Impact of industrial atmospheric emissions (PM$_{10}$) on ambient air quality in the region of Arzew, Algeria

S. Naili (a*), A. Morsli (a)

(a) Department of Chemical Engineering, Faculty of Chemistry, University of Sciences and Technology of Oran - Mohamed Boudiaf, El Mnaoua, BP 1505, Bir El Djir 31000, Oran, Algeria.

Corresponding author. E-mail: nailisaid66@gmail.com
Received 15 Feb 2021, Revised 15 Mar 2021, Accepted 27 Mar 2021

Abstract
The main objective was to assess the level of air pollution, in accordance with World Health Organization (WHO). This work focused on the impact of atmospheric emissions, such as particulate matter (PM$_{10}$) generated by industrial activities of petroleum refining, liquefied natural gas processing and petrochemicals, on ambient air quality in the region of Arzew (Algeria) during 2019. The study found that PM$_{10}$ level greatly exceeded (51.18 μg/m$^3$) the annual average (20 μg/m$^3$) recommended by the WHO during the sampling period. This study also demonstrated that PM$_{10}$ levels are dependent on industrial emission rates and weather seasons, peaking in the summer mainly due to stable weather conditions.

Keywords: Air pollution; Particulate matter (PM$_{10}$); Air quality; Industrial emission.

1. Introduction
Ambient air pollution represents the greatest environmental threat to human health in the world. In 2013, the WHO classified outdoor air pollution as carcinogenic to humans [1]. Epidemiological studies have repeatedly shown that there is a relationship between air pollution, mainly due to particles and gases, and the number of illnesses in people with respiratory problems, as well as the number of deaths from cardiovascular and respiratory diseases in the elderly [2]. Air pollution, especially from oil–gas industry emissions, including mining, refining, storage, transportation between different storage facilities and refuelling, is complex [4,5]. It includes for example particles (PM$_{10}$) [3-17]. Industrial activities are more dangerous in densely populated places, such as industrial cities [18,19] where large populations are exposed to air pollutants. The main source of air pollution in the study area comes mainly from the hydrocarbon activities located in the industrial area of Arzew, that they are punctual (emissions of pollutants by chimney) or fugitive (accidental releases of drains or storages) [6,7,20]. the knowledge and the control of these emissions are important data to quantify and reduce their environmental impact.
2. Experimental

2.1. Standards for PM\textsubscript{10} in air quality

The World Health Organization (WHO) guideline values for pollutants that are measured in this study are listed in Table 1 [21].

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Guideline value (μg/m\textsuperscript{3})</th>
<th>Exposure time</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM\textsubscript{10}</td>
<td>50</td>
<td>daily</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Year</td>
</tr>
</tbody>
</table>

2.2. Sampling site

This study was carried in 2019, in the Arzew region, characterized by industrial hydrocarbon activities. Covering an area of 2700 hectares, this industrial zone stretches for approximately 12 km along the bay of Arzew. It includes the processing and liquefaction of natural gas, petroleum refining and petrochemicals. The mobile ambient air monitoring station was placed in an industrial site near a residential area whose coordinates are: Latitude - 35 ° 49'16.52 "N and Longitude - 0 ° 17'54.34' W, at 53 m above sea level (Figure 1), and less than 300 m from the western residential part of the small town of Ain El Bia.

![Geographical location of the measurement site.](image-url)
2.3. Meteorological parameters in the sampling site

The levels of this type of pollution depend on weather conditions such as the stability of the atmospheric boundary layer, wind speed and direction, temperature, humidity, turbulence, precipitation, topography, etc. [22]. These factors control the transport, distribution and impacts of these pollutants on ambient air quality. Some of the parameters that characterize the climate, such as wind speed, wind direction, humidity, precipitation and temperature in the study area were studied in this study. These parameters were evaluated by the Arzew meteorological station (National Meteorological Office) during the measurement period. The distance between the weather station and the air quality monitoring site is 4 kilometers. Table 2 shows the meteorological parameters recorded in this study.

Table 2: Monthly averages of meteorological parameters during 2019.

<table>
<thead>
<tr>
<th>Months</th>
<th>Wind speed (m/s)</th>
<th>Wind Direction (frequency)</th>
<th>Humidity (%)</th>
<th>Temperature (°C)</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>11.8</td>
<td>SW</td>
<td>71</td>
<td>14.3</td>
<td>39.6</td>
</tr>
<tr>
<td>February</td>
<td>7.4</td>
<td>NE</td>
<td>70</td>
<td>13.5</td>
<td>22.4</td>
</tr>
<tr>
<td>March</td>
<td>7.4</td>
<td>SW</td>
<td>76</td>
<td>16.7</td>
<td>10.7</td>
</tr>
<tr>
<td>April</td>
<td>8.2</td>
<td>WSW</td>
<td>76</td>
<td>16.8</td>
<td>25.1</td>
</tr>
<tr>
<td>May</td>
<td>8.2</td>
<td>NE</td>
<td>73</td>
<td>20.0</td>
<td>11.9</td>
</tr>
<tr>
<td>June</td>
<td>7.8</td>
<td>NNE</td>
<td>61</td>
<td>22.4</td>
<td>1.5</td>
</tr>
<tr>
<td>July</td>
<td>6.4</td>
<td>NNE</td>
<td>60</td>
<td>26.0</td>
<td>0.3</td>
</tr>
<tr>
<td>August</td>
<td>6.4</td>
<td>WSW</td>
<td>58</td>
<td>26.3</td>
<td>0.0</td>
</tr>
<tr>
<td>September</td>
<td>6.6</td>
<td>WSW</td>
<td>64</td>
<td>24.2</td>
<td>11.7</td>
</tr>
<tr>
<td>October</td>
<td>6.8</td>
<td>SW</td>
<td>66</td>
<td>20.9</td>
<td>19.3</td>
</tr>
<tr>
<td>November</td>
<td>7.4</td>
<td>WSW</td>
<td>66</td>
<td>16.7</td>
<td>30.5</td>
</tr>
<tr>
<td>December</td>
<td>10.4</td>
<td>SW</td>
<td>67</td>
<td>15.5</td>
<td>34.3</td>
</tr>
</tbody>
</table>

2.4. Sampling and methods of measurement

The ambient air quality monitoring system (mobile laboratory) was manufactured by Environment S.A. This system is composed of several transducers and analysers using various instrumentation techniques. PM$_{10}$ was measured by the beta radiation absorption method (model: MP101ML-035). The gas sample was drawn using a fibreglass filtration tape and the system recorded the volumetric flow of gas. The dust particles were then trapped by the filter tape and measured radiometrically. The radiometric measurement was carried out using a Carbon 14 source (14$^C$) and a radioactive radiation detector (Geiger-Müller counter). The low-energy beta rays are absorbed during their collision with electrons; their number is proportional to the density of gas. Therefore, absorption becomes a function of the mass of the irradiated material, but is independent of its physicochemical nature.
3. Results and discussion

As Figure 2 shows, the concentrations of PM$_{10}$ varied during the sampling period. The highest levels were recorded during summer. Indeed, this was 76.74 μg/m$^3$ in August and 65.75 μg/ m$^3$ in July. These excessive concentrations are mainly owing to the prevailing low-pressure weather conditions that are unfavourable to a good dispersion in the atmosphere, as well as to the high levels of pollutant emissions. During the winter and fall seasons, this pollutant showed the lowest concentrations in 24 h, especially in January (37.21 μg/ m$^3$), February (41.74 μg/m$^3$) and December (43.37 μg/m$^3$). These low concentrations are also directly related to the prevailing weather conditions that are favourable to a good dispersion in the atmosphere, as well as to the low levels of PM$_{10}$ emissions in ambient air.

Figure 3 shows the hourly variation of PM$_{10}$ during 2019. The curves of the hourly variation during the sampling period are characterised by relatively high values (hourly average equal to 51.91 μg/m$^3$). In the summer season, PM$_{10}$ reached a first maximum concentration of 96.08 μg/m$^3$ at 19:00, with a second peak of 93.83 μg/m$^3$ at 20:00 in August. The lowest average concentration of this pollutant (24.31 μg/m3) was recorded in January at 09.00. Similar profiles were observed relatively for the curves of the hourly variation of mean concentrations of PM$_{10}$ during the winter season.

Figure 4 shows the average daily PM$_{10}$ concentrations during the measurement period. The curves of the daily variation of the average concentrations of PM$_{10}$ are characterised by an overrun of the threshold in the directives (50 μg/m$^3$ in daily average) by 42% as recommended by the WHO, specifically in the days of August, July and June. The average daily PM$_{10}$ concentrations reached three maximum concentrations, namely 192.47 μg/m3, 176.69 μg/m$^3$ and 113.74 μg/m$^3$, recorded in August. The lowest concentrations of this pollutant were recorded in January and February (not exceeding 37.21 μg/m$^3$ and 41.74 μg/m$^3$ daily average, respectively).

![Fig 2: Mean monthly variations of PM$_{10}$ during 2019.](image-url)
Fig 3: Mean hourly variations of PM$_{10}$ during 2019.
Fig 4: Mean daily variations of PM$_{10}$ during 2019.
The results of the seasonal variation in PM$_{10}$ concentrations, which were measured, showed a variation during the 2019. The highest levels were recorded during summer season, especially in August and July. These excessive concentrations are mainly owing to the prevailing weather conditions during the sampling period, in addition to the proximity to industrial emission sources could be attributed either to the point source emissions (pollutants discharged from torches or stacks) or to fugitive emissions (accidental leaks from pipelines or storage tanks), resulting from the hydrocarbon and petrochemical-related industrial activities [6,7,20]. These concentrations are less severe during the months of January, February and December and relatively less during the spring and fall seasons but stronger during the months of July and August. Indeed, the first two months of the sampling period coincided with the summer season. This dry season is characterised by a sharp decrease in rainfall (an average of 0.6 mm), with weak winds (at an average of 6.9 m/s), accompanied by a rise in temperature (an average of 24.9 °C), which favours stagnation and consequent air saturation by the increase in the quantity of PM10 particles released in the atmosphere. This situation is mainly caused by certain dysfunctions in the industrial processing operations, relating either to the transformation and liquefaction of gas, the refining of petroleum or the petrochemical synthesis, with a correlation between certain meteorological parameters. During that period, relatively high temperatures combined with low winds to an increase in the PM$_{10}$ particle concentrations. Under these meteorological conditions, polluting emissions (An average of 65.8 μg/m$^3$ in the summer) are high; they accumulate in a thin layer of the atmosphere and this causes an increase in the amount of aerosols. The daily averages exceed the guide value of 50 μg/m$^3$ in a fairly generalised manner over the entire measurement period in August and mostly in July, with some variations from one day to another (between 37.82 μg/m$^3$ and 192.47 μg/m$^3$).

In general, the number of days in which the regulatory limit for PM$_{10}$ was exceeded was 154 days and the average annual particulate concentration (51.18 μg/m$^3$) exceeded the limit value (20 μg/m$^3$ annual average) recommended by the WHO. Thus, ambient air is considered to be fairly polluted by dust from industrial activities related to hydrocarbons, which leads to negative effects of PM$_{10}$ emissions on human health and ambient air quality in industrial environments.

4. Conclusion
In view of the results obtained, we can conclude that the quality of the ambient air in the Industrial Zone of Arzew is lower than the objective of the air quality setting the content of PM$_{10}$ dust, according to the directive of the WHO. Thus, these data confirm the need to maintain sustained action by the inspection of installations classified as Installations Classified for the Environmental Protection (ICPE) in the area of atmospheric emissions. Beyond the respect of the regulatory values which are imposed on the establishments, the action of the inspectorate aims to obtain reductions of emissions at the source, thanks to the evolution of technologies, as well as the assurance that, locally, the emissions do not create an unacceptable health risk for exposed populations.

Acknowledgements
The authors would like to thank the Air Quality Investigation and Control Network at the Department of Health and Environment in the Regional Direction of the Industrial Zone of Arzew for access to its
database. The authors also express their gratitude to the Arzew National Meteorological Office for providing the meteorological data used in this study.

References