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Temporal Variations of Urban Air Pollutants in Damietta Port, North Egypt

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Air pollution is considered one of the most important factors that affect the surrounding environment and the human health. This study investigated seasonal variation in air pollutants parameters (CO, NO_2, O_3, SO_2 and PM_{10}) in Damietta Port (DP), Egypt using the archive data, from the Egyptian Environmental Affairs Agency (EEAA) branch in DP, for the period from 2015 to 2017. Statistical results showed that the mean concentration of CO was 2.7, 6.2 and 3.2 mg/m_3 in 2015, 2016 and 2017 respectively. Mean concentration of NO_2 was 27.9, 28.5, and 16.5 $\mu g/m_3$ in 2015, 2016 and 2017. Ozone mean concentration was 27.7, 25.1, and 16.5 $\mu g/m_3$ in 2015, 2016 and 2017. PM_{10} mean concentration was 83.5, 111, and 74.4 $\mu g/m_3$ in 2015, 2016 and 2017. Mean concentration of SO_2 was 17.5, 22.3, and 11.9 $\mu g/m_3$ in 2015, 2016 and 2017. The CO concentration increased from 2015 to 2017, due to increasing port activities from vessels, cargo handling equipment, and heavy-duty vehicles. On the other hand, ozone decreased from 2015 to 2017, and this may be related to the improvement and application of safety and environmental rules, and systems in the port. From the collected results, it was observed that some pollutant concentrations were exceeded, beyond the threshold limit for CO and PM_{10}, according to Environmental Law no. 4/1994. Finally, we recommend to monitor and measure the concentration of different air pollutants in the port regularly, to assess, analyze, and control the environmental risks to achieve health in the surrounding environment for the port man-power.

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1. INTRODUCTION

Urban air quality in Egypt, like all developing countries, has deteriorated gradually because of rapid urbanization, population growth, and industrialization [1]. The pollutants are added to the environment through various natural processes, as well as anthropogenic sources, industrial processes, auto exhaust, and domestic sources [2]. The air pollutants are categorized as particulate matter, and gases, and their associated forms including carbon, nitrogen, sulfur compounds, and ozone, that have adverse effects on human health, and cause environmental damage [3]. Outdoor air pollution, mostly PM 2.5, is estimated to lead to 3.3 million premature deaths per year worldwide [4]. The high concentration of air pollutants has worsened human health [5], and quality of life. This increased level of air pollutants in urban areas is responsible for deficits in pulmonary functions, cardiovascular disease, neurobehavioral effects, and mortality [6,7,8]. Different studies in the US and Europe have reported significant associations between daily mortality and PM_{10} [9] [10]. It is well-know that both respiratory and cardiovascular diseases are the major causes of death. Many studies have also shown positive associations between daily PM_{10} concentrations and daily hospital admissions for respiratory diseases (e.g., asthma, pneumonia, chronic obstructive pulmonary disease (COPD), etc.) [11] [12]. Other studies have reported increased hospital admissions for cardiovascular diseases (e.g., congestive heart failure, increase in coronary artery disease, etc.) associated with increased particle concentrations [13]. The impact of gaseous and particulate pollutants on health varies with season, hence seasonality has always been a factor in determining the concentration of pollution in the lower atmosphere [14]. Poor air quality is considered a significant problem, not only does it affect human health, but also ecosystem health, crops, climate, visibility and man-made materials [15]. The morbidity and premature mortality due to air pollution entails significant economic and social costs. These include, but are not limited to, the cost to society of premature deaths, the costs of healthcare for the sick, due to poor air quality, and the loss of productivity associated with sickness and/or caregiving for oneself or others [16]. Thus, significant cost savings can be added to the health gains attainable through air pollution abatement. The aim of this present study is to investigate the temporal variations of air pollutants (CO, NO_2, SO_2, O_3 and PM_{10}) in New Damietta Port (Fig. 1) from 2015 to 2017.

2. MATERIALS AND METHODS

2.1 Study Area

DP is located 10 km to the west of the Nile River (Damietta Branch), 70 km to the west of Port Said and 200 km from Alexandria Port with total area 11.8 million m_2 (Fig. 1). The land area covers approximately 7.9 million m2, and the water area is approximately 3.9 million m2. The percentage of water to land area is 1: 2. The channel is approximately 11.3 km long, 300 m wide, and 15 m in depth. The Nile River connects to the port via a barge channel 4.5 km long and 5 m deep. The width of the barge channel is 90 m. The DP connects to the main transportation network through railways and highway roads between Damietta and Mansoura.

2.2 Sampling and Analytical Methods

The investigated air pollutants (particulates and gases) were collected by the Egyptian Environmental Affairs Agency (EEAA) branch in the DP from 2015 to 2017. Air pollutants were measured using Thermo Environmental Instrument (TEI) Model 42i for NO, NO_X, TEI Model 48i for CO, TEI Model 410i for CO_2, TEI Model 49i for O_3, and Thermo ESM Andersen, FH 62 I-R for PM_{10}.

3. RESULTS AND DISCUSSION

3.1 Temporal Variations of CO Concentration

Carbon monoxide (CO) is often associated with combustion of fuels, heating devices (e.g., boilers, furnaces), vehicles, truck, or bus exhaust from attached garages, nearby roads, or parking areas. At moderate concentrations, angina, impaired vision, and reduced brain function may result. At higher concentrations, CO exposure can be fatal [17,18].

In this study, CO concentrations varied from 2015 to 2017 as illustrated in Fig. 2 and Table 1. The annual mean of CO concentrations in 2015 was 2700 μ/m_3, and ranged from 200 to 6800 μ/m_3. In 2016, the concentration ranged from 100 to 11609 μ/m_3, with an annual mean of 6200 μ/m_3, and ranged from 100 to 1300 μ/m_3, with an annual mean of 3190 μ/m_3 in 2017. According to Table 2, the concentration of CO exceeds the local threshold limit (10000 μ/m_3/ 8 hours) during the months (August, September and October, late summer/ early autumn) in 2016 and 2017, and this might have cause hazardous effects on human health and the environment in the study area.

Fig. 1. Map of the study area showing sampling site at Damietta Port, Egypt

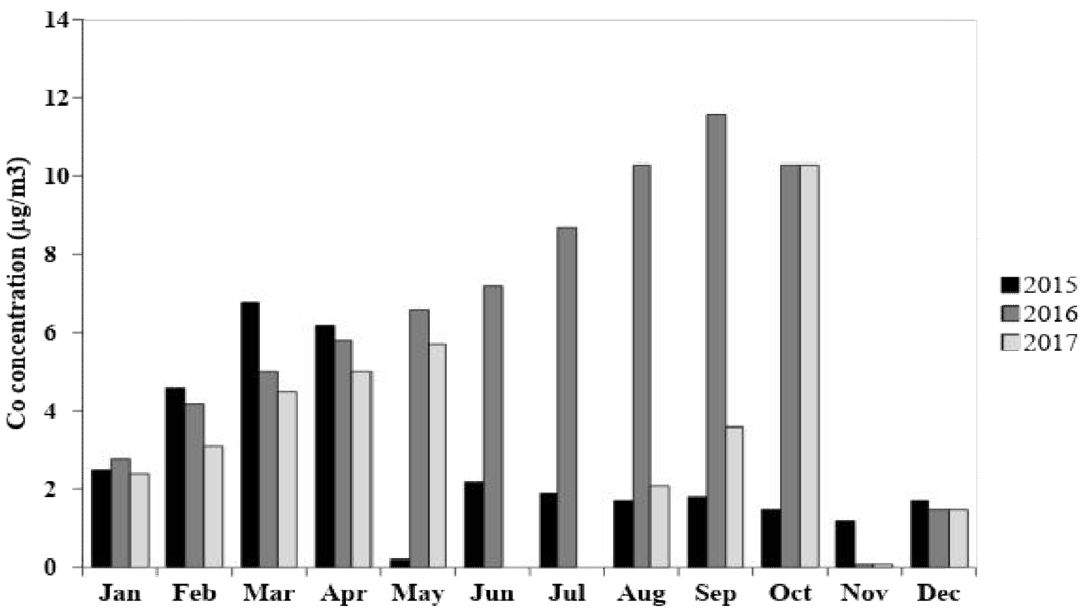

Fig. 2. Annual variation of CO concentrations in 2015, 2016 and 2017 at the DP site

Table 1. Summary statistics of the investigated air pollutants; CO, NO_2, SO_2, O_3 and PM_{10} concentrations in 2015, 2016 and 2017

Year	Air pollutants	Min.	Max.	Mean	Median	Standard deviation	Coeff.of variation	Stnd. skewness	Stnd. kurtosis
2015	CO	0.2	6.8	2.69	1.85	2.053	76.26%	1.707	0.274
	NO_2	1.8	66.8	27.93	18.8	23.920	85.66%	1.104	-0.609
	SO_2	6.2	72.4	17.52	13.15	17.513	99.98%	4.666	7.926
	O_3	11.2	35.8	27.73	31.8	8.131	29.32%	-1.410	-0.212
	PM_{10}	29.8	130.1	83.48	87.3	29.547	35.39%	-0.591	-0.184
2016	CO	0.1	11.6	6.18	6.2	3.651	59.13%	-0.180	-0.674
	NO_2	2.7	68.1	28.47	27.85	16.635	58.44%	1.444	1.707
	SO_2	13.52	69.75	22.33	17.515	15.332	68.67%	4.481	7.374
	O_3	7.2	69.6	25.11	21.56	18.175	72.37%	1.925	1.887
	PM_{10}	63.8	250.9	110.98	105.55	49.255	44.38%	3.219	4.605
2017	CO	0.1	10.3	3.19	2.75	2.963	92.84%	1.672	1.361
	NO_2	2.1	74.8	16.53	10.4	22.647	137.05%	2.648	2.448
	SO_2	9.14	18.23	11.87	10.9	4.959	41.79%	-1.370	1.499
	O_3	7.2	38.35	16.50	13.285	11.980	72.61%	1.193	-0.189
	PM_{10}	11.6	126.9	74.38	83.6	47.586	63.97%	-0.882	-0.699

Table 2. The threshold limits of air pollutants according to local (Egyptian environmental law no. 4(1994) and International thresholds (US EPA, EU EPA, etc)

Pollutant	Local threshold limit	International limits US EPA	EU EPA
CO	10000 µg/m_3/ 8 hours	9000 µg/m_3/ 8 hours	10000 µg/m_3/ 8 hours
NO_2	150 µg/m_3/ 24 hours	100 µg/m_3/ 1 hour	200 µg/m_3/ 1 hour
SO_2	150 µg/m_3/ 24 hours	75 µg/m_3 / 24 hours	125 µg/m_3 / 24 hours
O_3	120 µg/m_3/ 8 hours	70 µg/m_3/ 8 hours	120 µg/m_3/ 8 hours
PM_{10}	150 µg/m_3/ 24 hours	150 µg/m_3/ 24 hours	50 µg/m_3/ 24 hours

3.2 Temporal Variations of NO_2 Concentration

NO_2 primarily gets in to the air from the burning of fuel, and from vehicle emissions, power plants, and off-road equipment. NO_2 exposures over short periods cause respiratory diseases, particularly asthma, coughing, wheezing, or difficulty breathing. Longer exposures to high concentrations of NO_2 may increase susceptibility to respiratory infections [19,20,21]. In this study, the annual variation of NO_2 concentration from 2015 to 2017 was illustrated in Fig. 3. The annual mean of NO_2 concentration in 2015 was 27.93 µg/m_3, and ranged from 1.8 to 66.8 µg /m_3. The annual mean in 2016 was 28.5 µg/m_3, which is slightly higher than in 2015, and ranged from 2.7 µg /m_3 to 68.1 µg /m_3. In 2017, the annual mean concentration of NO_2 was 16.5µg /m_3, and ranged from 2.1 to 74.8 µg /m_3, which is the maximum value over the three period (Table 1). NO_2 concentration did not exceed the local threshold limits (150 µg/m_3/ 24 hours, Table 2) or International thresholds that were shown in (Table 2), and have no any adverse effects on human health or the environment of the study area.

3.3 Temporal Variation of SO_2 Concentration

Sulfur dioxide (SO_2) is derived from natural sources, such as volcanoes, or anthropogenic contributions, which is a major air pollutant in many parts of the world [22]. Oxidation of SO_2, especially at the surface of particles in the presence of metallic catalysts, leads to the formation of sulfurous and sulfuric acids. Neutralization of SO_2, by ammonia, leads to the production of bi-sulfates and sulfates. Inhalation is the only route of exposure to SO_2 that is of interest with regard to its effects on health [23]. Short-term exposures to SO_2 have been connected to increased emergency department visits and hospital admissions for respiratory illnesses, particularly for at-risk populations including children, older adults, and those with asthma [24]. According to Table 1 and Figure 4 in this study, the mean values of SO_2 concentration were 17.52, 22.3, and 11.9 µg/m_3 in 2015, 2016, and 2017 respectively. While the annual concentration of SO_2 ranged from 6.2 to 72.4 µg/m_3, (the highest values) in 2015 from 13.52 to 69.8 µg/m_3 in 2016, and from 9.14 to 18.2 µg/m_3 in 2017. Based on the above results,

SO_2 concentration values did not exceed the local threshold limit (150 µg/m_3/ 24 hours, Table 2). Therefore, SO_2 had no adverse effect on human health or the environment in the study area.

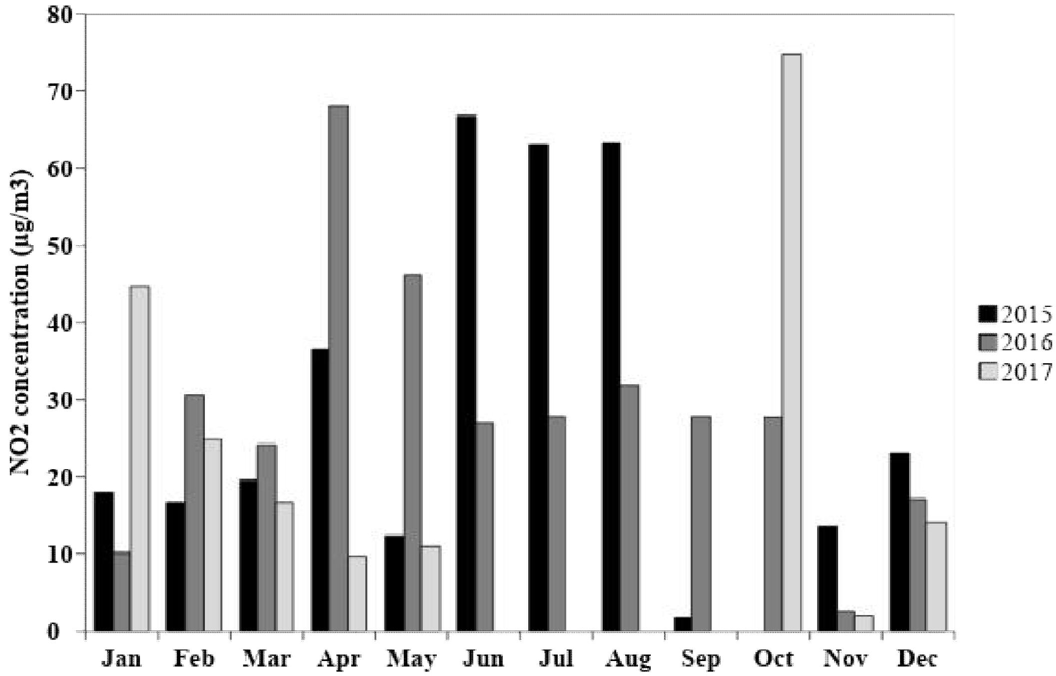

Fig. 3. Annual variation of NO_2 concentrations in 2015, 2016 and 2017 at the DP site

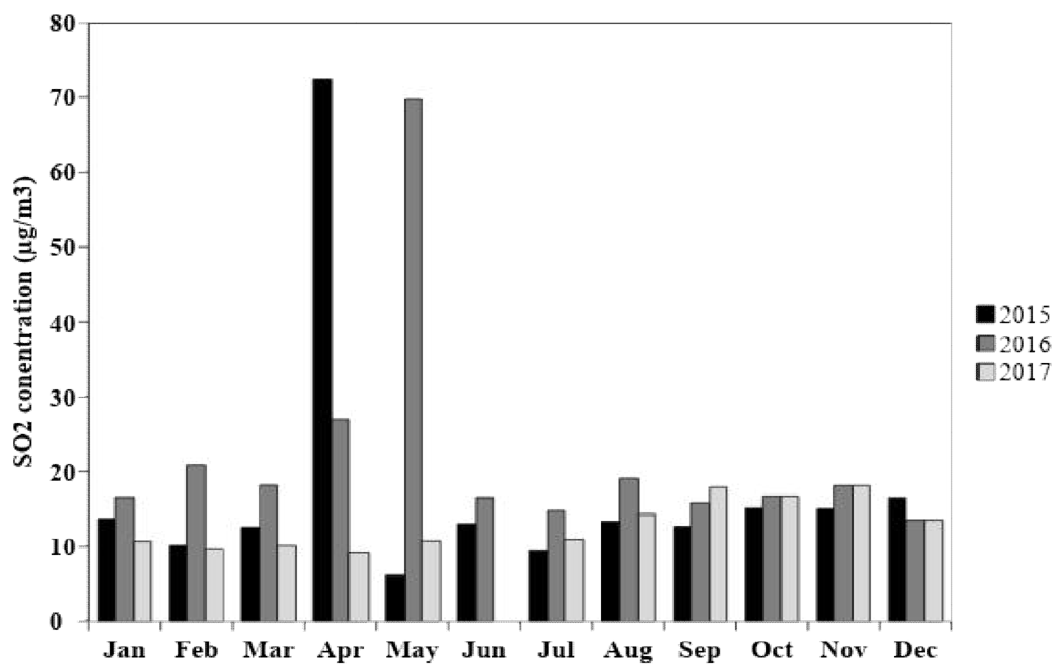

Fig. 4. Annual variation of SO_2 concentrations in 2015, 2016 and 2017 at the DP site

3.4 Temporal Variation of O_3 Concentration

Ozone is formed by photochemical reactions in the presence of precursor pollutants such as NO_x and volatile organic compounds, where its concentrations are often high in busy urban centers and lower in suburban and adjacent rural areas [25,26]. O_3 is also subject to long-range atmospheric transport, and is therefore considered as a trans-boundary problem. Based on its photochemical origin, O_3 displays strong seasonal and diurnal patterns, with higher concentrations in summer, and in the afternoon [27,28]. The correlation of O_3 with other pollutants varies by season, and location Epidemiological studies also addressed the effects of short and long-term exposures to O_3, and provided important results [23]. However, the health effects of O_3 have been less studied than those of PM, and thus more research is needed, especially addressing the spatial and seasonal patterns, and misclassification, of individual exposure in association with health outcomes [23,29]. Annual variations of O_3 concentration from 2015 to 2017 were illustrated in Fig. 5. In 2015, the mean value of O_3 concentration was 27.7 μg/m_3, and ranged from 11.2 to 35.8 μg/m_3. In 2016, the mean value was 25.1 μg/m_3 and ranged from 7.2 to 69.6 μg/m_3. While in 2017, the mean value was 16.5 μg/m_3, and ranged from 7.2 to 38.4 μg/m_3. O_3 values are under the local threshold limit (120 μg/m_3/8 hours, Table 2), and with no adverse effects on human health or the environment in the study area.

3.5 Temporal Variations of Particulate Matter PM_{10} Concentration

Air borne Particulate Matter (PM_{10}) has a diameter of equal to or less than 10 microns. Exposure to PM_{10} in particular, poses a definite risk to human health, because it is more likely to be inhaled, and the fine fraction of PM_{10} (i.e., $PM_{2.5}$) is respirable, and may reach the alveolar region of the lung [30,31]. PM, almost regardless of source, has detrimental health effects [23]. Particles can either be directly emitted into the air (primary PM) or be formed in the atmosphere from gaseous precursors such as SO_2, NO_x, ammonia, and non-methane volatile organic compounds (secondary particles). Anthropogenic sources of primary PM include combustion engines (both diesel and gasoline), solid-fuel (coal, lignite, heavy oil, and biomass) and other industrial activities and materials such as building, mining, cement, ceramic, bricks, and smelting [32,33]. Secondary particles are mostly found in fine PM, while soil and dust re-suspension is a contributing source of PM in arid areas, or during episodes of long-range transport of dust [23,34]. The annual variations of PM_{10} concentrations are shown in Fig. 6. The mean value of PM10 concentration in 2015 was 83.48 μg/m_3, and ranged from 29.8 to 130.1 μg/m_3. In 2016, the mean value of PM_{10} was 110.98 μg/m_3, and ranged from 63.8 to 250.9 μg/m_3 which is the highest value of PM_{10} in the found study. While in 2017, the mean value of PM_{10} was 74.4μg/m_3, and the concentration ranged from 11.6 to 126.9 μg/m_3. PM_{10} values exceeded the local threshold limit (150 μg/m_3/ 24 hours, Table 2). The maximum value of PM_{10} concentration was in January, 2016, and it is related to the weather condition, that had a serious effect on the air pollutant concentrations. In general, the concentrations of PM_{10} during winter are higher than summer, resulting in a higher risk to health during winter. This can cause adverse effects on the human health in the study area.

Pearson's correlation has been applied to air pollutant data in the present study, and the results are illustrated in Table 3. There is a high significant correlation between the studied air pollutants such as CO and PM_{10} (0.931), NO_2, and O_3 (0.964), NO_2 and SO_2 (0.907), and, PM_{10} and SO_2 (0.947). Also, there is a medium significant between some other parameters as NO_2 and PM_{10} (0.724), O_3 and PM_{10} (0.515), and O_3 and SO_2 (0.763). There is no significance between CO, NO_2 (0.422) and CO, and O_3 (0.167).

Table 3. Pearson's Correlation analysis among air pollutants

	CO	NO_2	O_3	PM_{10}	SO_2
CO	1				
NO_2	0.422	1			
O_3	0.167	0.964**	1		
PM_{10}	0.931**	0.724*	0.515*	1	
SO_2	0.765*	0.907**	0.763*	0.947**	1

**. Correlation is medium significant, **. Correlation is high significant*

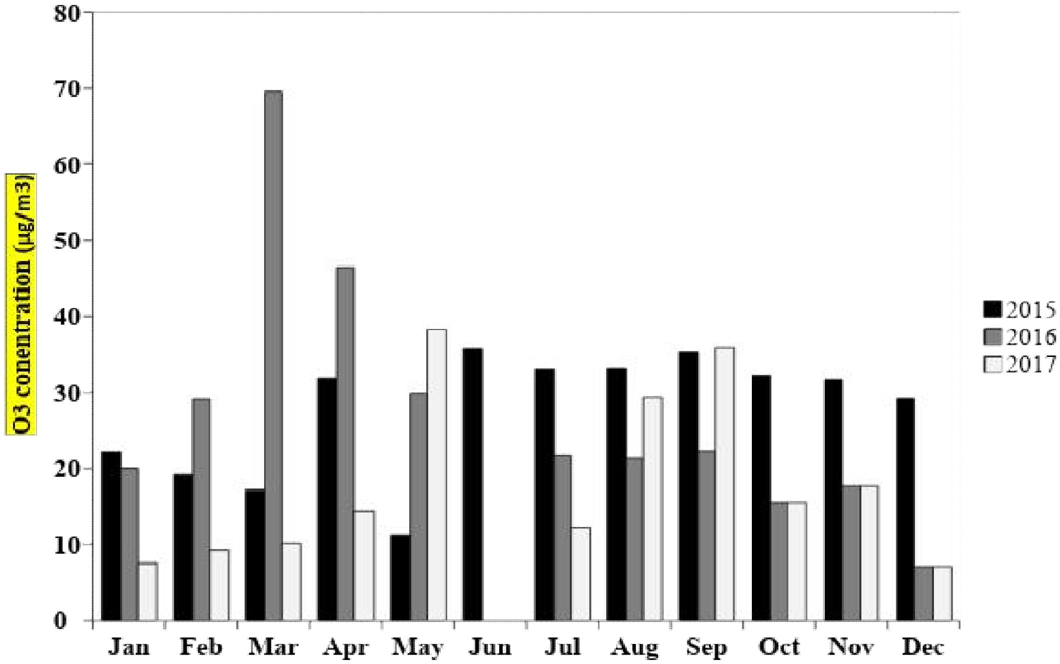

Fig. 5. Annual variation of O_3 concentrations in 2015, 2016 and 2017 at the DP site

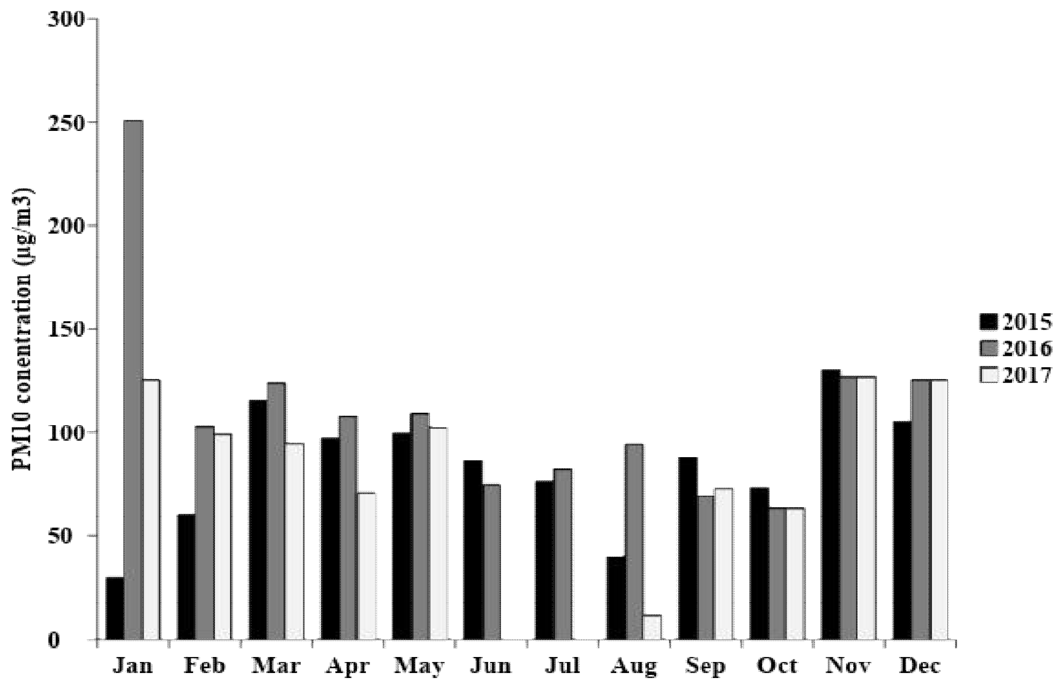

Fig. 6. Annual variations of PM_{10} concentration in 2015, 2016 and 2017 at the DP site

4. CONCLUSION

Damietta Port is considered one of the marine ports in Egypt that is exposed to various kind of hazards, and this is related to different daily activities including diesel trucks, servicing cargo, handling equipment, and fueling of ships. CO concentrations increased from 2015 to 2017, due to increased fossil fuel burning related to the high activity of the port. On the other hand, ozone decreased from 2015 to 2017, and this may be related to improvement of applied safety and environmental rules and systems in the port. From the collected results, some pollutants concentrations exceeded the threshold limit, e.g., CO and PM_{10}, according to the environmental law no. 4/1994. Finally, we recommended monitoring and measurement of the concentration of different air pollutants in the port regularly to assess, analyze, and control environmental risk to achieve occupational health criteria, and safety, for the port workers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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