Boutarfa, Fares; Idres, Abdelaziz; Mekti, Zohir et al.

**Article**

# Airborne dust pollution emitted by El Hadjar Metallurgical Complex : quantification, characterization, and occupational health hazards

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**Fares Boutarfa,
Abdelaziz Idres,
Zohir Mekti,
Radouane Graine,
Fahem Tiour,
Nadiia Dovbash,
Aissa Benselhoub,
Stefano Bellucci**

# AIRBORNE DUST POLLUTION EMITTED BY EL HADJAR METALLURGICAL COMPLEX: QUANTIFICATION, CHARACTERIZATION AND OCCUPATIONAL HEALTH HAZARDS

*The iron deposits of Ouenza and Boukhadra represent one of the main sources of iron ore supply for the Algerian steel industry. Being a fundamental wealth available to Algeria, the exploitation of iron ores and its use causes strong negative consequences on the environment, mainly by the expansion of dust, which will be a source of environmental degradation. The metallurgical industry is an integral part of the Algerian economy. Environmental problems that negatively affect the health of people and the environment is air pollution. These issues are relevant to the site and the town of Annaba, where the metallurgical industry is developed. Environmental awareness is characterized by strong environmental sensitization; especially in urban areas with metallurgical pollution sources. The object of this study is taking samples from sites that generate more dust within the steel complex_plant. This study aims to characterize steelmaking dust from different sites of the plant in order to identify the mineral phases and their chemical compositions. The various analytical methods used include physico-chemical analysis, X-ray fluorescence (XRF), crystal phases, crystal size, lattice parameters, microdeformations, laser granulometry analysis, X-ray diffraction, microscopy Electronic Scanning and Analysis (EDS) Energy Dispersion Spectroscopy. It was found that the average monthly quantity of dust released by the dust collectors of the Agglomerated Material Preparation (AMP) unit is 108.45 tons. The results obtained from the dust samples analysis of dust samples from the different points of the site differ in their mineral and chemical composition. The research confirmed the presence of iron oxides, silicon, many different mineral phases. The results of dimensional analysis prove that the two samples are different in their sizes ESP1et and ESP2 is coarser than ESP3 and FF3A, these results can lead to long-term occupational illnesses.*

**Keywords:** *occupational illnesses, particulate pollution, Algerian pollution norms, environmental impacts, Annaba.*

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## 1. Introduction

Today steel production is an index of national wealth and is the basis of mass production in many industrial sectors. The Annaba steel plant produces an average of more than one million tons of steel annually. The Annaba region suffers from air pollution due to industrial activities. However, steel and metallurgy are considered among the most polluting activities. Poor air quality poses major risks to human health and to the natural environment [1, 2].

Scientific work is carried out on steel industrial sites, these metallurgical companies as a source of air pollution and a risk factor for the deterioration of the population health population [3–5]. Environmental Consciousness (EC) is characterized by high environmental awareness, especially in urban areas with mining and metallurgical sources of pollution [6, 7] carried out a study on emerging air and particulate pollution challenges in China, India and Pakistan and mitigation solutions.

A study is carried out on the analysis of the impact of dust emissions from metallurgical enterprises on the environment [8]. It was focused on improving technological processes in enterprises and expanding the base of raw materials by involving new deposits and production waste poses a significant threat to the environment.

Authors of [9] conducted a study on the mineralogical and chemical specificity of dusts from iron and non-ferrous metallurgy according to their magnetic susceptibility. This study aims to detail the characteristics and compare the dusts of various iron and non-ferrous metal production processes in order to identify the individual mineral phases.

For effective control of positive dust emissions, an innovative Automated Dry Fog Dust Suppression System (DFDSS) was developed using hybrid nozzles, sensors, actuators, controllers, screw compressors, air receivers, pumps, motors and a water system with filtration installation [10].

One of the biggest plagues of our times is air pollution, not only for its impact on climate change but also for its impact on public and individual health by increasing morbidity and mortality [4].

Filtration of dust nanoparticles emitted from metallurgical processes is currently problematic, due to rapidly increasing pressure drop and inefficient filter cleaning, leading to high maintenance costs. Authors of [11] have suggested a pre-coating technique to overcome cleaning difficulties caused by metallic nanoparticles. It consists of protecting the surface of the filter with a layer of dust made up of particles of micron size, which is easily evacuated during cleaning.

*The aim of this research* is the analysis and physico-chemical characterization of dusts generated by the Agglomerated Material Preparation (AMP) unit of El Hadjar Steel Plant (SIDER-Annaba) on the environment. Representative samples of each point with a mass of 20 kg have been taken from the site of the plant according to the process type.

## 2. Material and Methods

**2.1. Description of the study area and location of sampling sites.** Annaba steel plant is supplied with iron ore by two deposits of Ouenza and Boukhadra representing physico-chemical and mineralogical characteristics suitable for the production of a very good quality of the final product [12, 13].

For the combustion process: The dust was sampled from the common dust collector installation (ESP1 and ESP2). For the dust collector or ambient process: The dust was sampled from the common dust collector installation (ESP3 and FF3A). The sampling points have been located by GPS using a portable Garmine Trex device (France).

The samples taken from the two dust-generating sites were subjected to various physical and physico-chemical analyses. The experimental techniques relate to physico-chemical analysis by X-ray fluorescence (XRF) were carried out on a device of the swiss brand (Thermo Scientific™ ARL™ PERFORM'X 178).

The samples were analyzed at ANNABA Sider el hadjar central laboratory. The granulo Laser analyses were performed on (Fritsch Analyste22 Nano Tec plus Wet Dispersion Unit) a German apparatus at the laboratory of MMATERIALS Technology and process engineering (LTMGP) University of Bejaia. the analysis has been done by wet process at an ambient temperature, with a percentage ratio of solid mass (the concentration of solid in the solvent) of 1/10 (0.1 g/ml). The solvent used is distilled water.

Observations by MEB and the analysis by the X-ray spectrometry (EDS) of dispersive energy are carried out on a QUANTA 250 type microscope (France)have been done at the level of Amar El Askri National High School of Metallurgy and Mines (Annaba).

In addition, analyzes by X-ray diffraction (XRD) were carried out on (Rigaku ultima IV apparatus) USA, at the level of the research Unit Laboratory URMA – Annaba where the samples are put in the form of powders. This method of analysis is based on the diffraction of X-rays by the material. The analysis of the diffraction spectra was made using X'Pert Highscore software, which makes it possible to determine the crystal structure.

The geographical location of the steelmaking site of the study area is presented in the Fig. 1.

The sampling location of the samples at the Preparation of the Agglomerated Material of El Hadjar Steel plant (SIDER-Annaba) is presented in Table 1 and Fig. 2.

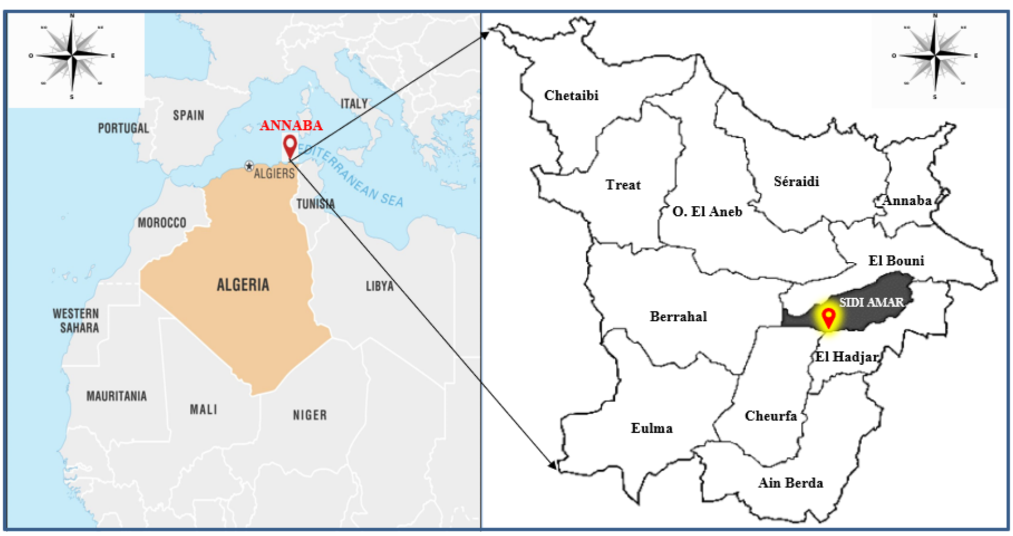


**Fig. 1.** Geographical location of the study area

**Table 1**

GPS coordinates of dust-generating emission sources

| Stacks | Height (m) | Exhaust Gas Flow (Nm$^3$/h) | Coordinates GPS |
|---|---|---|---|
| Stacks Electrofilter sinter chain ESP1 and ESP2 | 50 | 1400000 | N36°47'20.7''E007°41'33.0'' |
| ESP3 agglomeration ambience dust extractor stack | 20 | 750000 | N36°47'21.5''E007°41'26.8'' |
| FF3A agglomeration atmosphere dust extractor stack | 20 | 750000 | N36°47'21.5''E007°41'23.9'' |

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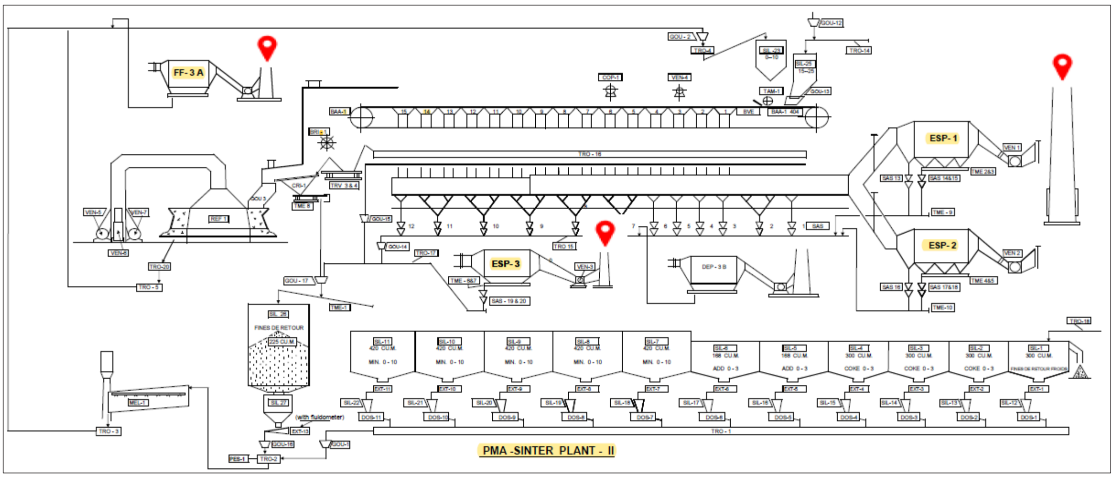


**Fig. 2.** Samples collection sites at the AMP unit (office technology unit AMP-company sider)

## 3. Results and Discussion

**3.1. Dimensional analysis by laser granulometry of samples.** The ESP1 and ESP2 samples are composed of three (03) populations whose D90 corresponds to particles of 56.915 μm. The finest particles of the latter are <0.4 μm.

ESP3 and FF3A samples are composed of three populations, of which D90 corresponds to particles with a diameter of 33.706 μm. The finest particles of the latter are <0.2 μm.

The ESP1 and ESP2 samples are coarser than the ESP3 and FF3A with a large population <50 μm, whereas the latter has a large population <20 μm.

The graph curves giving the different populations existing in the different samples as a function of the volume percentage are represented in Figs. 3, 4.

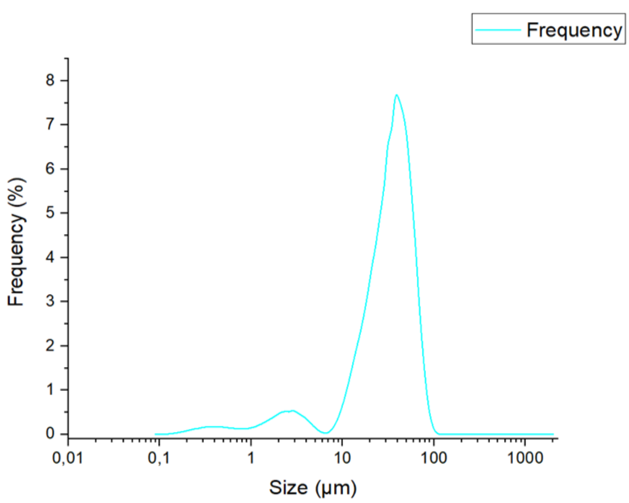


**Fig. 3.** Dimensional analysis of the samples ESP1 and ESP2

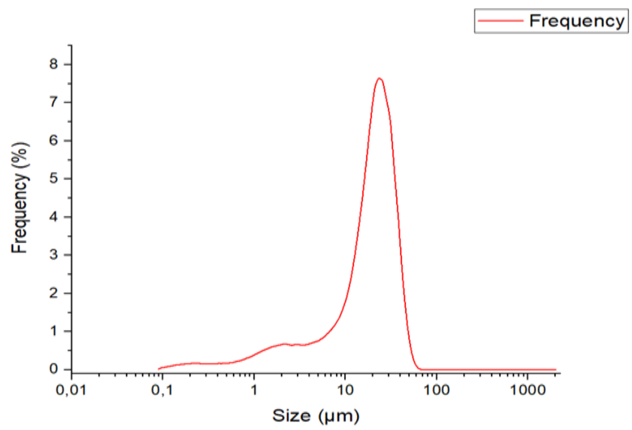


**Fig. 4.** Dimensional analysis of the samples ESP3 and FF3A

It is easier to compare the particle sizes from the «quartiles» D10, D50 and D90 which are the particle sizes (in μm) cutting the cumulative curve at the ordinates 10, 50 and 90.

The results of the laser granulometry analyzes are gathered together in Table 2.

**Table 2**

Results of dimensional analysis of samples ESP1, ESP2, ESP3 and FF3A

| Samples ESP1 and ESP2 | D10 | D50 | D90 |
|---|---|---|---|
| Grain size (μm) | 9.980 | 31.945 | 56.915 |
| Samples ESP3 and FF3A | D10 | D50 | D90 |
| Grain size (μm) | 2.616 | 19.007 | 33.706 |

**3.2. X-ray fluorescence analysis.** The X-ray fluorescence analysis tests of the particles of the dust collectors ESP1 and ESP2 as well as ESP3 and FF3A during the month of July 2022 gave the results shown in Table 3.

**Table 3**

Results of X-ray fluorescence analysis of particles from AMP dust collectors

| Sample | $Fe_2O_3$ | $SiO_2$ | CaO | BaO | $Al_2O_3$ | $Na_2O$ | $Na_2O_3$ | MnO | $SO_3$ | SrO | MgO | $P_2O_5$ | $TiO_2$ | $K_2O$ | LOI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ESP1 and ESP2 | 60.70 | 10.27 | 7.98 | 6.56 | 2.29 | – | 2.71 | 1.32 | 0.20 | 0.45 | 0.32 | – | – | 0.24 | 5.50 |
| ESP3 and FF3A | 58.30 | 9.37 | 11.80 | 4.14 | 2.82 | 1.31 | – | 2.00 | 0.70 | 0.49 | 0.42 | 0.13 | 0.12 | – | 7.65 |

It is noted that the sample from the ESP1 and ESP2 process dust collectors is rich in iron with a content of 60.7 % compared to that of the ESP3 and FF3A ambient dust collectors not exceeding 58.3 %, this difference is due to the nature of operation of each type of dust collector because the first has direct contact with the iron-rich raw material, while the second is linked to the air treatment operation after agglomeration.

In the samples of ambient dust collectors ESP3 and FF3A the value of calcite CaO is 11.8 %, while the one of the samples ESP1 and ESP2 is 7.98 %. This increase is due to the release of calcite after the heat treatment. According to the results obtained, it can be seen that the value of the other elements is almost the same before and after agglomeration.

**3.3. X-Ray Diffraction Study (XRD).** XRD spectra analysis is a technique that uses X-ray diffraction to study crystal structure, lattice parameters of materials, sample purity. The X-ray diffraction spectra using a Bragg Brentano focusing diffractometer were obtained by radiation of ($CuK\alpha_\lambda = 1.54$ A°). The scan is in the range: $2\theta = 10-120°$ from which the step is 0.002°/min. The analysis of the diffraction spectra was made using X'Pert Highscore software that makes it possible to determine the crystalline structure, the average size of the crystallites, the mesh lattice parameters. The results obtained are listed in Tables 4, 5.

The grain size is calculated from the X-ray diffraction spectra using Scherrer's relationship [27]:

$$D = \frac{K\lambda}{\beta\cos(\theta)}, \quad (1)$$

$$\varepsilon = \frac{\beta htl}{4\tan(\theta)}, \quad (2)$$

where $D$ is the size of the grains, $\beta$ the intrinsic half width and $K$ is a constant with a value very close to unity, equal to 0.94. This relationship was used just to get an idea of the particle size. The results of these measurements give average values between 41 nm and 43 nm and the micro-deformations are $2.77 \cdot 10^{-4}$ and $4.44 \cdot 10^{-4}$ respectively for the sample ESP3 and FF3A and ESP1 and ESP2 (Fig. 5). Let's also note that the size of the crystallins calculated by XRD is lower than the size of the crystallins measured by the laser analysis.

In addition, the structural parameters $a$, $b$ and $c$ for the layer sample Tables 4, 5 the lattice parameters corresponding to the JCPDS file (Joint Committee on Powder Diffraction Standards) n°85-0794 [15], 72-1664 [17] were obtained, 85-0514 [19], 86-1356 [24], 78-0430 [25], 70-3321 [23], 73-2096 [26], 87-0952 [15] for the samples ESP3, FF3A, ESP1 and ESP2.

**Table 4**

Identification of the peaks observed on the spectra of the samples ESP1 and ESP2

| Ref. Code | Compound Name | Chemical Formula | Quantification (%) | Lattice constant (Å) | | |
|---|---|---|---|---|---|---|
| | | | | *a* | *b* | *c* |
| 87-0952 [14] | Phosphorus Oxide | $P_2O_5$ | 43 | 16.80 | 7.62 | 5.29 |
| 85-0794 [15] | Silicon Oxide | $SiO_2$ | 24 | 4.70 | 4.70 | 157.3 |
| 89-3072 [16] | Aluminum Oxide | $Al_2O_3$ | 17 | 4.74 | 4.74 | 13.10 |
| 72-1664 [17] | Sulfur Oxide | $SO_3$ | 5 | 5.13 | 10.82 | 12.4 |
| 80-2377 [18] | Iron Oxide | $Fe_2O_3$ | 4 | 5.07 | 5.07 | 13.70 |
| 85-0514 [19] | Calcium Peroxide | $CaO_2$ | 3 | 5.00 | 5.00 | 5.93 |
| 76-1363 [20] | Magnesium Oxide | $MgO_2$ | 3 | 4.81 | 4.81 | 4.81 |
| 72-1047 [21] | Arsenic | As | 4 | 3.7 | 3.7 | 10.73 |
| 89-4082 [22] | Sodium | Na | – | 3.87 | 3.87 | 6.14 |

**Note:** *a*, *b*, *c* – crystallographic parameters

**Table 5**

Identification of peaks observed on the spectra of the samples ESP3, FF3A

| Ref. Code | Compound Name | Chemical Formula | Quantification (%) | Lattice constant (Å) | | |
|---|---|---|---|---|---|---|
| | | | | *a* | *b* | *c* |
| 870952 [14] | Phosphorus Oxide | $P_2O_5$ | 3 | 15.80 | 8.03 | 5.23 |
| 85-794 [15] | Silicon Oxide | $SiO_2$ | 27 | 4.91 | 4.91 | 5.41 |
| 70-321 [23] | Aluminum Oxide | $Al_2O_3$ | 14 | 4.67 | 4.67 | 12.07 |
| 72-664 [17] | Sulfur Oxide | $SO_3$ | 4 | 7.01 | 12.06 | 13.63 |
| 86-356 [24] | Iron Oxide | $Fe_2O_3$ | 7 | 8.2 | 8.2 | 8.2 |
| 85-514 [19] | Calcium Peroxide | $CaO_2$ | 16 | 5.03 | 5.03 | 5.94 |
| 78-430 [25] | Magnesium Oxide | MgO | 4 | 4.13 | 4.13 | 4.13 |
| 73-096 [26] | Sulfur Oxide | $SO_2$ | 26 | 5.98 | 5.93 | 6.42 |

**Note:** *a*, *b*, *c* – crystallographic parameters

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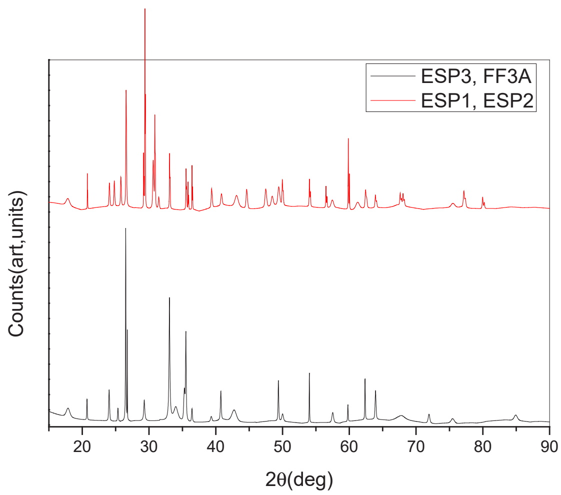


**Fig. 5.** DRX Spectra of the sample ESP1 and ESP2 and ESP3 and FF3A

The chemical elements existing in the sample have a very important economic value such as $SiO_2$, MgO, $Al_2O_3$, $TiO_2$, which requires a specific filtration system and reused in other industrial fields as per the economic importance.

The analysis of the XRD spectra confirms the formation of two large toxic phases $P_2O_5$, $SO_2$ and non-toxic $SiO_2$, $SO_3$, $CaO_2$, $Fe_2O_3$, MgO, $Al_2O_3$ for the samples ESP3, FF3A, ESP1 and ESP2. In addition, it is important to note that the size of the nanoparticles is between 41 nm and 43 nm (using the Scherrer method).

**3.4. Study by scanning electronic microscope (SEM).** In the Scanning Electronic Microscope, ferrous elements are observed in many aspects: size, shape and structure. The results showed composite grains consisting essentially of iron and dolomite, calcite and quartz and barium. Let's note that the sizes of the grains of the samples ESP3 and FF3A and of the samples ESP1 and ESP2 are between 50 µm and 150 µm in Figs. 6, 7. The particle size of the samples ESP3 and FF3A is very thin and strongly agglomerated compared to ESP1 and ESP2 samples.

EDS (Energy Dispersive Spectroscopy) is an X-ray analysis that provides information on the elementary composition of a material. It works by directing a beam of electrons towards the sample and measuring the energy of the X-rays emitted as a result of interactions between electrons and atoms of the sample. This information can then be used to identify the elements present in the sample and to determine their relative concentrations [28].

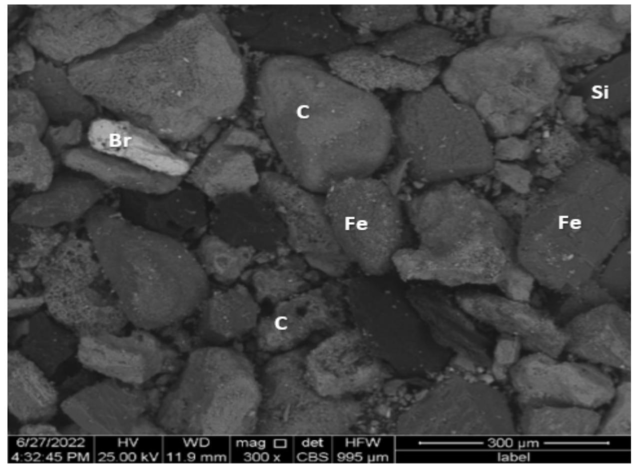


**Fig. 6.** Gangue with mixed elements consisting of Br, Fe, Ca, Si, Mn and ferrous elements O and C from the samples ESP1 and ESP2

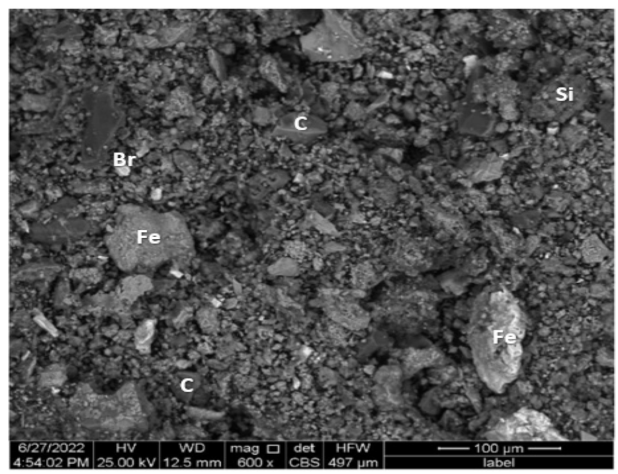


**Fig. 7.** Gangue with mixed elements consisting of Br, Fe, Ca, Si, Mn and ferrous elements O and C from the samples ESP3 and FF3A

The EDS microanalysis Figs. 8, 9 performed on a microparticle shows the coexistence of Ba, Ca, Si, Fe, Al, Mn, C, and O in the same place K with the same amount of material, which proves the formation of the stoichiometric compound of FeO, CaO, SiO, AlO and MnO.

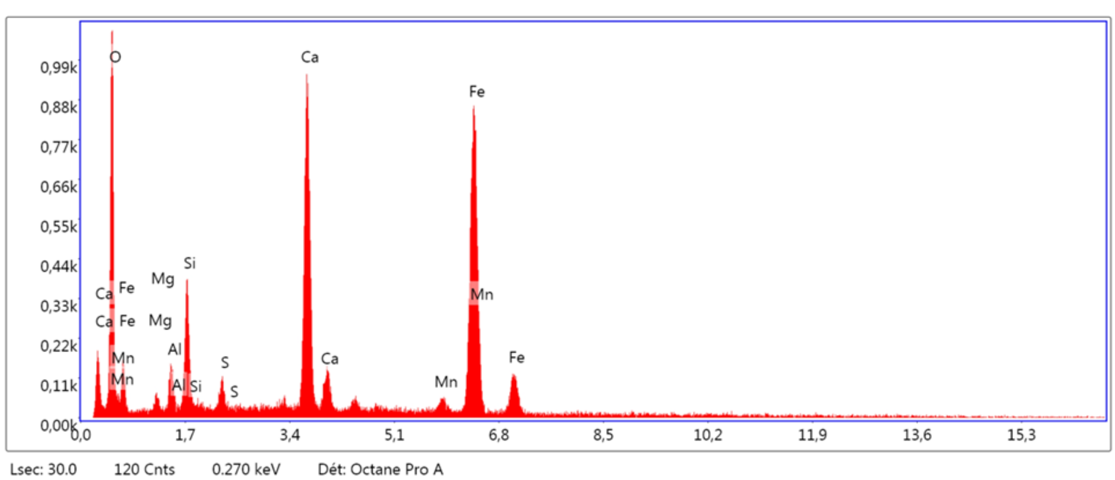


**Fig. 8.** Chemical composition of the samples ESP1 and ESP2

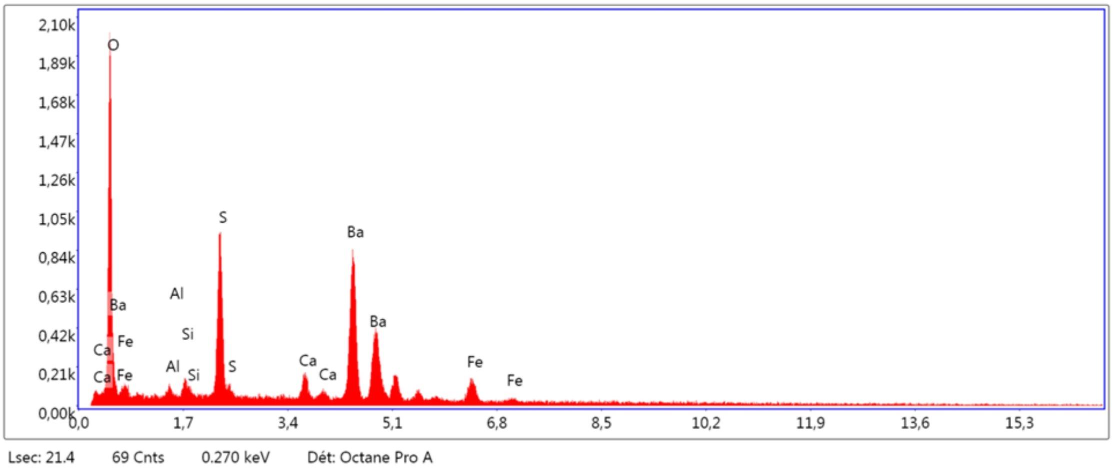


**Fig. 9.** Chemical composition of the ESP3 and FF3A

The results show that the stoichiometric ratio between the elements Ba, Ca, Si, Fe, Al, Mn and O is roughly observed, taking into account the error of the EDS microanalysis because the analysis beam is a little bit wide and therefore it can analyze an area that does not only contain these elements. However, it can be said that we are witnessing the adjustment of the local concentrations of Ba, Ca, Si, Fe, Al, Mn and O according to a mechanism of spinodal transformation of the mixture Ba+O, Ca+O, Si+O, Fe+O, Al+O, Mn+O to locally form precipitates of FeO, CaO, SiO, AlO and MnO.

**3.5. Quantitative evolution of dust emissions generated by the stacks of the AMP unit.** As far as the fixed sources of atmospheric emissions, the characterization results of the pollutant load are estimated with theoretical emission factors taken from the document produced by the USEPA and entitled «Compilation of Air Emission Factor for Stationary Sources – Volume I, Method AP-42» [29].

According to the obtained results from the quantification of dust and atmospheric emissions from the AMP unit shown in Table 6 and Fig. 10.

It is noted that the evolution of the quantity of dust from the agglomerated material preparation unit is higher than the standard set by Algerian law in decree 06-138, and varies from one month to another. This variation is due to several factors including the main factor that is related to the performance and yield of dust collection systems, which are unstable due to repetitive shut downs problems caused by the lack and non-respect of the preventive maintenance.

The other secondary factor is linked to the operating rate of the suction systems in parallel with the production of agglomeration, sometimes the air suction systems operate empty, which increases the ratios of dust generated in relation to the production of the agglomeration.

It is recommended to synchronize the air suction systems with the production line and ensure good maintenance of the equipment and installations of the sinter unit.

**Table 6**

Evolution of AMP dust quantities in (Tons)

| Year 2022 | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AMP Releases (T) | 159.59 | 112.57 | 200.08 | 116.35 | 8.36 | 162.17 | 123.23 | 15.43 | 141.58 | 0 | 94.72 | 167.34 |
| AMP Standard (T) | 51.30 | 36.92 | 65.85 | 59.96 | 4.24 | 82.23 | 62.31 | 7.72 | 71.32 | 0 | 47.97 | 86.08 |
| Deviation (T) | 108.29 | 75.65 | 134.23 | 56.39 | 4.12 | 79.94 | 60.92 | 7.71 | 70.26 | 0 | 46.75 | 81.28 |

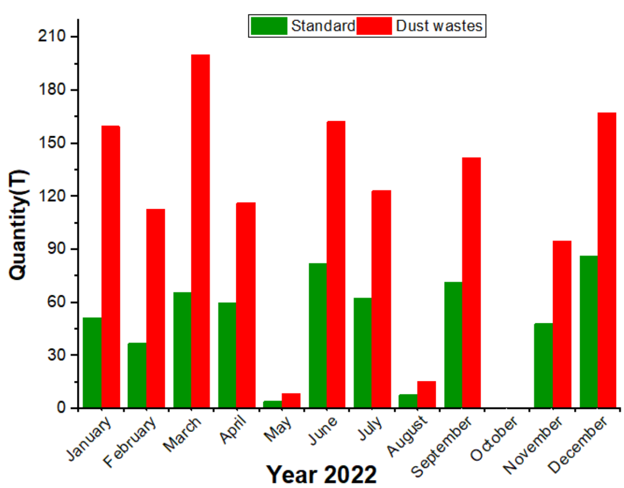


**Fig. 10.** Evolution of dust quantity released by the AMP unit

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**3.6. Occupational diseases at the hot zone.** The results of a professional risk assessment with the use of an injury safety indicator allow the prediction of professional risk levels in different workplaces, which helps to develop the optimal management decisions for the preservation of safety life and health of workers in companies [30]. Improvements in professional health and safety fields can contribute to economic benefits, both for the company and for society. Accidents and professional diseases can lead to significant financial losses for a company. A survey on the working conditions of the professional diseases in the hot zone (Fig. 11) carried out during the period 1989–2022 highlighted:

– Hard working conditions likely to present long- and short-term risks to the health of employees (physical effort, aggressive environment, alternating work), etc.
– Dust; nuisance affecting up to 40 % of the workforce in the hot or melting zone sector; 12 % of the workers presented radiological images of pneumoconiosis, especially in the raw materials area (coal, ore); the positions most concerned are those of warehouseman handlers, then foundry workers and smoke masons.

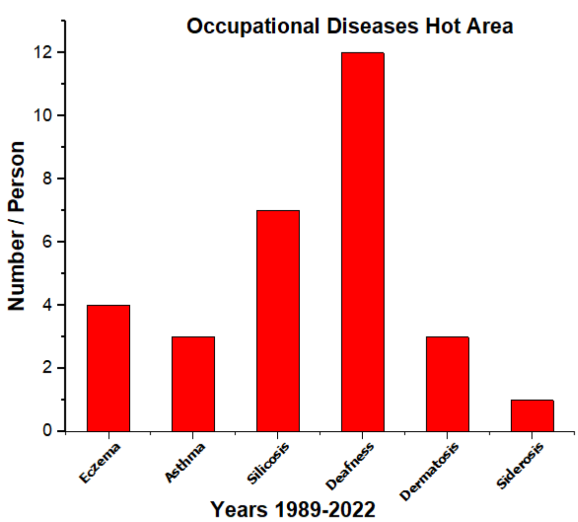


**Fig. 11.** Occupational diseases in the hot area (Medical Department-company sider)

The SIDER El-Hadjar company manages and operates for its needs 02 quarries located one in the wilaya of Annaba, the other in the wilaya of Skikda. The first quarry is a quartzite quarry intended for the trial of blast furnaces is located at a place called Ain Djebara. The second quarry is intended to produce limestone for the steel complex is located in Djendel.

Workers exposed to mineral dust (silica; limestone, dust) mainly occupying the positions of: mining machine operator – driller – crusher operator – other AMP unit staff. For the environmental factor, dust is responsible for more than 50 % of declared medical incapacities.

A rate of 5 % of declarations of professional diseases are consecutive to prolonged exposure to dust.

**3.7. Limitations and perspectives on the results of the study.** Recently, the threats of air pollution are considered an acceptable opinion, as they bypass some insurmountable doubts, and join similar ones, such that related to climate change, for example. The research follows and the results are similar, as the mitigation of pollution factors has become a major necessity for the concerned institutions and organizations, as the safety of the population is closely related to the atmospheres in which they live.

El Hadjar Iron and Steel Complex consists of a group of workshops that produce and transform steel. It is then a complex that aspires to integration according to its size and manufacturing process in the long term.

In fact, the complex sits on an area estimated at more than 850 hectares, and it should be noted that the activities are wide and multiple, as it should be attempted to cover all major developmental projects undertaken by Algeria in recent decades.

The complex was built in two phases:
– The first phase, 1969–1976.
– The second phase, 1972–1982.

It is noted through the aging of facilities and equipment, and this greatly increases the loss of raw materials, which results in more and more emissions of pollutants into the atmosphere.

Face to this situation, it became necessary to invest in the renewal of equipment and the restoration of various units, and the decision has already been taken and the rehabilitation work has begun. This will allow the rehabilitated complex facilities to perform better in order to:
– Better Reliability.
– Better Maintainability.
– Better Availability of facilities.

The triptych (R.M.A) is an essential element in the maintenance of the equipment and will be highlighted by the new rehabilitation, the latter allowing the complex from an environmental point of view to reach in a short time the allowable threshold in terms of dust value ≤100 mg/m$^3$ according to the Algerian standard for atmospheric emissions, as stipulated in Decree 06-138 of the current environmental standard. In addition, these measures taken will allow achieving the new strategy by 2023 and producing about (02) two million tons of steel annually, and reducing current costs by 50 %.

## 4. Conclusions

The research study covers two dust-generating sites such as the ESP1 and ESP2 agglomeration chain electrofilter chimneys, as well as the ESP3 and FF3A ambient dust collector stack.

The samples ESP1 and ESP2 are composed of three (03) populations whose D90 corresponds to particles of 56.915 μm. The finest particles of the latter are less than 0.4 μm.

The samples ESP3 and FF3A consist of three populations, of which D90 corresponds to particles with a diameter of 33.706 μm. The finest particles of the latter are less than 0.2 μm. The samples ESP1 and ESP2 are coarser than the samples ESP3 and FF3A with a large population less than 50 μm whereas for the case of ESP3 and FF3A, it presents a large population <20 μm.

The chemical composition of the samples taken from the two sites showing differences on the different oxides, this difference is due to the nature of operation of each type of dust collectors because the first has direct contact with the iron-rich raw material, on the other hand the second is linked to the air treatment operation after sintering.

DRX specters have clearly shown coexistence two main toxic phases $P_2O_5$, $SO_2$ and non-toxic $SiO_2$, $SO_3$, $CaO_2$, $Fe_3O_4$, $MgO$, $Al_2O_3$ for the samples ESP3, FF3A, ESP1 and ESP2.

Scanning electronic microscopy shows composite grains consisting mainly of iron and dolomite, calcite and quartz and barium. Let's note that the sizes of the grains of ESP3 and FF3A are minimal which do not exceed 50 μm by contribution to the sizes of the grains of the ESP1 and ESP2 sample does not exceed 200 μm. The granulometry of the samples ESP3 and FF3A very thin and strongly agglomerated in relation to the samples ESP1 and ESP2.

The evolution of the quantity of dust from the agglomerated material preparation unit (AMP) is higher than the standard set by Algerian law in decree 06-138. This variation is due to the performance and yield of the defective dust collection systems.

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## Conflict of interest

The authors declare that they have no conflict of interest concerning this research, whether financial, personal, authorship or otherwise, that could affect the study and its results presented in this paper.

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## Data availability

The paper has no associated data.

## Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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***Fares Boutarfa,*** *Postgraduate Student, Laboratory of Valorization of Mining Resources and Environment, Department of Mining, Badji Mokhtar University, Annaba, Algeria, ORCID: https://orcid.org/0000-0001-5182-7559*

***Abdelaziz Idres,*** *Professor, Laboratory of Valorization of Mining Resources and Environment, Department of Mining, Badji Mokhtar University, Annaba, Algeria, ORCID: https://orcid.org/0000-0001-8029-0930*

***Zohir Mekti,*** *PhD in Mining Engineering, Lecturer, Department of Mining, Badji Mokhtar University, Annaba, Algeria, ORCID: https://orcid.org/0000-0002-6153-7026*

***Radouane Graine,*** *PhD, Researcher, Research Center in Industrial Technologies, CRTI, Algiers, Algeria, ORCID: https://orcid.org/0000-0003-1208-7476*

***Fahem Tiour,*** *PhD in Mining Engineering, Mining Engineering Laboratory, Department of Mining Engineering, National Polytechnic School, Algiers, Algeria, ORCID: https://orcid.org/0000-0002-4731-6323*

***Nadiia Dovbash,*** *PhD, Researcher, National Scientific Centre «Institute of Agriculture of the National Academy of Agricultural Sciences», Chabany, Ukraine, ORCID: https://orcid.org/0000-0002-4741-2657*

✉***Aissa Benselhoub,*** *PhD, Associate Researcher, Environmental Research Center (C.R.E), Annaba, Algeria, ORCID: https://orcid.org/0000-0001-5891-2860, e-mail: aissabenselhoub@cre.dz*

✉***Stefano Bellucci,*** *Senior Reasearcher, INFN-Laboratori Nazionali di Frascati, Frascati, Italy, ORCID: https://orcid.org/0000-0003-0326-6368, e-mail: bellucci@lnf.infn.it*

✉*Corresponding author*