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ASSESSMENT OF AIR QUALITY INDEX IN ANNABA

In recent years, the world has been witnessing serious ecological imbalances due to the catastrophic situation and the damage caused to the environment. Human activities as waste disposal, cement units, smelting, chemical industries etc., are the main causes of pollution. Air pollution directly affects the human living standards, pollutants requires regular control in view of their direct impact on health, such as nitrogen oxide, sulfur dioxide, ozone, and particulate matter. Algeria adopts international standards to monitor the levels of pollution recorded in Algerian cities and compare them with global levels. Thus, the object of this study was the air quality index (AQI) in Annaba (Northeastern of Algeria). This study aimed to evaluate AQI in Annaba. In this context, quantitative estimates of polluted waste resulting from some industrial activities have been conducted in order to determine the degree of its danger and the extent of its contribution to the deterioration of the air quality. The monitoring of pollutants allowed to identify the benefits of comprehensive environmental assessment. The air quality index was determined using various pollutants parameters (dust, ozone, nitrogen dioxide and sulfur dioxide). A ten-point scale ranking of the overall air quality index of pollution accepted in Algeria allows making the differentiated assessment of negative impacts of existing industrial agglomerations on the environment. However, the analysis performed on samples DC1 and DC2 with SEM (TESCAN model VEGA II) and BSE detector (Backscattered Electrons) shows that the particles sizes are estimated to range from hundreds of microns to a few microns, a different morphology and irregular shape. Our results will enable policy makers to appropriate measures to be taken, and which are based mainly on sensitizing economic operators to environmental issues in order to adopt an environmentally friendly industrial system.

Keywords: *particulate matter, atmospheric pollution, air quality, thresholds, Northeastern of Algeria.*

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1. Introduction

In recent years, the world has been witnessing serious ecological imbalances due to the catastrophic situation and the damage caused to the environment [1–3]. Human activities as waste disposal, cement units, smelting, chemical industries etc., are the main causes of air pollution [4, 5]. Air pollution directly affects human health and standard of living in light of the increase in industries that produce polluting materials and the aggravation of the resulting dangers, which has become an impediment to the normal life of many people [6, 7]. Algeria has recorded many cases of concern, especially children, who suffer from health as a result of the waste that spreads in the atmosphere due to gaseous emissions from multiple sources. A pollutant is a body of anthropogenic origin or not, in solid, liquid or gaseous state, contained in the atmosphere and which, is not part of the normal composition of the air or which is present there in abnormal quantity [8, 9]. According to a criterion of toxicity, specificity of sources and the pollution generated, the main pollutants measured by air quality monitoring bodies are nitrogen oxides (NO_X), sulfur dioxide (SO_2), carbon monoxide (CO), suspended particles (SP), lead (Pb), volatile organic compounds (VOC) and ozone (O_3) [10, 11].

Among the pollutants in question, particles are among the most studied. Their effects depend on their size, nature and composition, which vary according to their origin. Their size is expressed in relation to their mean aerodynamic diameter (∅) [12, 13].

Particles in suspension in the urban atmosphere constitute a vast and chemically and physically heterogeneous group. The toxicity of dust is essentially linked to the fraction of aerodynamic size less than 10 μm («particulate matter 10» – «PM10») [1, 2, 14]. They can penetrate to the lower respiratory tract, carrying on their surface other pollutants that can be toxic, which leads to biological and health significance. Suspended particles, in particular PM10, represent a major indicator of air quality from a health point of view, as they are numerous and consistent, beyond geoclimatic contexts, populations and sources of emissions, studies attributing to them a responsibility in the occurrence of a wide range of biological and health effects [15]. As a result of air pollution in industrialized countries, sectors of the economy such as agriculture and forestry suffer largely. The intensity and volume of damage to vegetation near large settlements and industrial facilities is constantly increasing [16].

Based on the presented material, a ten-point scale ranking of the overall index of air pollution accepted in Algeria allows making the differentiated assessment of negative impacts of existing industrial agglomerations on the environment. Therefore, *the aim of this study* was to determine the air quality index (AQI) in Annaba, NE Algeria.

2. Material and Methods

2.1. Description of the study area. The province of Annaba is situated between latitudes 36°30N and 37°30N and longitude 7°20E and 8°40E. Its area is 1411.98 km^2; its population has increased recently to 650.000 inhabitants, which is in general concentrated at the level of municipalities and hamlets. It is bounded to the south by the province of Guelma, to the west by the province of Skikda, in the east by the province of El Tarf and to the north by the Mediterranean Sea (Fig. 1) [6]. The climate is typically Mediterranean with an average annual temperature of 18 °C, and an annual rainfall ranging from 650 to 1000 mm, with a winter peak and a deficit during summer. The city of Annaba is bounded to the north and the west by the Edough massif (highest altitude: 850 m), the Mediterranean Sea to the east and the Seybouse alluvial plain to the south. The Edough massif is characterized by a basement of gneiss, schist, and micaschist. Alluvial plain featured by Tertiary gravelly and sandy clayed layers at depth and arable Quaternary clay cover [17].

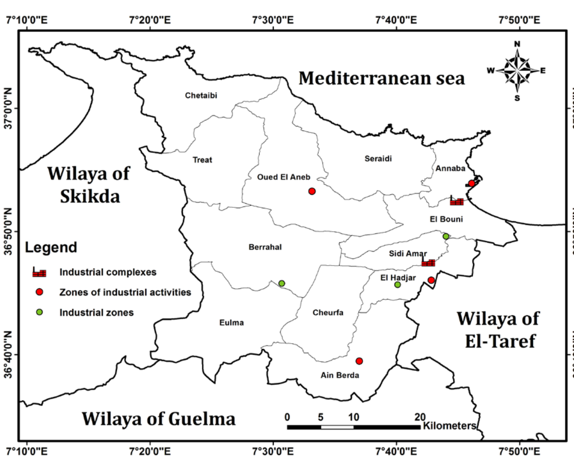

Fig. 1. Geographical location of the study area [6]

2.2. Socio-economic and industrial context of the Annaba region. Annaba region is known for its great agricultural and industrial activity. Agriculture in this region is observed throughout the plain, with a very wide variety of crops, cereals, market gardening and arboriculture. The industrial sector in the region is intense and remarkable; it is positioned especially along the Meboudja river. Three categories of industries are observed:

– Heavy industries with El Hadjar Metallurgical Complex, SIDER, SNVI and Ferrovial, etc.;

– Chemical industries with the phosphate and nitrogen fertilizer complex (FERTIAL);

– Agro-food industries presented by ORELAIT and several food industries or processing represented by small businesses. All urban and industrial discharges flow directly into the rivers, except that of the FERTIAL plant, which release these wastes to the sea [17].

2.3. Air pollution and its impact on human health and the environment. Atmospheric pollution or «air pollution» is a type of pollution characterized by altered levels of air quality and purity. This degradation is generally caused by one or more elements (particles, substances, materials, etc.) whose degrees of concentration and duration of presence are sufficient to produce a toxic and/or ecotoxic effect [18], which explains why this kind of pollution is a public health issue, both globally and individually.

The quality of the air we breathe has undergone a significant change over the past decade, mainly due to the «introduction by man» directly or indirectly, into the atmosphere, of substances with harmful consequences danger on:

– human health;
– biological resources and ecosystems;
– material goods;
– climate [19].

All human activities (industry, transport, heating, agriculture, incineration of waste in the open air, etc.) affect the quality of the air we breathe and generate atmospheric pollution. Nature itself, through pollens, volcanoes, the biological activity of soils, oceans and plants also contributes to this pollution.

In Annaba region, the main air pollutants mainly came from [20]:

– human activities, in particular road traffic;
– emissions from aging industrial installations (stationary sources) and all activities using combustion;
– thermal installations;
– domestic heating;
– incineration of waste in the open air.

According to statistics from the World Health Organization (WHO), three million people die every year as a result of air pollution around the world, in particular: Children (immature respiratory system), old people, and people suffering from respiratory and cardiovascular diseases [21].

In Algeria, a study was performed by the program of technical assistance of the Mediterranean environment (METAP), the deterioration of environment in Algeria costing 1.7 billion USD per year, or 3.6 percent of GDP. Additionally, the national report on the state of environment demonstrated that 30 % of consultations are for respiratory diseases, 40 % of infant mortality (children under 1 year) is caused by respiratory diseases and 600.000 asthmatics suffer permanently [6].

Air pollution does not only attack human health, but also affects our environment and our ecosystem represented by global phenomena at the local, regional and even continental scale, observed, through:

– climate change;
– problem of substances depleting the ozone layer;
– deterioration of the disappearance of certain flora and fauna species.

Similarly, meteorological conditions can also favor pollution, on a local or continental scale, or contribute to their dispersion [22]. Table 1 summarizes the impacts of pollution on human health and environment.

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Table 1

Effects of pollutants on human health and environment

Pollutants	Environmental impacts	Health effects
Nitrogen dioxide (NO_2)	– Damages diverse plants and ozone formation. – Acid Rain. – Greenhouse effect (indirectly)	– Penetrates the deep respiratory tract where it weakens the pulmonary mucosa against infectious attacks, especially in children. – An irritating gas that penetrates the finest ramifications of the respiratory tract, causing bronchial hyper-reactivity in asthmatic patients and increases susceptibility of the bronchi to infections in children
Sulfur dioxide (SO_2)	– Deterioration of plants and ecosystems as well as buildings. – Precursors of acid rain	– Causes attacks in asthmatics. – Increases breathing difficulties and affect respiratory function in children
Suspended particles <10 μm (PM10)	– Effects on crops. – Soiling of buildings	– Mutagenic and carcinogenic properties. – Impaired respiratory function
Ozone (O_3)	– Harmful effect on vegetation. – Contributes to the greenhouse effect and acid rain	– An aggressive gas that easily penetrates to the finest respiratory tracts. – Causes coughing, lung damage and eye irritation
Heavy metals	– Toxic Fallout	– Neurotoxic. – Kidney, lung and bone toxicity. – Respiratory carcinogen
Volatile organic compounds (VCO)	– Involved in the process of the greenhouse effect and the stratospheric ozone hole	– The effects vary according to the nature of the chemical compound. – They range from simple olfactory discomfort to irritation, to a reduction in respiratory capacity, to mutagenic and carcinogenic effects

2.4. Parameters influencing air quality. Air quality is not only dependent on the amount of pollutants emitted by sources. It is also linked to the climatic, meteorological, topological and morphological conditions of the environment. Once emitted by a source of pollutant, its evolution in the atmosphere is dependent on the wind, the stability of the atmosphere, solar radiation, the topography and morphology of the environment.

2.4.1. Meteorological situations. Low-pressure situations (low pressures) generally correspond to fairly strong air turbulence and therefore good dispersion conditions. On the other hand, anticyclonic situations (high pressures) where the stability of the air does not allow the dispersion of pollutants leads to episodes of pollution. There is a clear relationship between wind speed and pollutant concentration levels. A weak wind therefore favors the accumulation of pollutants. Wind speed increases with altitude.

2.4.2. Wind effect. There is a clear relationship between wind speed and pollutant concentration levels. The dispersion of pollutants increases with wind speed and turbulence. A weak wind therefore favors the accumulation of pollutants. Wind speed increases with altitude. As pollutants rise, horizontal dispersion is facilitated by the wind. The stronger the wind, the lower the pollution levels in the city.

The evolution of the mean time profile of wind speeds recorded very moderate values. It characterizes a maximum period (depending on the reference site) that occurs between 12:00 H, 19:00 H, and a longer minimum period over the rest of the period (Fig. 2).

The wind rose of the reference station clearly shows that the prevailing winds are from North East to South West. On the other hand, at the station of Annaba city and El Bouni is variable according to their position (within the urban fabric).

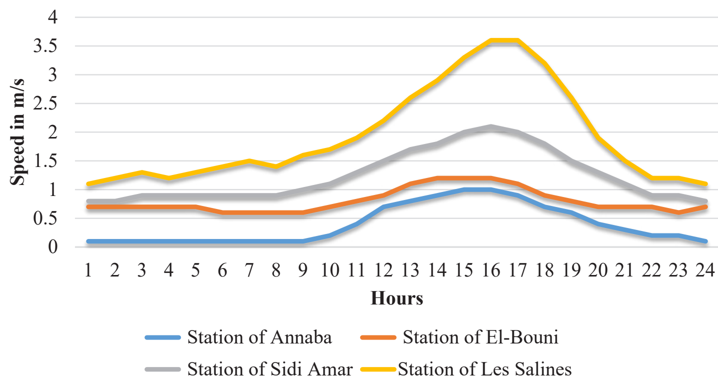


Fig. 2. Wind speed average hourly profile in Annaba province

2.4.3. Influence of local topography. The topography of Annaba is favorable to the formation of temperature inversions which are situations allowing the accumulation of pollutants and consequently the rise in concentration rates. The effects of sea breezes, particular relief (land and slope), play an important role in the transport of clouds of pollutants. Indeed, the clouds of pollutants are carried by the land breeze at night towards the sea, and during the day, these clouds of pollutants return to the city by the sea breeze effect.

2.5. Algerian standards relating to air pollution. In 2006, and after developing a database relating to air quality due to road traffic, the Ministry of Territorial Planning and the Environment deemed it necessary to create Algerian standards relating to thresholds limited in case of air pollution to be respected. Thus, Decree No. 06-02 of January 7, 2006 comes into force after its adoption by the government. The executive Decree No. 06-02 of 7 Dhou El Hidja 1426 corresponding to January 7, 2006 defined the limit values, alert thresholds, and air quality objectives in the event of atmospheric pollution, and imposes the implementation of procedures for informing and alerting populations during a pollution episode. They exist for ozone, nitrogen dioxide and sulfur dioxide.

The information threshold is the concentration level beyond which short-term exposure could present a health risk. The alert threshold corresponds to a concentration level of polluting substances in the atmosphere beyond which short-term exposure presents a high risk for human health and the environment and above which emergency measures must to be taken [6]. Table 2 shows the Algerian standards relating to the main air pollutants.

Table 2

Algerian norms relating to air pollutants

Thresholds \ Pollutants	NO_2	SO_2	O_3
Information thresholds	400 μg/m^3	350 μg/m^3	180 μg/m^3
Warning thresholds	600 μg/m^3	600 μg/m^3 (hourly average exceeded for three consecutive hours)	360 μg/m^3

2.6. Pollutants monitoring. The calculation of the total index of atmospheric pollution in the city of Annaba is carried out according to the approved methodology, taking into account the data from the automatic weather stations. These indicators include particulate matter (PM), sulfur dioxide, nitrogen dioxide, and man-made ozone (Table 3).

Historically, the metallurgical complex of El Hadjar was considered as one of the main polluting sources in Annaba region [1]. Table 4 shows the atmospheric emissions data of El Hadjar metallurgical complex in Annaba, according to a calculation model based on energy balances and emission factors.

Table 5 summarizes the chemical analysis of ores from Ouenza and Boukhadra mines.

Table 3

Pollutants quantification

Stations \ Pollutants	NO_2 μg/m^3	O_3 μg/m^3	PM μg/m^3
Annaba	32	35	39
El Bouni	7	29	73
Sidi Amar	8	33	57
Les Salines	5	32	36

Table 4

Atmospheric emissions data from El Hadjar metallurgical complex

Plant units \ Pollutants	CO_2 (t/year)	Particles (t/year)	SO_2 (t/year)	NO_x (t/year)
Coke plant	142494.85	781.26	501.113	1145.08
PMA	339726.39	2813.58	1719.410	1250.48
HFx	1695980.18	1738.96	12.149	297.77
ACO1	162665.48	16.15	0.468	78.05
ACO2	85985.42	7.49	0.242	40.27
ACE	11622.49	0.35	0.046	8.40
LAC	59998.46	2.46	0.295	270.42
LAF/Annealed	9392.59	0.48	0.046	10.78
LAF/Galvanized	20202.84	1.02	0.099	23.18
LFR	55678.44	2.82	0.274	63.88
LRB	22334.67	1.13	0.110	25.62
TSS	47604.28	2.41	0.234	54.61
Coprosid	41984.90	2.13	0.206	48.17
AMM	3488.53	0.18	0.017	4.00
Fluid/Boilers	76507.03	3.88	0.376	87.77
PDE/Power station	27882.57	1.41	0.137	31.99
Source:	2803549.09	5374.31	2235.086	3408.49
Environmental	Department	of El Hadjar	Metallurgical	Complex

Table 5

Chemical Analysis of Ores from Ouenza and Boukhadra mines

Ores \ Content in (%)	Fe	SiO_2	$BaSO_4$	CaO	Mn	MgO	S
Ouenza mine	46	8	0.03	9	2	13	0.05
Boukhadra mine	55	10	0.20	3	2.10	0.14	0.10

From the data in Table 5, let's note the presence of a high content of iron (Fe) and silica (SiO_2), and low content (traces) of sulfur (S) in ores from Ouenza and Boukhadra, such presence could possibly influence the environment and health [23].

2.7. Presentation and determination of the air quality index (AQI). The definition of an AQI results from the desire to make information accessible to as many people as possible without entering into sometimes complex scientific considerations. This index is a qualitative assessment of air quality that has little scientific value. Indeed, it summarizes in a single parameter the results for pollutants whose effects on health can be very different and defines the air quality in relation to the pollutant for which the situation is the worst. Let's therefore comparing very different data and should in no case begin to establish statistics on these indexes [24].

These indexes are based on the levels of ozone, nitrogen dioxide, sulfur dioxide and PM particles. They therefore do not take into account heavy metal or organic compounds whose effects result rather (but not always) from long-term exposure. The indexes therefore relate to the main irritant pollutants. For each of the pollutants, a concentration scale is defined to calculate a sub-index. The concentration scales are based both on the limit values imposed by international guidelines and on historical data (Table 6). The AQI is then determined as being the highest sub-index, therefore the poorest quality. If one of the sub-indexes is missing, the overall index is not calculated and a minimum of 50 % valid data is required to calculate a sub-index. In this paper, let's only use the sub-indexes precisely to avoid mixing up different concepts [3, 25]. In Table 6, let's refer to establish a distribution of the days according to the categories defined for the sub-indexes, site by site, the definition of a single index for the entire region being an overly simplistic notion that does not reflect local differences.

Table 6

Air quality index (AQI)

Index	PM10	SO_2	NO_2	O_3
	Daily Average, μg/m^3	Hourly Average, μg/m^3	Hourly Average, μg/m^3	Hourly Average, μg/m^3
1	0–9	0–39	0–29	0–29
2	10–19	40–79	30–54	30–54
3	20–29	80–119	55–84	55–79
4	30–39	120–159	85–109	80–104
5	40–49	160–199	110–134	105–129
6	50–54	200–249	135–164	130–149
7	55–79	250–299	195–199	150–179
8	80–99	300–399	200–274	180–249
9	100–124	400–599	275–399	250–359
10	>125	>600	>400	>360

Taking into account the concentration of each of the four parameters, the corresponding sub-indexes are determined.

The measured pollutants are considered excellent indicators of air quality.

The final score follows the highest value of the sub-index. According to the ten-point scale ranking, the air quality assessment is made in the following terms: Excellent, very good, good, pretty good, average, poor, very poor, bad, very bad, execrable (Table 6).

3. Results and Discussion

3.1. Particulate matter pollution. Throughout the world, the form of pollution that currently poses the most problems is that linked to the presence of increasingly fine particles in the atmosphere and emitted progressively in large quantities. The potential harm of these particles results from their size (the finer they are, the deeper they penetrate into the alveoli of the respiratory system) and the toxic compounds they carry (lead, carcinogenic polycyclic aromatic hydrocarbons, etc.). Fine particles and in particular the finest from diesel engines are nowadays a public health problem in all cities over the world.

The monitoring networks are thus equipped with analyzers for PM10 particles, PM2.5 respirable particles and increasingly PM1 (diesel particles). Both classes of particles PM10 and PM2.5 are strictly regulated by the WHO and by industrialized countries. The content of PM in Annaba is presented in the Fig. 3.

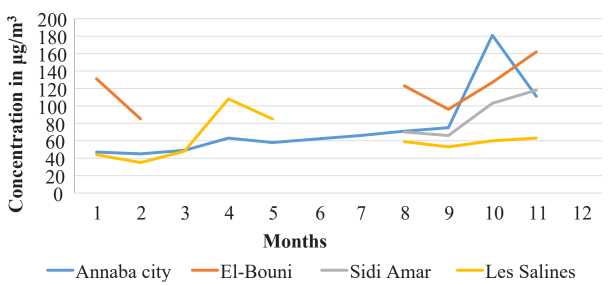


Fig. 3. Evolution of the PM content in Annaba province

Dust concentrations are relatively high compared to the current standard of around 30 μg/m³. Particulate pollution originates on the one hand from road traffic and industrial activities at the edge of urban centers and on the other hand from low soil cover, resulting in the raising of dust at moderate wind and meteorological conditions, appearance of the sirocco during the dry period.

3.2. Dust morphology. The shape of PM generally can stimulate flight and reduce the sedimentation rate of a particle [12]. The speed is a function of the aerodynamic diameter. The PM collected from the Dust Collectors (DC1 and DC2) at El Hadjar metallurgical complex of Annaba; have different morphology and irregular shape (Fig. 4–8). The analysis was performed on samples called DC1 and DC2. They were visually shown in the form of granular powder.

For the study of these powders, it was carried out using a scanning electron microscope (SEM) of the TESCAN model VEGA II, which uses a tungsten filament thermionic source. The powders have been bonded on carbon-based adhesive tape placed on aluminum sample holder (stub). The images show a jagged surface with particles of different sizes and shapes.

Fig. 4, *a*, *b* shows the morphological variety of the particles present in the dust DC1.

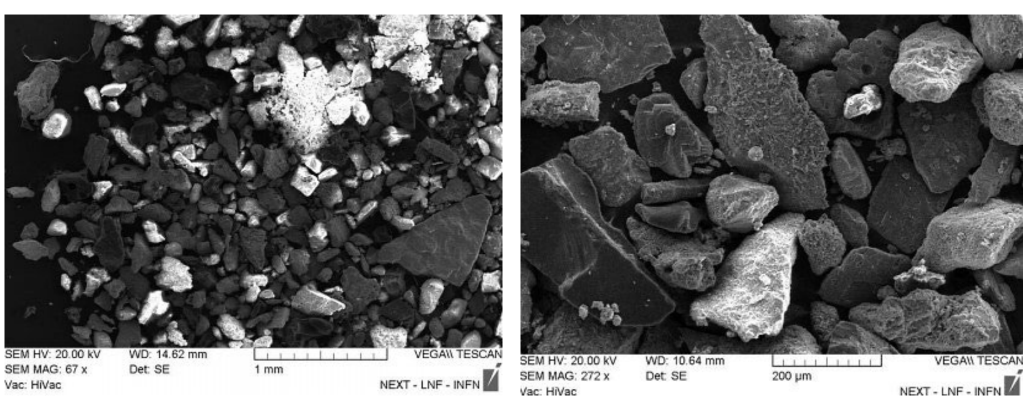
Fig. 5, *a*, *b* illustrates the diversity in morphology of some DC1 particles. As it is possible to see, some seem to show structures similar to «fibers» broken and supported or immersed in amorphous material; others instead resemble lamellar structures. It is estimated that particles range in size from hundreds of microns to tens of microns. The DC1 powders were metalized with a thin layer of platinum-gold because they were non-conductive and difficult to analyze.

The DC2 powders are formed by particles of different shapes and sizes.

Fig. 6, *a*, *b* shows the morphological variety of the particles present in the dust DC2.

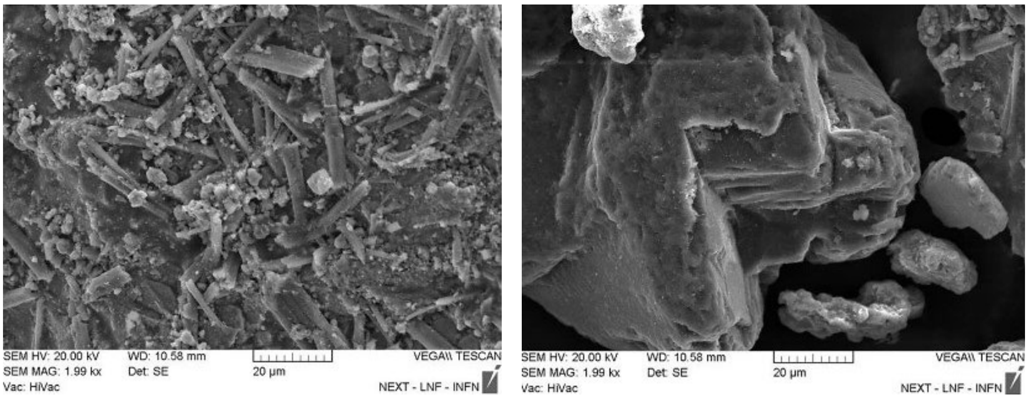
Fig. 7, *a*, *b* shows the diversity in the morphology of some particles of DC2. As it is seen, some of them seem to show filiform structures immersed in amorphous material or different shapes. The particle size is estimated to range from hundreds of microns to a few microns. The DC2 powders were metalized with a thin layer of platinum-gold because they were non- conductive and difficult to analyze. On the DC2 sample, a measurement with BSE detector (Backscattered Electrons) was carried out, and which allows having an image in the gray scale, that identifies the presence of species with different atomic numbers.

Fig. 8 demonstrates the different atomic species presented in the sample DC2, the black color indicates the lowest atomic number, and the white color indicates the highest atomic number, relative to the area under consideration.



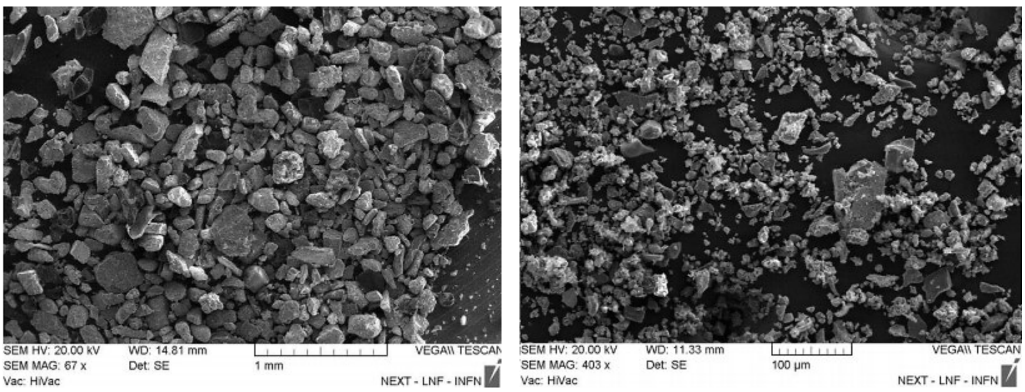
a *b*

Fig. 4. Two different magnifications of the particles present in the dust DC1: *a* – magnification of 1 mm; *b* – magnification of 200 μm



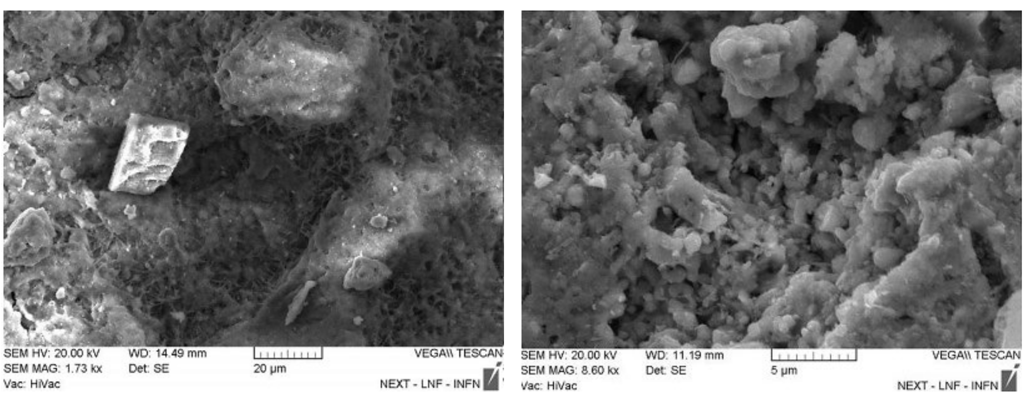
a *b*

Fig. 5. Particle details of DC1: *a* – fibers structures; *b* – lamellar structures



a *b*

Fig. 6. Two different magnifications of the particles present in the dust of DC2: *a* – magnification of 1 mm; *b* – magnification of 100 μm



a *b*

Fig. 7. Particle details of DC2: *a* – magnification of 20 μm; *b* – magnification of 5 μm

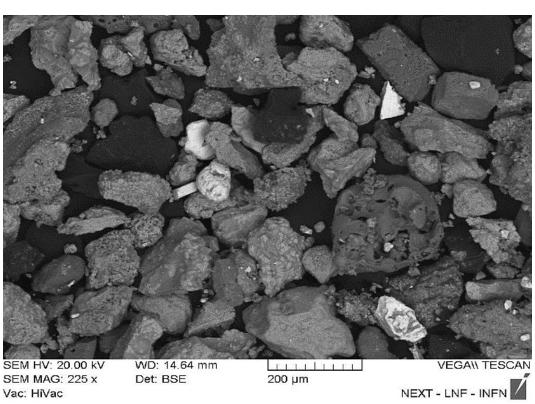


Fig. 8. BSE detector image of the sample DC2

3.3. Air quality assessment in Annaba province. In view of the concentrations recorded, overall air quality can be considered as good in Annaba city (Fig. 9).

Sometimes, air quality has been affected by the presence of PM10 dust pollution.

From Fig. 10, the quality of the air is generally rated good to pretty good in Sidi Amar. However, air quality was affected, for a period equal to one quarter of the year, by heavy dust pollution and sometimes by nitrogen dioxide.

As shown in Fig. 11 the overall air quality in El Bouni can also be rated as good to medium. Nevertheless, the air quality is bad for an average period close to the month. Dust pollution is, as for other urban sites, the most significant. However, at Les Salines the air quality is generally considered very average to poor. The character of

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background pollution is not considered critical for all pollutants, with the exception of ozone for which critical thresholds and warnings have been exceeded during the summer period which is affected by strong sunshine and by the local breezes of land and sea.

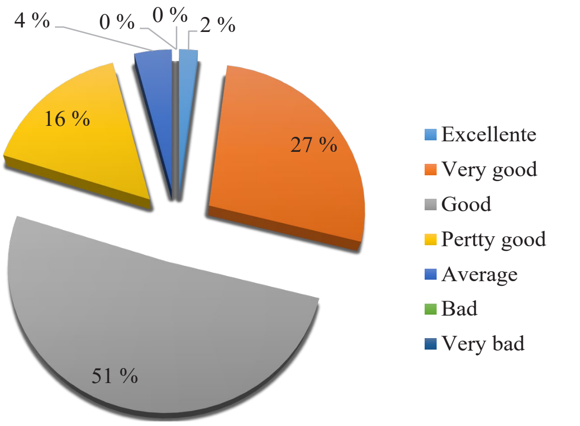

Fig. 9. Air quality in Annaba city

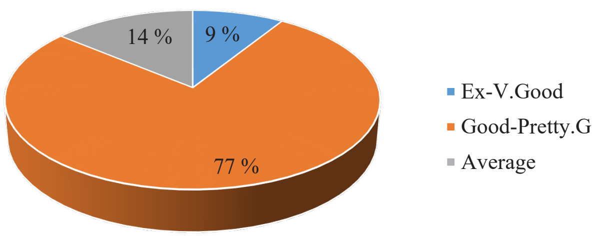

Fig. 10. Air quality in Sidi Amar

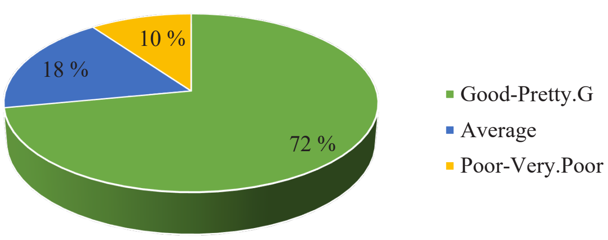

Fig. 11. Air quality in El Bouni

Corresponding to Fig. 12, the poor air quality is due to the meteorological situation allowing poor dispersion of pollutants.

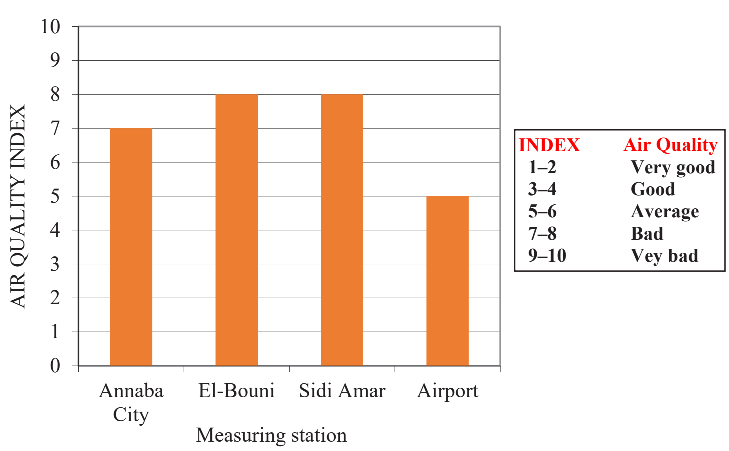

Fig. 12. Air quality index (AQI) in Annaba province

Overall, air quality in the Annaba area varies from fairly good to bad. The poor quality is due in most cases to dust levels and to a lesser extent to photochemical pollution during the summer season.

3.4. Limitations and perspectives on the results of the study. A significant number of citizens suffer from serious and incurable diseases such as asthma, allergies, respiratory diseases, and pneumonia due to air pollutants, in addition to food, agricultural, and animal products being polluted.

To improve the air quality, public authorities should undertake actions that come in several forms to try to preserve the health of the citizen in urban areas. Among these actions are:

- noise reduction;
- reduction or stability of CO_2 emissions by the use of less polluting means of transport;
- better integrated use of all modes of transport, with particular emphasis on the promotion of more environmentally friendly vehicles such as rail and urban public transport;
- promoting public and collective passenger transport for regional, urban, and interurban travel, also in the interest of balanced spatial planning, is essential in the case of the nuisances generated by increased motorization, taking into account the inherent necessities. However, the fuel used for all modes of transport must also be environmentally friendly; it is preferable to promote the use of clean fuels to have better air quality in urban areas with high population density;
- natural gas vehicles provide a real alternative to petroleum products while continuing to use conventional engine technologies;
- policy makers must appropriate measures to be taken, which are based mainly on sensitizing economic operators to environmental issues in order to adopt an environmentally friendly industrial system.

A sustainable surveillance, periodic monitoring and the creation of a database relating to air pollution, can play a key role to effective evaluation and decreasing negative effects of air pollution in the study zone.

4. Conclusions

Urban air pollution is a pervasive risk that cities must adapt to avoid significant and growing health and economic impacts. In fact, nearly 3 million people worldwide died due to excessive exposure to outdoor air pollution. In addition, the number of deaths due to ambient air pollution is expected to increase and become the main cause of premature mortality.

Historically, the metallurgical complex of El Hadjar was considered as one of the main polluting sources in the Annaba region. In ores from Ouenza and Boukhadra, let's note the presence of a high content of iron (Fe) and silica (SiO_2), which presence could possibly influence the environment and health but the content of sulfur (S) is negligible (traces).

Dust concentrations are relatively high compared to the current standard of around 30 μg/m^3. Particulate pollution originates on the one hand from road traffic and industrial activities at the edge of urban centers and on the other hand from low soil cover, resulting in the raising of dust in the moderate wind and meteorological conditions, appearance of the sirocco during the dry period. The ozone pollution recorded during the summer period is due to the sunshine favored by the presence of the primary pollutants (NO_2, HC, CO).

The analysis performed on samples DC1 and DC2 with SEM (TESCAN model VEGA II) and BSE detector (Backscattered Electrons) shows that the particles sizes are estimated to range from hundreds of microns to a few microns, a different morphology and irregular shape.

Poor air quality is due to the meteorological situation allowing poor dispersion of pollutants. Overall, AQI in the Annaba area varies from fairly good to bad. The poor AQI is due in most cases to dust levels and to a lesser extent to photochemical pollution during the summer season.

The ten-point scale ranking of the overall AQI of pollution accepted in Algeria allows making the differentiated assessment of negative impacts of existing industrial agglomerations on the environment. Such assessments will enable policy makers to appropriate measures to be taken, which are based mainly on sensitizing economic operators to environmental issues in order to adopt an environmentally friendly industrial system.

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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.

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