Dispersion of Quarry´s Dust - Pilot Study

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ABSTRACT: The mining industry involved, among other factors, exposure to dust, which affects workers, and also the surrounding populations. In this article, the dispersion of dust in the air environment was studied and the dust sampling was based on the French standard NFX 43 007:2008. The dust flux deposition was determined in twenty-four sampling points located inside and around the quarry. It was verified that the points with higher level of dust correspond to the operating area access, crushing plant, and a national road, with the average of 369.49 $mg.m^{-2}.day^{-1}$, 337.70 $mg.m^{-2}.day^{-1}$ and 152.65 $mg.m^{-2}.day^{-1,}$ respectively. The lowest value of dust flux deposition corresponded to a point located in a limit of the quarry, with the value of 14.37 $mg.m^{-2}.day^{-1}$. Through this study it was concluded that the surrounding population could be affected by the dust quarry, although, the dispersion will greatly depends on the meteorological conditions, among other factors.

1 INTRODUCTION

1.1 *Mining industry*

The dust exposure, and in particular, the exposure to silica crystalline affect the human health and can originate silicosis, one of the oldest industrial diseases. In 2001, the European Occupational Disease Statistics (EODS) has classified the silicosis as the sixth occupational respiratory disease (Karjalainen & Niederlaender, 2004). In fact, in mining industry there are the added risks associated with exposure to chemical agents such as dust, which could be dangerous for human health. The exposure to this agent could affect not only the workers of the quarry but also the surrounding population.

In mining industry there are several processes that originate fine particles, such as the site preparation, drilling, blasting, crushing, loading, stockpiling, transportation, among others (Petavratzi et al. 2005, NEPSI 2006). Taking into account all these sources it is almost inevitable that the surrounding areas are not affected by fugitive dust (Cattle et al. 2012).

Dust may cause potential risks to human health (workers and surrounding populations), to environment, working conditions, and workers´ productivity. Its effects may change depending on the particles concentration, size, shape, sharp edges and their chemical composition (Petavratzi et al. 2005, Polichetti et al. 2009).

1.2 *Pilot study*

The pilot study was carried out in a company located in the North of Portugal. The activity is characterized by quarry exploitation (gneiss), and it is responsible for the production of crushed aggregates and riprap to coastal protection. This company is constituted by 180 workers, 30 of them are associated to the quarry, and the operators' number is around 10. For this, the work procedure includes different phases: rock removal, selection of the material for riprap, transporting the remaining material to the processing plant for the production of crushed aggregates, storage the material by granulometry in silos with large capacity or in open air stocks and, at the end, the loading system.

In the process unit there are two crushing circuits:

– a crushing plant with large capacity - primary crusher, secondary crusher, vibrating screens, and the conveyors belts which carry the material directly to the silos. It is important to highlight that the conveyors belts are encapsulated and the silos are closed.
– a mobile crushing circuit which receives the smaller materials. On this one there are belts that are not covered and the produced stock is stored in the open air.

Through the above mentioned characteristics it was verified that by the fragmentation process, transport and deposition, or by the exposure in the prevailing wind direction, mainly in what concerns the storage in the open air, these circuits present a strong potential to produce dust.

Another element of this system is the sand washing. However, due to the use of water, this unit is not responsible for the dust production. In this quarry there is also a decantation unit for sludge and a filter press.

For exploitation activities, in a general view, there is some equipment operating on a defined place and with appropriate functions, such as:

- *Rock* / mining area / drilling and blasting
- *Dumper* / mining area – primary crushing plant / transportation of material to the crushing plant
- *Wheel Loader* / mining area and stock zones / transportation of material with different dimensions to the stock location or trucks loading
- *Track excavator* / mining area / excavation and, trucks and dumpers loading

The main objective of this work was focused on the analysis of the dispersion of dust, which affect the workers and the surrounding population, by environmental air, in the neighborhood of a quarry, and the variation of dust flux deposition over time.

2 MATERIALS AND METHODS

The general procedure used to achieve the main objective was based in the following tasks: to measure the total dust flux deposition in different sampling points within the quarry and its surroundings; to record the meteorological conditions during the several sampling periods in order to evaluate their influence on dust dispersion; to assess how local residents are affected by dust coming from the quarry; to study the effect of tree cover in the quarry surroundings; to compare the levels found within the quarry and its surroundings with the values obtained for the closer communication infrastructures (national road and municipal roads).

2.1 *Sampling procedure*

Through the analysis of dust flux deposition in the quarry's surroundings, this study tried to understand the dispersion plume in the study area and thus, to assess if the workers/population are affected by particles coming from the quarry. The methodology for collecting dust samples was based on the French standard NFX 43 007:2008 - Air quality – Ambient air – Determination of the mass of dry atmospheric depositions – Sampling on deposit plates - Preparation and treatment, which details the placement of plates, coated with resin, the locals to analyze and subsequent treatment of the samples collected. This standard seemed to be the most suitable for the results that this study was seeking.

In a first step the twenty-four sites were selected in order to evaluate the total dust flux deposition (Fig. 1). This selection was made aiming to cover four types of areas: surrounding the quarry, quarry zone, stocks zone and national road.

The four groups of sites correspond to the following points:

- Surrounding the quarry: 1, 2, 3, 4, 5, 6, 7, 23, 24;
- Quarry itself: 8, 9, 10, 11, 12, 13, 17, 18, 19, 20, 21;
- Stock zone: 14, 15, 16;
- National road: 22.

The second step was to clean the plates with alcohol and then with dichloromethane to remove all the impurities and then, put them in an oven at 105°C for one hour. When the cleaning phase is finished, the plates should be adequately numbered and stored in separate containers for subsequent transport to the sampling site. Although the cleaning procedure is not described in the standard NFX 43 007:2008, the previous version of it, in the year 1973, it is referred that the plates should be dried in the oven at 105ºC. The plates are made of stainless steel, with the dimensions of 5 x 10 cm.

Figure 1. Location of sampling points within and surrounding the quarry.

In the selected sites, the plates used for sampling were covered with resin (polydimethylsiloxane) using a glass sprayer with a pump. This procedure should be performed in an appropriate site to minimize possible interference in the results. The resin in the plates aims to allow the adhesion of dust after deposition.

Regarding the plates position and according to NFX 43 007:2008, they should be placed at a height exceeding 1.5 meters above the ground. However, this was not always possible. In the specific case of the plates bordering on certain benches, iron stakes were located to allow placement of the plates in horizontal position. In these cases, the plates were placed approximately at 0.5 meters above the ground, since a greater height would require a support system more resistant, otherwise they would be more susceptible to fall due to the vibrations caused by explosions or the projection of small fragments.

After the placement of the plates, the GPS coordinates of all sampling points were registered for the following spatial representation. In this study three (each one for a period of approximately 20 days) samplings campaigns were done in order to ensure the representation of the values obtained and to allow the study of the influence of meteorological conditions on dust deposition. The first sampling was performed between April and May, the second one during May and June and the third in June and July.

2.2 *Laboratory procedure*

After the sampling period, the plates were collected and treated in the laboratory according to the following procedure:

a) Connect the Erlemeyer flask with screw to the pump;
b) Weigh the virgin filter in a precision balance (three weightings);
c) Place the filter on top of the Buchner funnel, place the top part and the spring that allows the join of the both parts;
d) Using a pipette, place a small amount of dichloromethane in the surface of the plate containing dust;
e) Scrape with a spatula;
f) When the plate is completely cleared, proceed to the filtration connecting the pump;
g) Remove the filter from the Buchner funnel and weigh the sample with a precision balance (three weightings).

The dust flux deposition is calculated through the mass of the sample on each plate, the surface area, and the sampling time:

$$\text{Dust flux deposition } (mg.m^{-2}.day^{-1}) = m/(a \times t) \qquad (1)$$

where m = mass of dust (mg); a = surface area that collect dust (m^2); and t = exposure time (days).

3 RESULTS

3.1 *Dust flux deposition*

After the laboratory treatment the dust flux deposition was calculated taking into account the mass of the sample on each plate, the timing sampling and the area of the plate, Table 1.

The same results are presented in the Figure 2, to better understand the behavior of three samplings, and it is possible to observe that the data are consistent for all of them.

Table 1. Dust flux deposition for each sampling point, for the three samplings and correspondent average ($mg.m^{-2}.day^{-1}$).

	1st sampling	**2nd sampling**	**3rd sampling**	**Average**
No	**Dust flux deposition**	**Dust flux deposition**	**Dust flux deposition**	**Dust flux deposition**
1	100.95	4.44	49.84	51.75
2	53.81	3.59	27.30	28.23
3	48.25	-	3841	43.33
4	58.57	10.43	57.46	42.15
5	111.11	9.91	43.17	54.73
6	**20.95**	3.42	**18.73**	14.37
7	61.59	2.22	25.40	29.74
8	119.05	4.44	79.68	67.72
9	133.33	8.55	95.24	79.04
10	134.29	14.53	32.38	60.40
11	89.84	3.59	33.06	42.16
12	78.10	11.11	96.83	62.01
13	218.41	4.10	58.10	93.54
14	106.67	7.01	31.75	48.47
15	246.98	36.24	105.40	129.54
16	**598.41**	**198.80**	**215.87**	**337.70**
17	130.48	4.10	40.95	58.51
18	266.03	13.50	67.30	115.61
19	**591.67**	**48.55**	**468.25**	**369.49**
20	218.33	2.74	56.83	92.63
21	155.33	**1.71**	64.76	73.93
22	**304.00**	**46.32**	**107.62**	**152.65**
23	124.33	19.49	68.89	70.90
24	37.14	3.93	69.52	36.87

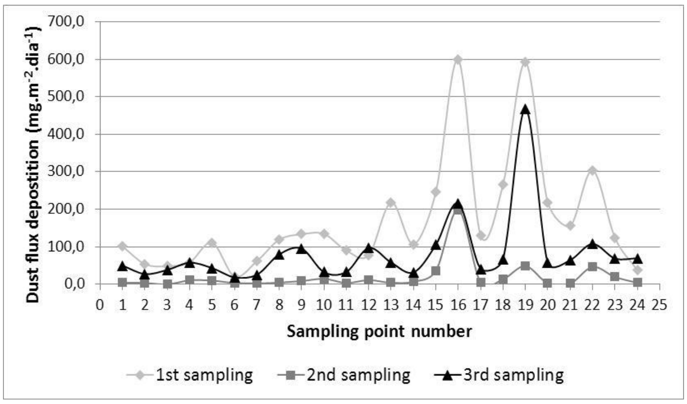

Figure 2. Dust flux deposition for each sampling point.

3.2 *Spatial representation*

For the spatial representation the GPS coordinates and dust flux deposition were introduced in ArcGIS and using the interpolation method of “Radial Basis Function”, available in the software used, the Figure 3-5 were obtained.

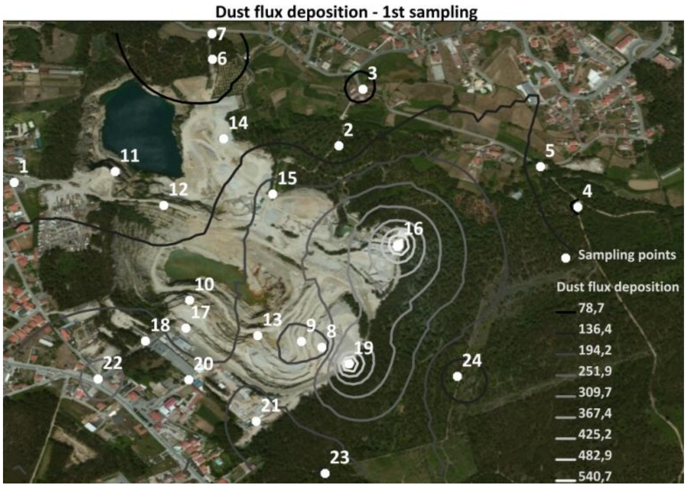

Figure 3. Dust flux deposition for the first sampling.

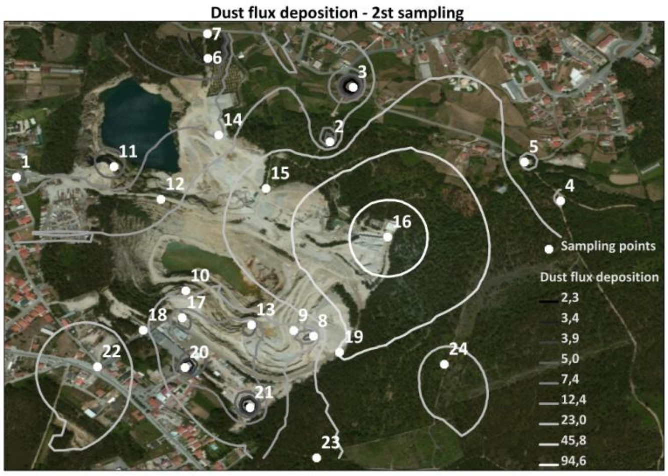

Figure 4. Dust flux deposition for the second sampling.

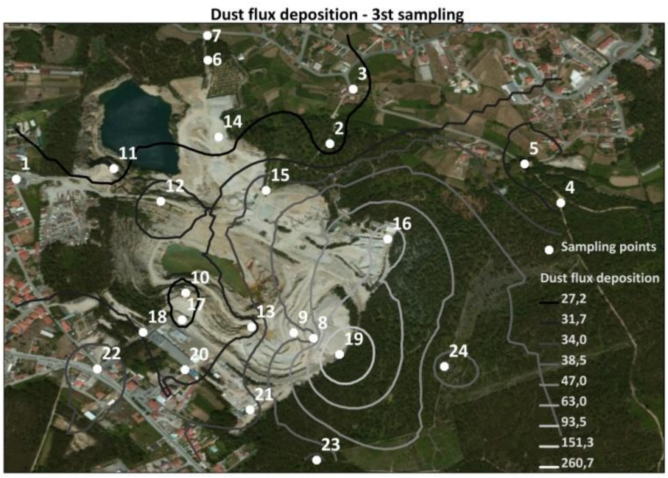

Figure 5. Dust flux deposition for the third sampling.

4 DISCUSSION

In 1st and 2nd samplings, the greatest dust flux deposition is presented, in decreasing order, at the points 16, 19 and 22. They are located close to the crushing plant (first crusher), on the quarry's internal road (with circulation of trucks and other equipment), and national road, respectively. These results were expected, since the crushing plant (16) originates a lot of dust which falls and deposits on the plate. In point 19, the high value is justified by the fact that it is a local of frequent circulation of trucks and other equipment and is located downwind from the quarry. The point 22 reflects the influence of national road because this point is located upwind from the quarry, and points number 17 and 18 present lower values, so, only the traffic may influence this value.

Regarding the 3rd sampling, one of the possible explanations for the fact that point 19 has more dust than point 16, may be the lower use of the crushing plant. The lower workload can be an influential factor for the observed behavior.

The lowest dust flux deposition corresponds to the sampling point no 6 for both 1st and 3rd sampling periods. Despite being on limit of the quarry, this point is not affected by dust coming from it, since it is located upwind from the quarry. The existing of a tree cover (mainly composed by evergreen trees) also contributes to the observed value. In the 2nd sampling the point correspondent to the lowest dust flux deposition was point 21, located in a construction site, in a low traffic area.

Regarding point no 24, although it is located downwind from the quarry, the low dust flux deposition in the 1st sample allows to confirm the barrier effect of the tree cover existing around, preventing the dust dispersion. In the 2nd and 3rd samplings this issue was not verified due to the beginning of an external work to the quarry which influenced the dust flux deposition.

Comparing the three samplings, it was observed that the 1st sampling presents the highest values, with an average of 166.98 mg.m^{-2}.day^{-1}. This could be related to the meteorological conditions, mainly due to the lower precipitation levels, since the wind velocity didn't vary greatly over the three sampling periods. On the other hand, the lowest average of dust flow deposition, 20.12 mg.m^{-2}.day^{-1}, was obtained in the 2nd sampling as well as the lowest values for all sampling points, when compared with the first one. In this period the precipitation reached the highest level, 0.12 mm.h^{-1}. This reason may have originated the reduction of dust flux deposition and also have influenced the adhesion of dust to the resin/plate.

The intermediate values of wind velocity and precipitation correspond to the intermediate value of dust flux deposition, registering an average for the twenty-four sampling points of 81.36 mg.m^{-2}.day^{-1}. Regarding the last samplings it is important to note that the average precipitation between the 2nd and 3rd sampling period is not very distinct, however in the 2nd there were 5 periods of precipitation during all the sampling period, and in the 3rd sampling there was only one initial period of precipitation.

The values obtained e.g. lower in the 2nd sampling are in accordance with the study of Dinis et al. (2012), where the lowest values of precipitation cause major dust flux deposition.

On the other hand, the results obtained may be related to intensity of work occurring in the quarry that are related with more or less detonations / explosions, trucks traffic, work level in the crushing plant, among others. However, the data used in this study didn't take into account this type of information. Nevertheless, in the Figure 2 is possible to observe that the results are coherent during the three sampling campaigns.

5 CONCLUSION

Under the scope of the study of dust dispersion in the air environment, some meteorological parameters were registered, such as wind direction and velocity, temperature and precipitation. Thus, it was concluded that the daily average of wind velocity presented the highest values in the 2nd sampling, 14.3 km.h^{-1}, and the lowest result in the 1st sampling, 13.4 km.h^{-1}. Regarding the wind direction, applying a circular method of circular statistics, the prevailing winds direction was classified as NNW. The temperature increased during all the sampling periods, ranging from 10 to 27ºC. In what concerns precipitation, the daily average was 0.03 mm.h^{-1} in the 1st period and 0.12 mm.h^{-1} in the 2nd one.

The collection of samples to the study of dust dispersion was based on the standard NFX 43 007:2008 – Air quality – Ambient air – Determination of the mass of dry atmospheric depositions – Sampling on deposit plates - Preparation and treatment. The results showed that the differences obtained between dust flux deposition in each sampling could be related with the meteorological conditions. The highest values were registered in the 1st sampling, which corresponds to the period with lowest precipitation and wind levels. On the other hand, the 2nd sampling corresponded to the period with lowest dust flux deposition, and in opposite, the highest precipitation and wind levels.

In general, the three samplings allow the conclusion that the critical points, of the 24 in analysis, are the local of access to the quarry, the crushing plant and the point located in the national road. In these sites, the average of three samplings for dust flux deposition was 369.49, 337.70 and 152.65 mg.m^{-2}.day^{-1}, respectively. The site with lowest dust flux deposition is located on the quarry limit, close to the stock zone. This site is not affected by the prevailing wind direction and the tree cover contributes to the reduced value, with the average of 14.37 mg.m^{-2}.day^{-1}.

Through this study it was possible to conclude that the surrounding population could be affected by the dust quarry, however, the dispersion will greatly depends on the meteorological conditions, such as the wind and precipitation, the season of the year and the workload. It was also verified that the national road is also a significant source of dust. Therefore, in many places, mainly northwest of the quarry, the recorded levels are due to the movement of vehicles or other activities that produce dust, and not exactly the quarry activity. It was also observed that, in the point located on the national road, the dust flux deposition is well above the values recorded in the municipal roads, such as the points 1, 3, 5 and 7. According to the results, the tree cover in the quarry surrounding fulfills its functions; however, the presence of a new work outside the quarry influenced the results desired for this site, especially in the 2nd and 3rd samplings.

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