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Impact of industrial atmospheric emissions on ambient air quality in Arzew area, Algeria

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Abstract This work focuses on identifying the source of BTEX (Benzene, Toluene, Ethylbenzene, Xylene) emissions generated by hydrocarbon-related industrial activities and evaluation of its impact on ambient air quality according to European Union (EU) regulations during 2019. The spatial distribution of BTEX concentrations suggest that massive emissions are mainly due to the oil refining activity. BTEX concentration levels at the sampling sites show that benzene was more dominant. Considering the level of atmospheric pollution relative to the indicative value (2 µg/m^3) recommended by the EU, the ambient air is considered to be quite polluted with benzene content (5.36 µg/m^3) produced mainly by emissions from the oil refining industrial complex.
Keywords: BTEX emissions; Industrial activities; Atmospheric pollution; Ambient air.

1. INTRODUCTION

Industrial gas emissions are some of the most important sources of environmental pollutants that can actually have negative effects on human health and environment [1]. It is important to better know and control these anthropogenic emissions in the atmosphere in order to improve the quality of air. These two actions constitute an unavoidable environmental and economic stake for the industrial world. In recent decades, global concern over the degradation of air quality has dramatically increased and several researchers have studied the impacts on the environment and human health resulting from industrial emissions in the air [2-8]. It is worth noting that industrial activities are more dangerous in densely populated areas, such as industrial cities where large populations are exposed to air pollutants [9,10]. Moreover, in professional circles, air pollution is directly linked to specific activities carried out on site; it has a direct impact on workers because of their prolonged exposure time [11].

The industrial zone of Arzew continually emits a wide range of pollutants [12-14], such as particulate matter (PM), nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC) of the BTEX type [15], in addition to greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4). These gas emissions can be either punctual (emissions of pollutants by a chimney) or fugitive (accidental releases of pipes or storage tanks). They can originate from hydrocarbon-related industrial activities, such as crude oil refining, natural gas and petrochemical processing and liquefaction complexes, as well as from hydrocarbon storage units that pose potential environmental hazards and may present a major risk to the health of workers and the health of the population living in surrounding areas [12-14].

2. Experimental

2.1. Description of the measurement campaign

During 2019, the measurement campaign included nine sampling sites represented by four industrial sectors hydrocarbons-related, namely the petroleum refining sector, the hydrocarbon storage sector, the natural gas processing and liquefaction sector and the petrochemical sector, located at the platform level of the Arzew industrial area using ambient air quality monitoring stations, as shown in Figure 1 and Table 1.

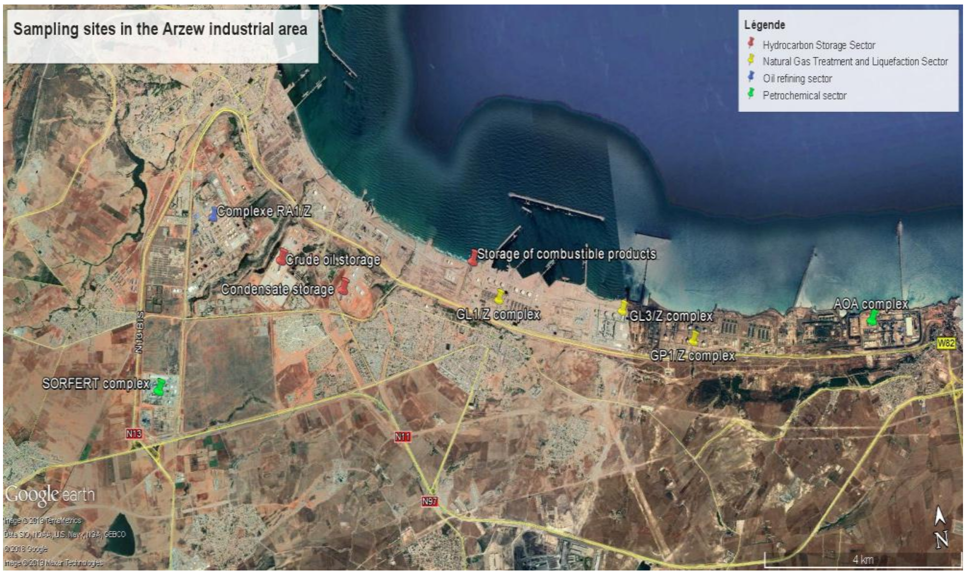


Figure 1. Geographical location of different measurement sites in the industrial zone of Arzew during 2019.

Table 1. Main characteristics of the different measurement sites during 2019.

Sectors	Industrial complexes and units	Geographical coordinates	
Oil refining	Industrial complex RA1/Z	35°49'47.66"N	0°19'37.58"W
Natural gas treatment	Industrial complex LPG1/Z	35°47'57.46"N	0°13'24.72"O
	Industrial complex LNG1/Z	35°48'37.51"N	0°15'56.63"O
	Industrial complex LNG3/Z	35°48'20.03"N	0°14'18.47"W
Petrochemical	Industrial complex SORFERT	35°48'21.16"N	0°18'47.30"W
	Industrial complex AOA	35°47'50.87"N	0°10'59.67"W
Hydrocarbon storage	Storage of crude oil	35°49'18.26"N	0°18'48.61"W
	Storage of combustible products	35°48'59.89"N	0°16'14.07"W
	Condensate storage	35°48'56.92"N	0°18'0.54"W

2.2. Measuring device

The air quality monitoring system (Fixed measurement stations) was manufactured by Environment S.A. This system consists of several transducers and analyzers using various instrumentation techniques. Volatile organic compounds (VOCs) of BTEX type were measured by the gas chromatography method using the VOC71M analyzer model. Metrology was based on the gas chromatography technique which consists of separating the compounds of interest in combination with detection by a Flame Ionization Detector (FID). The sampling operation was done cyclically, with two tubes filled with selective

sorbents. While one tube collects one sample, the other one desorbs the second sample which is then injected into a fused silica capillary column for separation. A controlled temperature gradient oven allows fast and accurate separation of the BTEX elements. The compounds of benzene, toluene, ethylbenzene and xylene were identified by their elution times in the capillary column.

3. Results and discussion

Table 2 shows the average concentrations of BTEX compounds in different sectors located in the industrial zone of Arzew during 2019. The concentrations of BTEX species vary in different sectors between 0.28 µg/m^3 to 5.36 µg/m^3 for benzene, 0.09 µg/m^3 to 0.61 µg/m^3 for toluene, 0.08 µg/m^3 to 0.58 µg/m^3 for ethylbenzene and for xylene is between 0.09 µg/m^3 and 2.18 µg/m^3. The highest average concentrations of benzene, toluene, ethylbenzene and xylenes species are observed, respectively, in the petroleum refining sector namely 5.36 µg/m^3, 0.61 µg/m^3, 0.58 µg/m^3, 2.18 µg/m^3, followed by the hydrocarbon storage sector with values of 1.97 µg/m^3, 0.53 µg/m^3, 0.21 µg/m^3, 1.5 µg/m^3, while the lowest are recorded in the natural gas processing sectors (0.53 µg/m^3, 0.13 µg/m^3, 0.18 µg/m^3, 0.4 µg/m^3) and petrochemicals (0.28 µg/m^3, 0.09 µg/m^3, 0.08 µg/m^3, 0.09 µg/m^3).

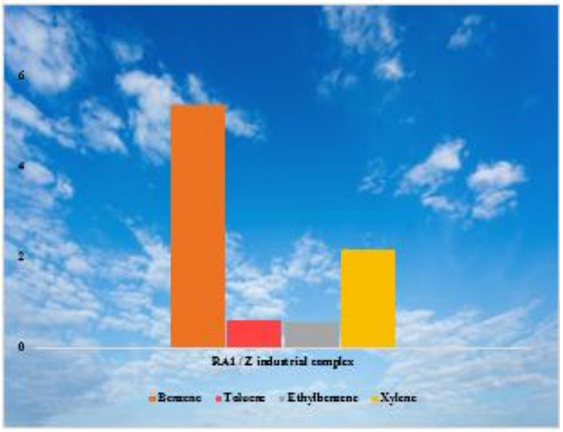
Table 2. Average concentrations of BTEX compounds in different sectors during 2019.

	Benzene	Toluene	Ethylbenzene	Xylene
Sectors	µg/m^3			
Oil refining	5.36	0.61	0.58	2.18
Hydrocarbon storage	1.97	0.53	0.21	1.50
Natural gas treatment and liquefaction	0.53	0.13	0.18	0.40
Petrochemical	0.28	0.09	0.08	0.09

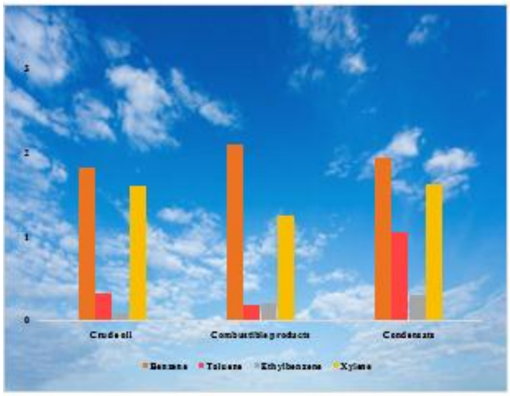
Figures 2 show the variations of BTEX compounds in different measurement sites represented by industrial complexes, namely RA1/Z, LNG1/Z, LNG3/Z, LPG1/Z, SORFERT and AOA, as well as hydrocarbon storage units which include crude oil storage, fuel storage and condensate storage. The concentration of benzene is highest in the site located near the industrial petroleum refining complex (5.36 µg/m^3), while in the other measuring sites varies between 0.18 µg/m^3 and 2.12 µg/m^3. In the RA1/Z measuring site, the concentration of toluene is 0.61 µg/m^3, ethylbenzene is 0.58 µg/m^3 and xylene is of the order of 2.18 µg/m^3, as shown in Figure 2(a). These high concentrations of BTEX compounds explain that these species come mainly from emissions from crude oil refining operations for the production of fuels such as gasoline, kerosene, diesel, fuel oil and naphtha. In addition, these high concentrations of BTEX recorded at the RA1/Z measurement site are observed in the winter season, which is characterized by low dispersion due to low wind speed (7.75 m/s) and low wind speed.

In sampling sites near hydrocarbon storage units, i.e. crude oil storage, fuel storage, and condensate storage, the species is also more predominant than toluene, ethylbenzene, and xylene, where the highest concentration is recorded in the fuel storage site (2.12 µg/m^3), as shown in Figure 2(b). The recorded concentrations of BTEX compounds at the condensate storage site are respectively 1.95 µg/m^3, 1.06 µg/m^3, 0.31 µg/m^3 and 1.63 µg/m^3, while at the site of condensate storage, the concentrations are low (1.83 µg/m^3, 0.34 µg/m^3, 0.1 µg/m^3, 1.62 µg/m^3, respectively). The relatively high concentrations of BTEX compounds recorded near the hydrocarbon storage units can be explained by the emissions due from storage tanks which contain a high density of volatile organic compounds (VOCs) such as BTEX, as they can easily be found in gaseous form in the atmosphere.

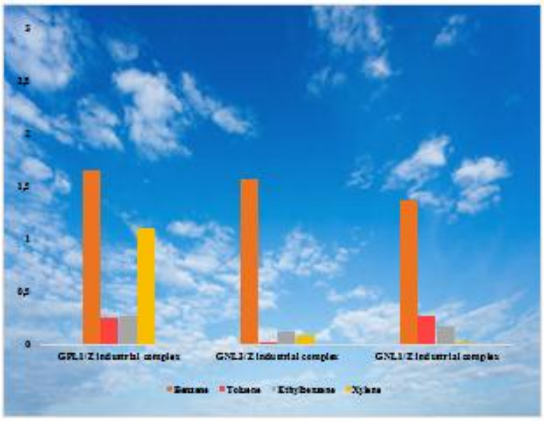
At the measurement sites located near the industrial natural gas processing complexes, namely LPG1/Z, LNG1/Z and LNG3/Z, low values are recorded for the BTEX compounds, as shown in Figure 2(c). The benzene species is always the predominant concentration, the highest value of which is recorded for the LPG1/Z complex (1.66 µg/m^3), followed by the LNG3/Z complex (1.57 µg/m^3) and then LNG1/Z complex (1.37 µg/m^3). The values of the concentrations of toluene and ethylbenzene are relatively similar in the complexes LNG3/Z (0.26 µg/m^3, 0.22 µg/m^3) and LPG1/Z (0.25 µg/m^3, 0.26 µg/m^3), respectively, while the LNG1/Z complex is recorded very low values, (0.01 µg/m^3, 0.12 µg/m^3, respectively). A high value of the xylene content is observed in the site of the LPG1/Z complex (1.11 µg/m^3), while the content of this species is relatively zero in the LNG3/Z complexes (0.01 µg/m^3) and LNG1/Z (0.07 µg/m^3).



(a) RA1/Z industrial complex



(b) Storage sites for crude oil, petroleum products and condensates



(c) LPG1/Z, LNG3/Z and LNG1/Z industrial complexes

(d) SORFERT and AOA industrial complexes

Figure 2. Variation of BTEX concentrations at measurement sites during 2019.

In the sampling sites near the AOA and SORFERT petrochemical complexes, the levels of BTEX compounds are very low compared to those observed at the hydrocarbon storage units and other industrial complexes, as shown in Figure 2(d). The average concentrations of BTEX in the AOA industrial complex (0.18 µg/m^3, 0.01 µg/m^3, 0.05 µg/m^3 and 0.03 µg/m^3, respectively) are lower than those recorded in the industrial complex SORFERT (0.37 µg/m^3, 0.16 µg/m^3, 0.10 µg/m^3, 0.15 µg/m^3, respectively). The low concentrations of BTEX in the SORFERT and AOA petrochemical industrial complexes can be explained only in the case of the combustion of products resulting from the synthesis of ammonia from light hydrocarbons, the raw material of which contains traces of substances such as volatile organic compounds, BTEX emission levels are low in ambient air.
Figure 3 shows the annual average levels of BTEX compounds for all the sites of the Arzew industrial pole in 2019. The benzene content represents the highest value recorded at a concentration of 1.82 µg/m^3 monitored. xylene at a concentration of 0.9 µg/m^3, while toluene and ethylbenzene are recorded the lowest levels at concentrations of 0.32 µg/m^3 and 0.22 µg/m^3, or 56 %, 27 %, 10 % and 07 %, respectively.

Through the recorded results of the average concentrations of BTEX compounds at the measurement sites, the high concentration of benzene indicates that this compound comes mainly from emissions from crude oil refining operations. These emissions can be either one-off, through pollutant emissions from the degassing and flaring processes of oil refinery treatment units or exhaust gas plants from the combustion of hydrocarbons, or fugitive, through leaks accidents in treatment plants and vapors of volatile organic compounds emitted from hydrocarbon storage tanks, as well as from the loading and unloading of hydrocarbons.

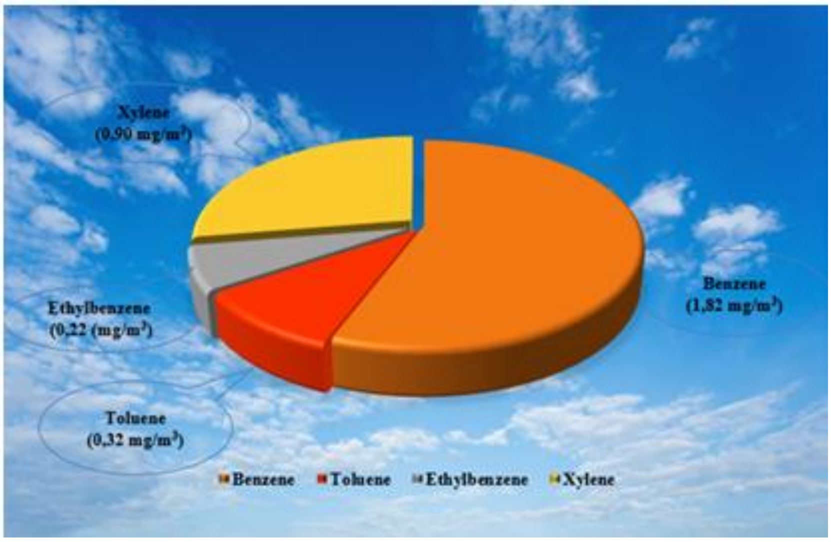


Figure 3. Distribution of annual average concentrations of BTEX in the industrial area of Arzew during 2019.

4. Conclusion

During 2019, the spatial distribution of BTEX concentrations at measurement sites near industrial complexes and hydrocarbon storage units indicates that the industrial complex for refining crude oil is the main source of emissions of BTEX compounds. Considering the level of air pollution compared to the indicative value, the average concentration of benzene at the site of the oil refining industrial complex exceeded the permissible limit according to EU regulations. Consequently, these results confirm the need for urgent action to reduce the negative impacts of BTEX emissions, in particular benzene, on human health and the quality of ambient air in industrial settings.

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