal to 9.67, 15.83, and 17.06 degrees while the relative humidity was equal to 27.89, 23.82 and 36.27% respectively.

Lack of rainfall as well as poor vegetation density in the region have always caused natural erosion. On the other hand, the drilling operation and the creation of a large pit, as large as 1.65 km, can increase the emission of dust containing toxic substances in the area. Tailings dams created by the mining activities, which are without any protective cover, are always exposed to wind. Therefore, erosion of these tailings dams and explosive operations in the mine always cause dust production in the area which can affect the life of surrounding residents. Mehriz Cement Factory is located at 27 km northwest of the mine and it is 33 km far from the villages. Thus, in addition to natural erosion and mining activities, Mehriz Cement Factory has contributed to the increase of toxic dust in the region.

***Sampler design***

In order to conduct this study, Continuous sampling of dust was performed during three months using Marble Dust Collector (MDCO). In the design of this sampler, three rows of marbles were placed in a plastic container With diameters and heights of 315 and 100 mm, respectively. To prevent dust escape, marbles with a diameter of 1.6 cm were selected (Fig. 2) [17].

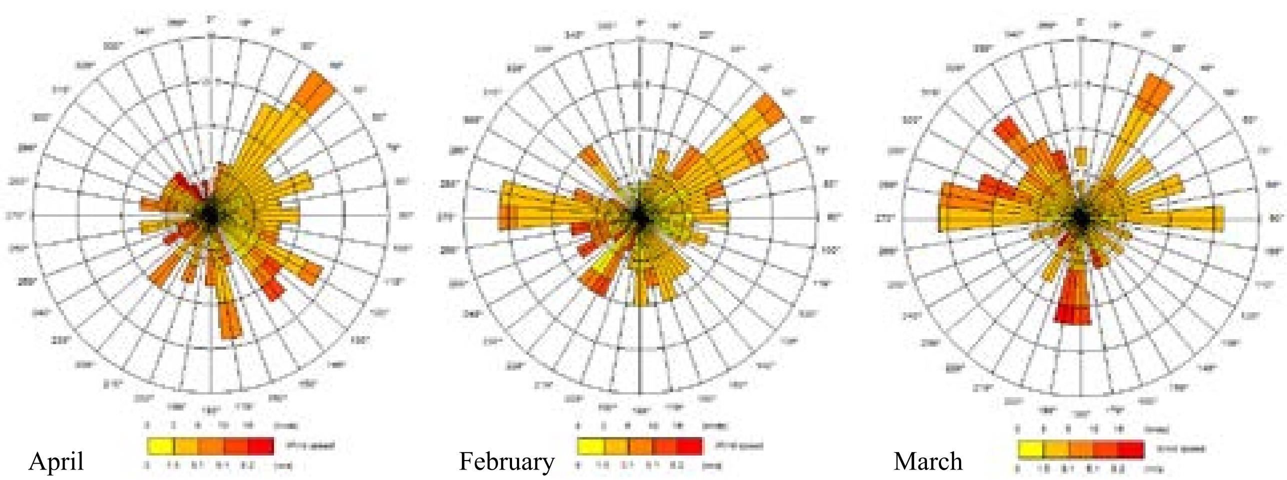


Fig. 1. Wind rose of Mehriz in February, March, and April of 2020

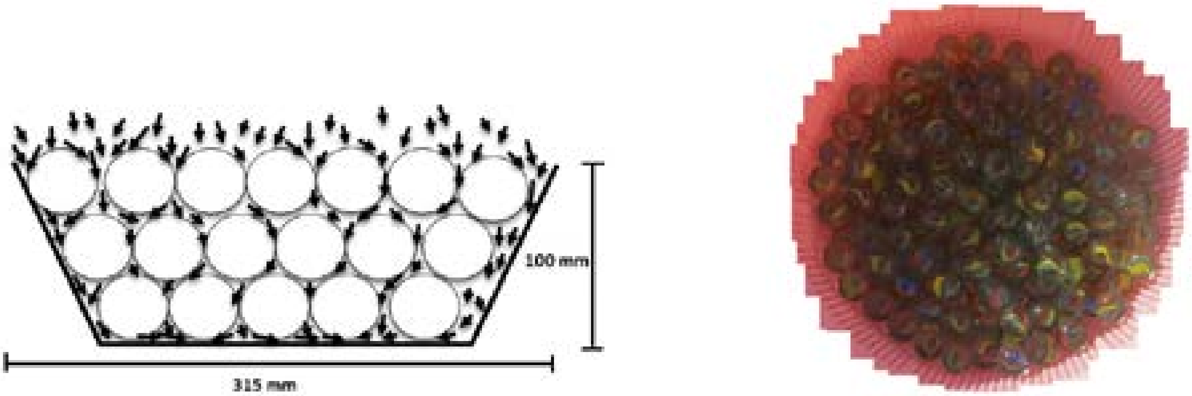


Fig. 2. MDCO samplers used in order to collect the falling dust

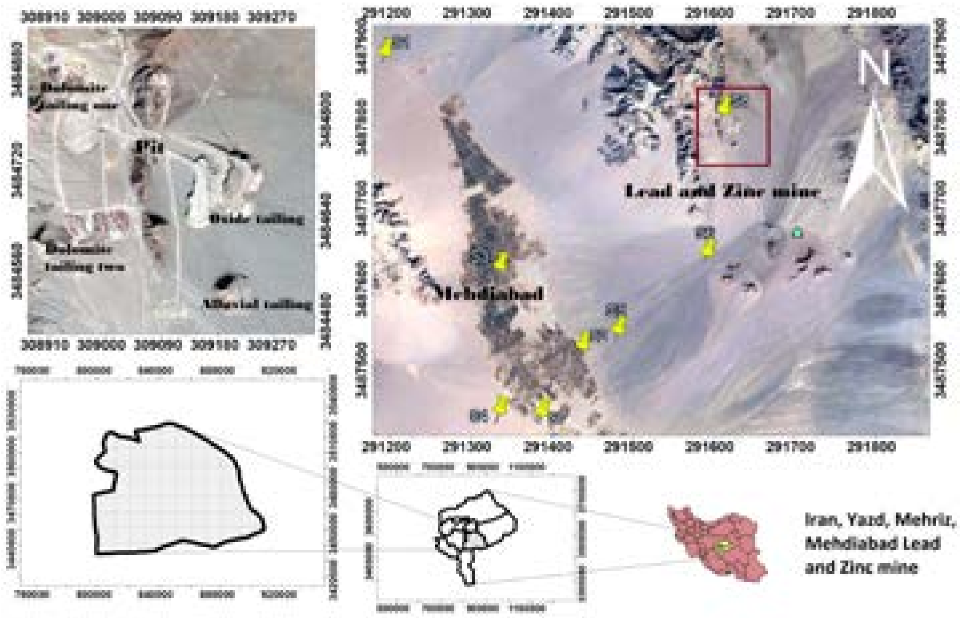


Fig. 3. Location of Mehdiabad lead and zinc mine in Mehriz, Yazd, and the sampling stations

***Selection of the sampling stations***

Systematic random sampling was performed along a transect (longitudinal cross sectional) facing the prevailing wind in the area. For this purpose, a 400 m × 400 m network was first drawn. Then, by removing a number of selected points that were not accessible by the samplers, such as mountains and roads, the position of the stations was determined [18]. In selecting the sampling stations, in addition to the prevailing wind direction of the region, the uses of the lands, such as residential and agricultural areas, were taken into account [19]. A total of eight sampling stations were installed and after three months, the gathered dust was collected. The location and names of the stations are shown in Fig. 3. In addition to dust, 4 different samples were collected from the mine tailings dam.

***Analysis of dust and tailing samples using XRD and SEM methods***

X-ray diffraction analysis is one of the most important non-destructive methods used to detect minerals in dust and tailings. In this study, using the X'PertPro X-ray diffraction device made in the Netherlands by Panalytical Company with

1.54 radiation the CuKα angstrom was conducted. Samples were scanned from a 5 ° to 80 ° θ2 angle of 0.05 ° θ2 per second on a rotary sampler. After the experiment, the results were analyzed using High Score Plus software and each mineral peak was related to the relevant mineral type and recorded and the amount of minerals existed in each sample was measured.

Scanning Electron Microscope was used in order to observe the size, shape, and morphological characteristics of the dust particles of the samples as well as the placement of the particles next to each other or even the placement of clays between different ranges of particles and even clay coatings on other compounds and particles. In this method, some dust samples were placed on black double-sided adhesive non-conductive carbon films to adhere to the special support bases. The throwing coating device was used to provide a gold coating to increase their conductivity and a gold cover as thick as 200 Å was placed on the samples. Then, the samples were placed under a microscope and secondary electron images with a magnification of 250 were taken from all the samples using a voltage of 15 kV and a working distance of 15.49 mm.

## Results and discussion

### *Distribution of the Size and Shape of the Particles*

The effect of airborne particles depends on their properties such as size, shape, and mineralogy [20]. Dust particle size distribution is a good indicator for assessing the origin of these particles and their transmission distance. For example, the existence of multi-peak distribution patterns indicates dust particles of different origins and the influence of different processes in the transport of these particles. In a study, the particle size distribution was introduced as an indicator for their deep access to the respiratory system as well as oxygen exchange areas of the lungs [21]. Fig. 4 shows the pattern of dust particle size and tailings distribution at sampling stations. According to the figure, the highest frequency percentage of particles smaller than 10 μm (54%) was observed in station S1 and the lowest percentage of frequency (25%) was recorded in station S5. In other stations, the frequency percentage of particles with a diameter of less than 10 μm was: S6 (52%)> S3 (51%)> S7 (44%)> S2 (43%)> S4 (35%) >S8 (28٪). Particles with a diameter range of 10-60 μm had the highest frequency percentage (74%) in S5 stations and the lowest frequency percentage (42%) in S2 station. The sequence of the frequency of particle in this size in other stations is observed as follows: S8 (72%)> S4 (63%)> S7 (55%)> S3 (49%)> S6 (47%) >S1 (45%). The order of this ranking for particles with a diameter of 100-60 μm is S2 (15%)> S1 (7%)> S4 (2%)> S5 = S6 = S7 (1%)> S8 and S3 (zero). The results of particle size distribution for mineral tailings showed that the frequency of the particles with a diameter of less than 10 μm was represented as follows: oxide tailing (65%)> dolomite tailing one (50%)> dolomite tailing two (48%)> alluvial tailing (40%). Particles in the size range of 10-60 μm have the highest frequency in alluvial tailings (51%)> dolomite tailings one = dolomite tailings two (47%)> oxide tailings (29%), respectively. Moreover, particles with a diameter of 100-60 μm have the highest frequency in alluvial tailings (9%)> oxide tailings (6%)> dolomite tailings two (5%)> dolomite tailings one (3%).

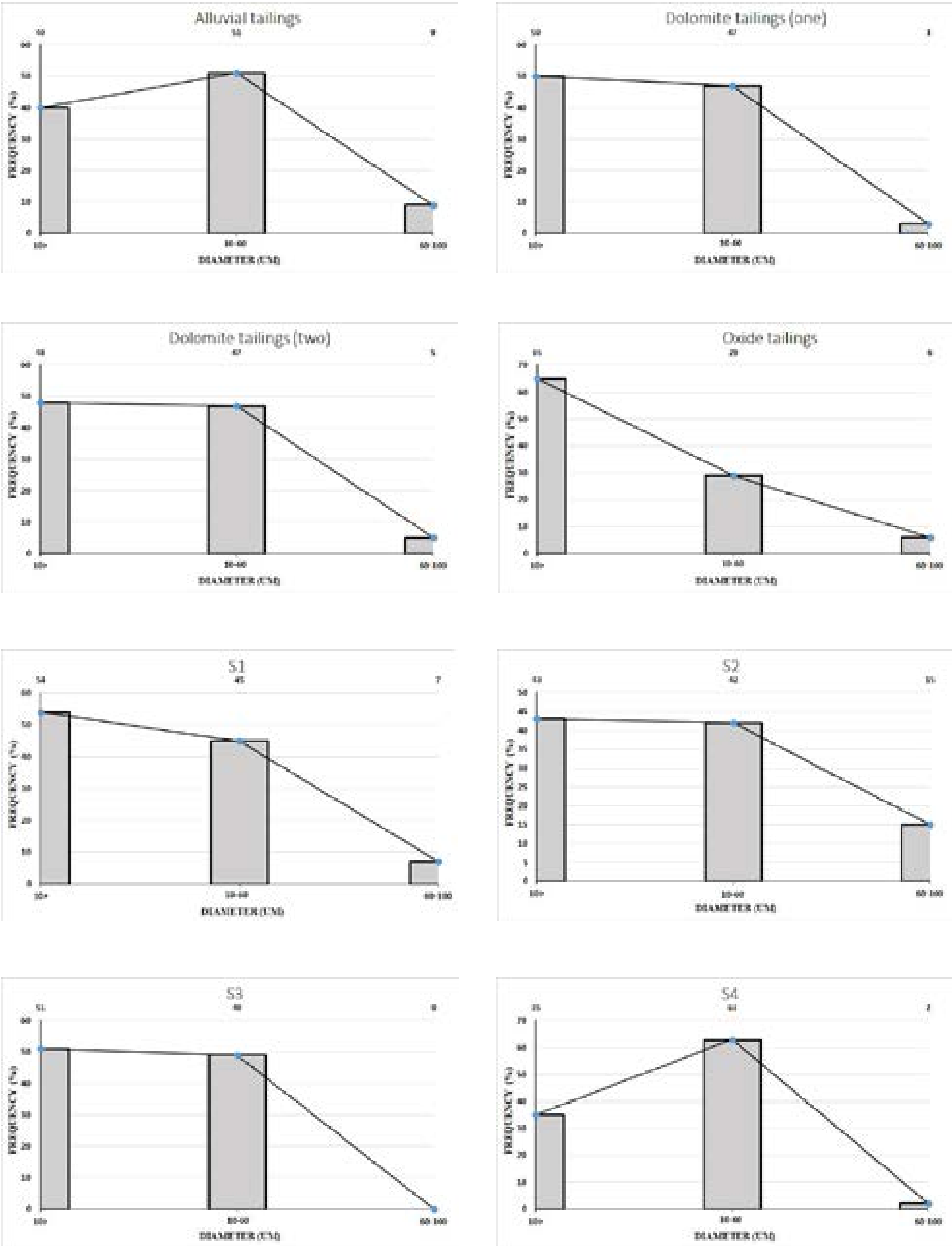


Fig. 4. Particle size distribution of the falling dust taken from sampling stations and tailings

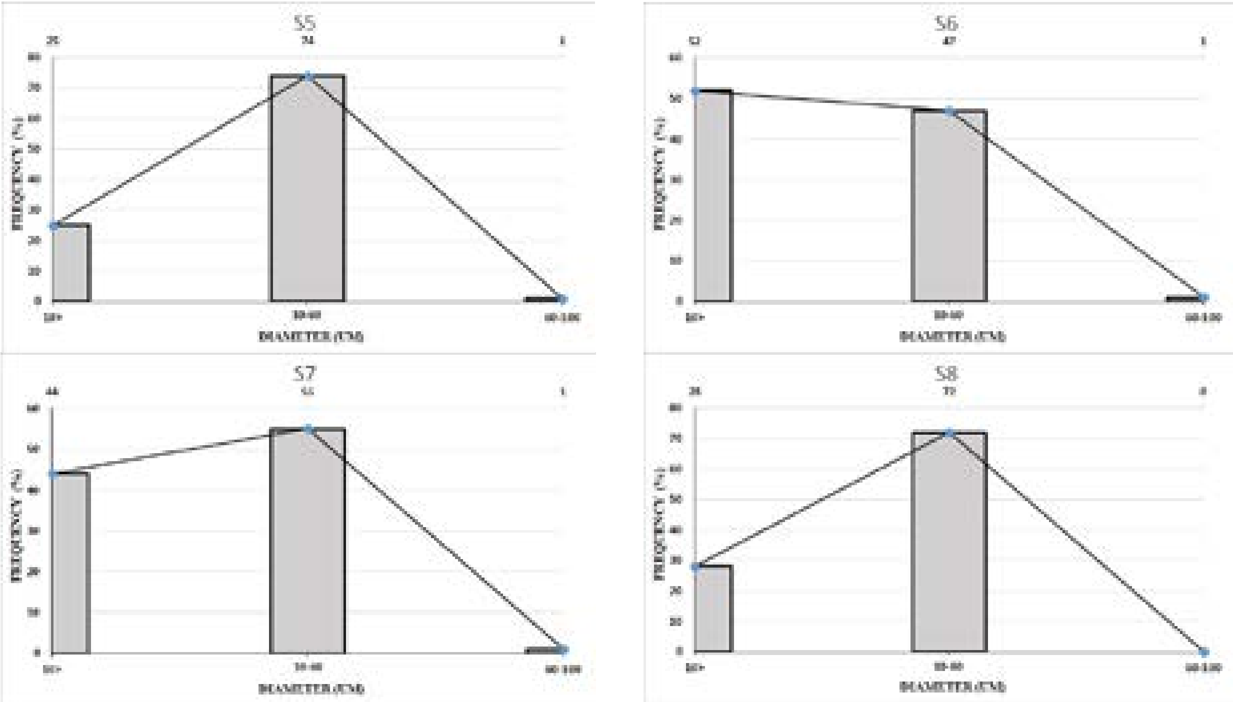


Fig. 4. Particle size distribution of the falling dust taken from sampling stations and tailings

The results of a research work, on the shape and morphology of dust particles falling on the cities of Sanandaj, Khorramabad, and Andimeshk showed that with increasing distance from the centers of dust generation, the particle size becomes smaller, so Sanandaj station, due to greater distance from dust hotspots, contain smaller particles [22]. Irregular and complex shapes of the particles lead to an increase in their active reaction surface. As a result, the morphology and shape of dust particles are important factors in determining their toxicity and risk for human health. In the present study, in the oxide andtailings dolomite two, the two forms of particles are mainly angular to slightly rounded, and in the alluvial and dolomite one tailings, they are mostly rounded with high to slight angular shapes. In SEM explorations, the morphology of the particles largely reflects the minerals that make up the dust particles. Of course, if the SEM method is combined with the application of a micro-analyzer (EDX), the chemical composition of each particle as well as its shape and mass can be measured perfectly. In the present study, only the SEM method was used to prepare the images. These images and the examination of the shape and size of the particles show that the samples have a certain uniformity in terms of shape and mineralogy. According to a study, spherical, irregular, elongated, prismatic, and rhombic shapes occurring in dust particles represent clay alumino silicate, quartz, and calcite particles in dust particles, respectively [20]. Accordingly, based on SEM images, particles smaller than 10 μm are spherical in shape and they are mostly of the clay mineral type. Moreover, particles with a diameter of 10-60 μm have an elongated, irregular, and prismatic shape mostly composed of quartz and calcite minerals. Irregularly shaped particles with a diameter range of 100-60 μm are mostly made of quartz (Fig. 5).

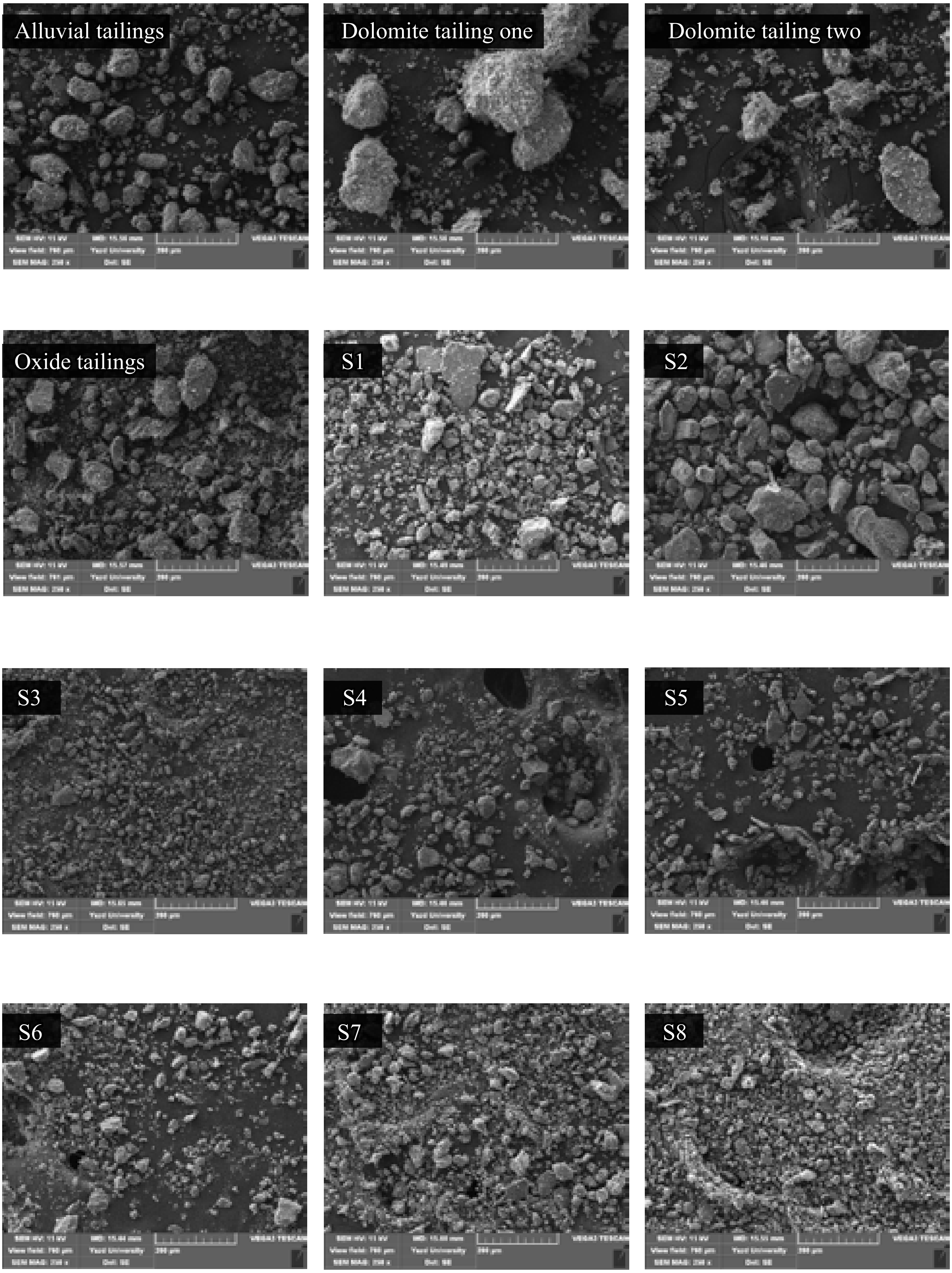


Fig. 5. Irregularly shaped particles with a diameter range of 60-100 μm are mostly made of quartz

***Mineralogy of dust particles and their possible sources***

The mineralogy of airborne particles and dust varies and depends on the minerals of the source areas, regional geology, and the direction of the dominant wind. The results of XRD analysis are shown in Fig. 6. According to the presented figures, the minerals anorthite (Ca $(Al_2Si_2O_8)$), dolomite (Ca Mg $(CO_3)_2$), albite ($NaAlSi_3O_8$), calcite ($CaCO_3$), quartz ($SiO_2$) and muscovite ($KAl_2(Si_3AlO_{10})(OH)_2$) have the highest frequency in the dust samples. The highest frequency of minerals in the dust particles were as follows: station S1= anorthite, calcite, and quartz, S2 = calcite, dolomite, low amounts of quartz, sodium-rich anorthite, S3=quartz, calcite, albite, and muscovite, S4=quartz, high amount of calcite, and albite, S5=quartz, calcite, low amount of albite, and Muscovite, S6=quartz, calcite, and anorthite, S7=quartz, calcium-rich calcite, and albite, S8=quartz, calcite, high amount of albite and dolomite.

In the tailing samples, the most frequent minerals in the tailing of the oxide section were dolomite, calcite, quartz, and hematite ($Fe_2O_3$), in the tailing samples of the alluvial section, four minerals of calcite, quartz, dolomite, and enstatite ($Mg_2(Si_2O_6)$) were observed. Moreover, in the first dolomite tailings dam quartz, Calcite, dolomite and muscovite and in the second dolomite tailings dam quartz, calcite, dolomite and muscovite were the most frequent minerals. The amount of major oxides in the dust particles indicates the mineralogical composition and composition of rocks in these particles and in areas where dust particles do not travel long distances, these oxides are used to determine the source or possibly multi-source of the particles. The similarity of the results on the types of minerals observed in tailings and dust particles show a significant effect of the tailings of Mehdi Abad lead and zinc mine on the chemical composition of the region's dust.

**Conclusion**

The results of this study show that dust and the type of particles in it can have devastating effects on humans and environment. The results of XRD analysis showed that many of the minerals in the tailings were the same as the ones in the dust samples collected from the stations. Therefore, mining activities have had a significant effect on

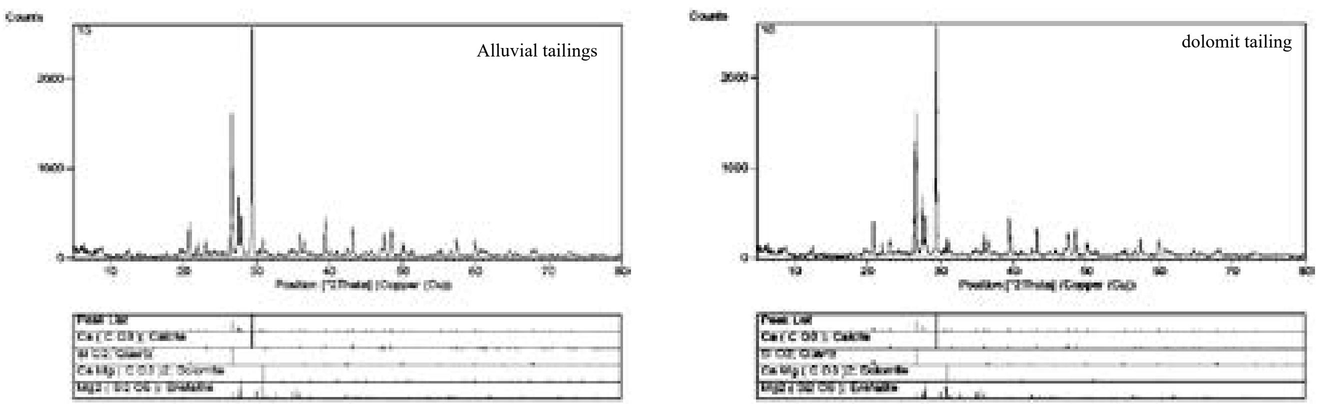


Fig. 6. display of Mineralogy characteristics of the dust particles by XRD

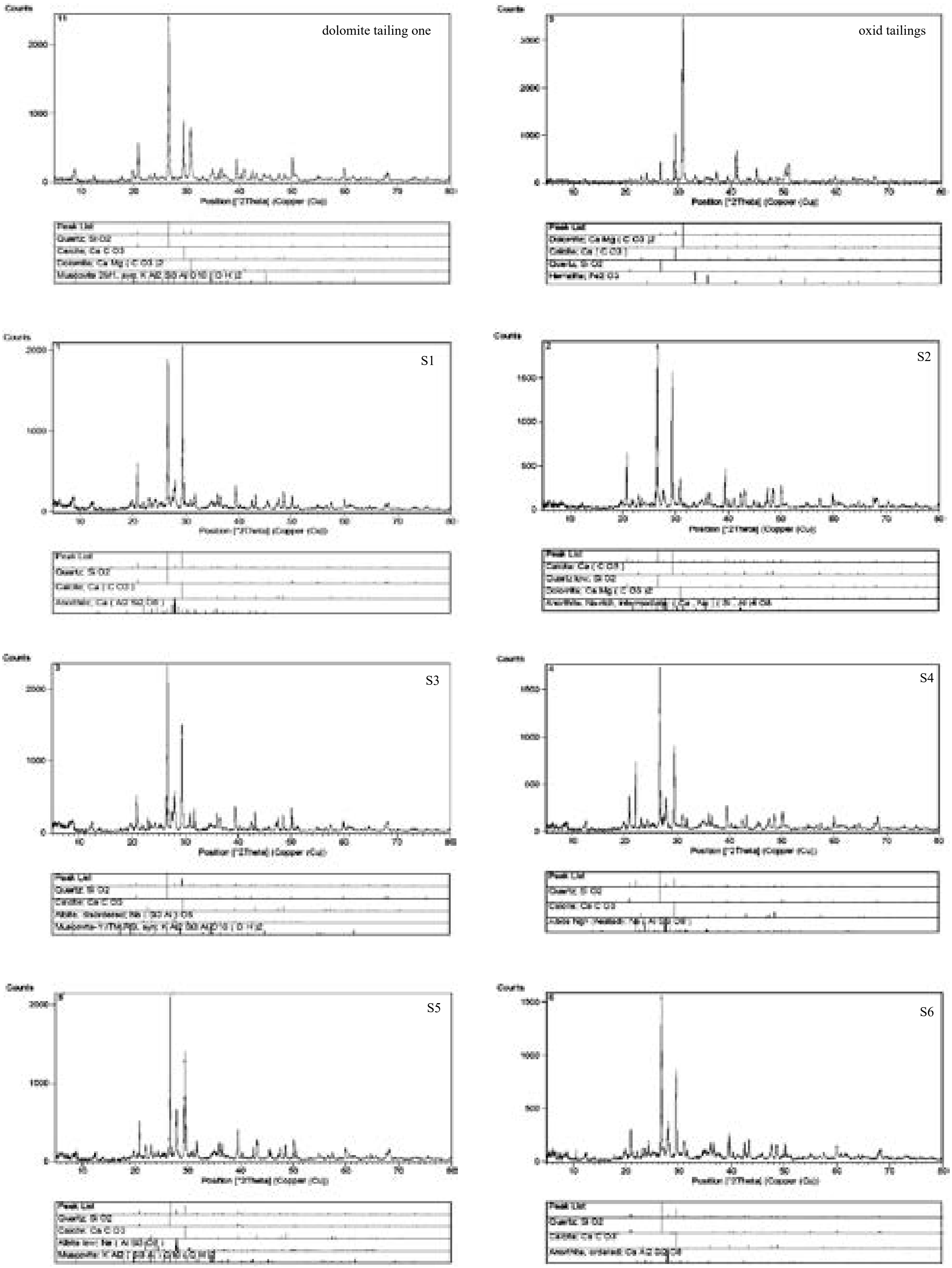


Fig. 6. display of Mineralogy characteristics of the dust particles by XRD

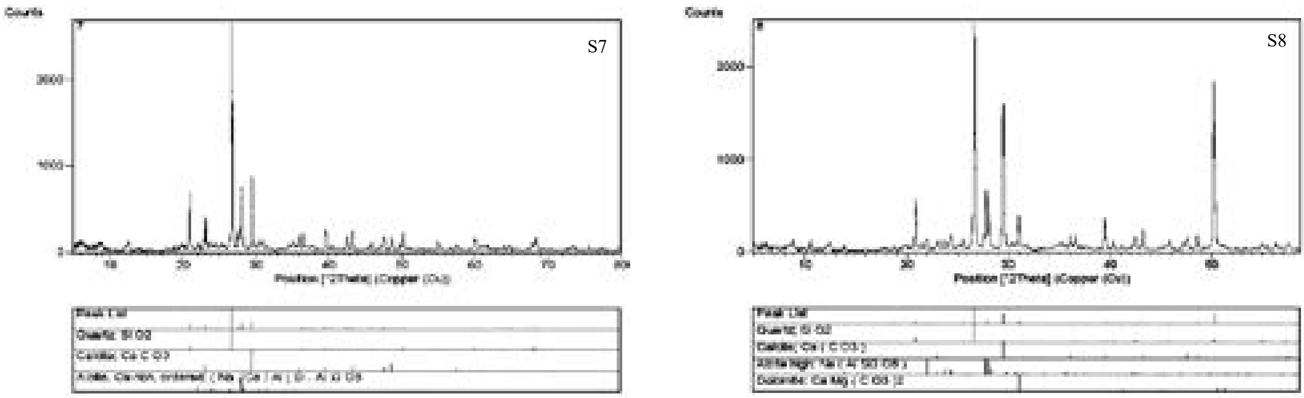


Fig. 6. display of Mineralogy characteristics of the dust particles by XRD

the qualitative characteristics of dust. The results of this study also showed that the predominant mineralogical composition of dust particles includes carbonates (dominant mineral: calcite) and silicates (dominant mineral quartz) that are found in all stations. The results of SEM images showed that spherical, irregular, and prismatic shapes are the most important forms of dust particles around the Mehdiabad lead and zinc mine. The other results revealed that the most important concern about the dust around the Mehdiabad lead and zinc mine is the abundance of minerals such as calcite and quartz, because these minerals are able to have heavy and dangerous elements. On the other hand, due to the sharpness and angularity of the particles, they can cause respiratory problems in the surrounding residents. Moreover, dusts containing calcite and quartz, fall on trees and agricultural products, cause leaf surface wear, change in leaf energy balance, pores close, and reduction of their number. The change in the alkalinity characteristics of plants, will damage the agricultural products [23]. In order to reduce the environmental impact of mining operations, the legislation of strict regulations on the discharge of tailings will be effective in preventing water pollution and airborne emissions, such as the Clean Air Bill, Clean Water, Resource Protection, etc. in the United States. Another way to reduce environmental pollution is to exploit mines at the expense of profound changes in mineral consumption as well as the global economy. It is important to note that what poses the greatest threat is the extraction and processing of minerals, not their consumption. Therefore, one of the solutions to reduce the environmental pollution of Mehdiabad lead and zinc mine, is to develop and create green space and tree planting areas around the mine as a green belt [24], support the private sector to invest on environmental protection, evaluate environmental strategies, and apply national policies and programs affecting the environment. In the meantime, one of the management strategies in order to manage and control dust in Mehdi Abad lead and zinc mine, is to create paving on the tailings to prevent the their erosion and the entry of hazardous minerals into sensitive population centers. In addition, water spraying on the tailings dams, to keep them moist, can be taken as other solutions.

**Financial supports**

This study was supported by general department of environmental protection of yazd province.

**Competing interests**

None of the authors have competing interests to disclose.

**Acknowledgements**

The authors are thankful to general department of environmental protection of yazd province and experts of Mehdiabad lead and zinc mine. We thank Ali Mohseni Nasab in the implementation phase of this research.

**Ethical considerations**

Ethical considerations (including plagiarism, informed consent, misconduct, data fabrication or falsification, double publication and submission) have been completely observed by the authors.

**References**

1. Moghaddas NH, Kazemi GA, Moghaddam HRA, Sanchooli R, Nejad FSH. The Environmental Impacts of Mining in Olang Area, Golestan Province (South Ramian). Geosciences Scientific Quarterly Journal. 2010;19(75):102-95.
2. Aznar-Sanchez JA, García-Gomez JJ, Velasco-Munoz JF, Carretero-Gomez A. Mining waste and its sustainable management: Advances in worldwide research. Minerals. 2018;8(7):1-27.
3. Lilic N, Cvjetic A, Knezevic D, Milisavljevic V, Pantelic U. Dust and noise environmental impact assessment and control in Serbian mining practice. Minerals. 2018;8(2):1-15.
4. Shojaee Barjoee S, Azimzadeh H, Mosleh Arani A. Evaluation of Individual and Integrated Pollution Indices of Some Heavy Metals in Atmospheric Dust Deposition Around Khak-e-chini, Tile and Ceramic, Sand and Gravel and Glass in Ardakan County Industries in Winter 2018. Journal of Environmental Health Engineering. 2020;7(3):314-37.
5. Entwistle JA, Hursthouse AS, Reis PA, Stewart AG. Metalliferous Mine Dust: Human Health Impacts and the Potential Determinants of Disease in Mining Communities. Current Pollution Reports. 2019;5(3):67-83.
6. Arami SA, Ownegh M, MohammadianBehbahani A, Akbari M, Zarasvandi A. The analysis of dust hazard studies in southwest region of Iran in 22 years (1996-2017). Journal of Spatial Analysis Environmental Hazarts. 2018;5(1):39-66. [In Persian].
7. Shojaee Barjoee S, Azimzadeh HR, Mosleh Arani A. Ecological Risk Assessment of Some Heavy Metals in the Dust Emitted from Non-Metallic Industries of Ardakan County of Yazd in Summer 2018: A Descriptive Study. Journal of Rafsanjan University of Medical Sciences. 2020;19(2):173-92. http://journal.rums.ac.ir/article-1-5035-fa.html [In Persian].
8. Shojaee Barjoee S, Azimzadeh H. Comparison of work environment air quality and application of geostatistic technique in the spatial distribution of PM2.5 and PM10 in a number of industrial workshops. Occupational Medicine Quarterly Journal. 2020;11(4):23-35 http://tkj.ssu.ac.ir/article-1-1012-fa.html [In Persian].
9. Shahsavani A, Yarahmadi M, Mesdaghinia A, Younesian M, Jaafarzadeh Haghighifard N, Naimabadi A, et al. Analysis of Dust Storms Entering Iran with Emphasis on Khuzestan Province. Hakim Health Systems Research Journal. 2012;15(3):192-202. http://hakim.hbi.ir/article-1-1040-fa.html [In Persian].
10. Rajabi M, Souri B. Evaluation of heavy metals among dustfall particles of Sanandaj, Khorramabad and Andimeshk cities in western Iran2012-2013. Iranian Journal of Health and Environment. 2015;8(1):11-22. http://ijhe.tums.ac.ir/article-1-5147-en.html [In Persian].
11. Shojaee Barjoee S, Azimzadeh H, Mosleh Arani A. Determination of pollution level, carcinogenic and non-carcinogenic risks of heavy metals of falling dust in industrial areas (Case study: Ardakan county industries). Iranian Journal of Health and Environment. 2020;12(4):571-92. http://ijhe.tums.ac.ir/article-1-6300-fa.html [In Persian].
12. Bit Lute R, Landi A, Hojati S, Sayyad G. Deposition Rate, Mineralogy and Size Distribution Pattern of Dust Particles Collected Around the Houralazim Marshland, Khuzestan Province. Journal of Water and Soil. 2015;29(3):695-707. https://doi.org/10.22067/jsw.v0i0.9946 [In Persian].
13. Zarasvandi A, Moore F, Nazarpour A. Mineralogy and morphology of dust storms particles in Khuzestan Province: XRD and SEM analysis concerning. Iranian Journal of Crystallography and Mineralogy. 2011;19(3):511-8. http://ijcm.ir/article-1-437-en.html [In Persian].
14. Ahmady-Birgani H, Feiznia S, Mirnejad H, Ahmadi H, Mc Queen K, Ghorban Pour M. Physico-Chemical Properties and Mineralogical Assessment of Aerosols and Dust Particles throughout the Western Iran(Case Study: Abadan & Urmia Cities). Journal of Range and Watershed Managment. 2017;70(3):551-67. doi: 10.22059/jrwm.2017.957 [In Persian].
15. Mahlouji R, Asghari Omid. Geometallurgical modeling of oxide/sulfide zones in Mehdi Abad deposit. Iranian Journal of Mining Engineering. 2017;12(36):111-22. http://ijme.iranjournals.ir/article_28861.html [In Per-

sian].
16. Ghasemi M, Momenzadeh M, Yaghubpur, Mirshokraei AA. Mineralogy and Textural Studies of Mehdiabad Zinc-Lead Deposit-Yazd, Central Iran. Iranian Journal of Crystallography and Mineralogy. 2008;16(3):389-404 http://ijcm.ir/article-1-622-en.html [In Persian].
17. Sow M, Goossens D, Rajot JL. Calibration of the MDCO dust collector and of four versions of the inverted frisbee dust deposition sampler. Geomorphology. 2006;82(3-4):360-75.
18. Shojaee Barjoee S, Mosleh Arani H, Mosleh Arani A, Elmi M. Spatial Distribution of Toxicity Unit Index and Environmental Risk Assessment of Some Heavy Metals in Industrial Dust of Ardakan county Based on Geostatistical Analysis in 2018. Journal of Torbat Heydariyeh University of Medical Sciences. 2020;7(4):58-70 [In Persian].
19. Shojaee Barjoee S, Azimzadeh H, kuchakzadeh M, MoslehArani A, Sodaiezadeh H. Dispersion and Health Risk Assessment of PM10 Emitted from the Stacks of a Ceramic and Tile industry in Ardakan, Yazd, Iran, Using the AERMOD Model. Iranian South Medical Journal. 2019;22(5):317-32. http://ismj.bpums.ac.ir/article-1-1175-fa.html [In Persian].
20. Zirjanizadeh S. Mineralogy, geochemistry and morphology of the dust storms particles in the city of Gonabad. Iranian Journal of Crystallography and Mineralogy. 2018;26(2):263-72. http://ijcm.ir/article-1-1096-en.html [In Persian].
21. Broomandi P, Bakhtiar Pour A. Dust source identification using physical-chemical characterization and numerical modeling in Masjed Soleyman. Iranian Journal of Health and Environment. 2017;9(4):517-26. http://ijhe.tums.ac.ir/article-1-5688-en.html [In Persian].
22. Rajabi M, Souri B. Evaluation of heavy metals among dustfall particles of Sanandaj, Khorramabad and Andimeshk cities in western Iran2012-2013. Iranian Journal of Health and Environment. 2015;8(1):11-22. http://ijhe.tums.ac.ir/article-1-5147-fa.html [In Persian].
23. Rezaii S AA, Zakerinpour Z,. An investigation on mineralogy and chemical composition of dust in different region of Kerman City. Iranian Journal of Crystallography and Mineralogy. 2013;21(2):289-302. http://ijcm.ir/article-1-18-en.html [In Persian].
24. Shojaee Barjoee S, Azimzadeh HR, Mosleh Arani A. Tolerance of Plants to Air Pollution in the Industrial Complex of Glass, Khak-e-Chini, Tile and Ceramics in Ardakan, Iran. Journal of School of Public Health and Institute of Public Health Research. 2020;18(1):73-92. http://sjsph.tums.ac.ir/article-1-5855-fa.html [In Persian].