

Temporal variations of Urban air pollutants in Damietta Port, North Egypt

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, NO₂, O₃, SO₂ and PM₁₀) in Damietta Port (DP), Egypt using the archive data from 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/m³ in 2015, 2016 and 2017 respectively. Mean concentration of NO₂ was 27.9, 28.5, and 16.5 µg/m³ in 2015, 2016 and 2017. Ozone mean concentration was 27.7, 25.1, and 16.5 µg/m³ in 2015, 2016 and 2017. PM₁₀ mean concentration was 83.5, 111, and 74.4 µg/m³ in 2015, 2016 and 2017. Mean concentration of SO₂ was 17.5, 22.3, and 11.9 µg/m³ in 2015, 2016 and 2017. ~~As a result~~ CO concentration increased from 2015 to 2017, due to increasing port activities, ^{is from} vessels, cargo handling equipment, and heavy-duty vehicles. On the other hand, ozone ~~was~~ decreased from 2015 to 2017, and this may be related to ^{the} improvement ~~of~~ ^{and application of} safety and environmental rules, and systems in the port. From the collected results, it was observed that some pollutant concentration ^{was} exceeded ^{the} threshold limit ^{for} CO and PM₁₀ according to ^{the} Environmental Law no. 4/1994. Finally, ^{we} ~~is~~ recommended to monitor and measure the concentration of different air pollutants in the port regularly, to assess, analyze, and control the environmental risk to achieve health ^{in the} surrounding environment for the port man-power.

Keywords: Air, contamination, human health, Ozone, PM₁₀

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, autoexhaust, 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 effect 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 ~~the~~ 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 PM₁₀ [9] [10]. It ~~is well-known~~ ^{is well-known} that ~~both~~ both respiratory and cardiovascular diseases are the major causes of death. Many studies have also shown positive associations between daily PM₁₀ concentrations and daily hospital admissions for respiratory diseases (e.g, asthma, pneumonia, chronic obstructive

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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 affects human health, but also ecosystem health, crops, climate, visibility and man-made materials [15]. The morbidity and premature mortality due to air pollution entail 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~~ ^{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, NO₂, SO₂, O₃ and PM₁₀) in New Damietta Port (Fig. 1) from 2015 to 2017.

2. Materials and Methods

2.1 Study area

Damietta Port 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 m² (Fig. 1). The land area ~~is approximately~~ ^{covers approximately} 7.9 million m², and water area is ~~about~~ ^a 3.9 million m². Percentage of water to land area is 1:2. The channel is ~~about~~ ^{approximately} 11.3 km long, 300 m wide, and 15 m in depth. The ~~Nile~~ ^{Nile} River connects to the port via barge channel 4.5 km long and 5 m deep. Width of the barge channel is 90 m. The DP connects to the main transportation network through railways and high way roads between Damietta and Mansoura.

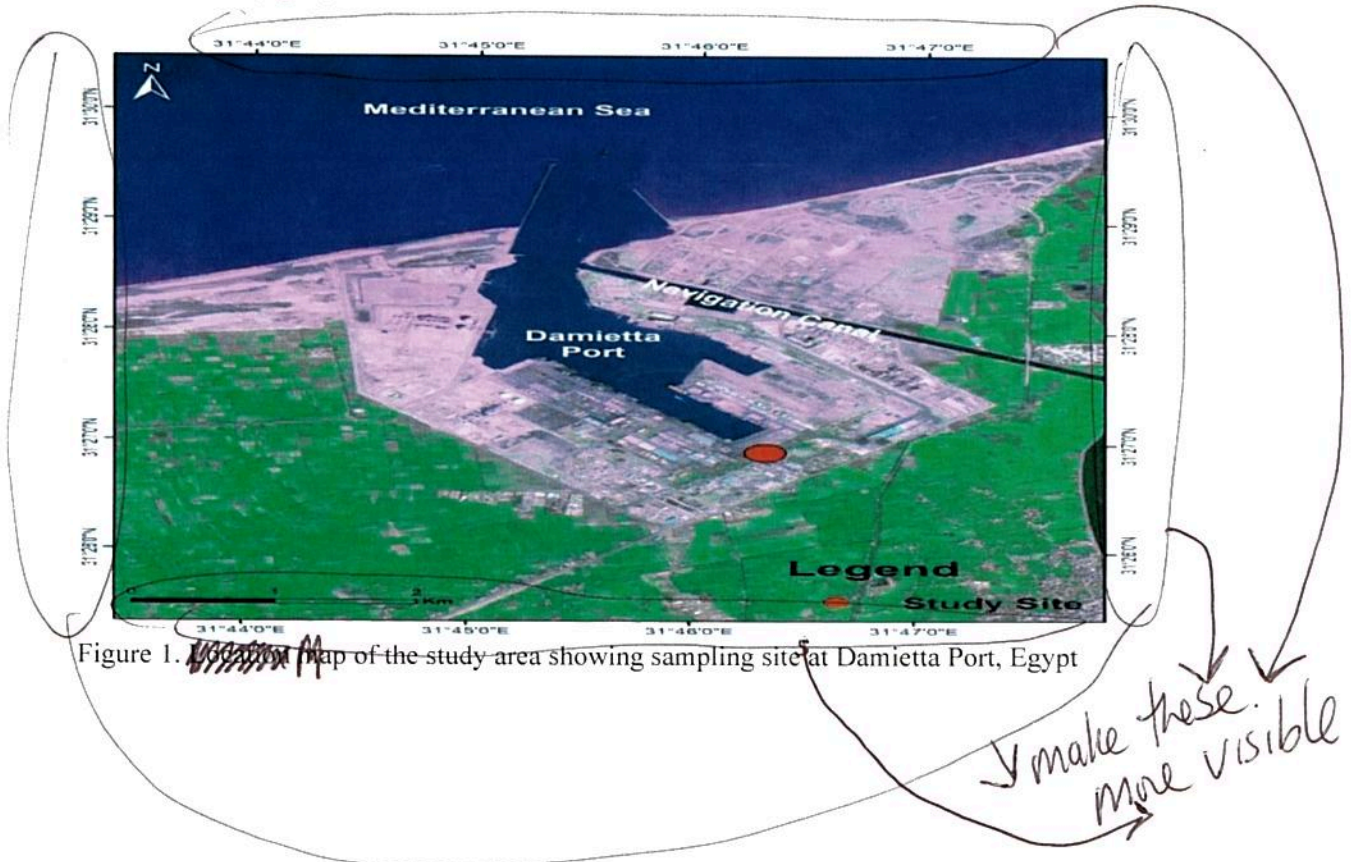


Figure 1. Map of the study area showing sampling site at Damietta Port, Egypt

2.2 Sampling and analytical methods

The investigated air pollutants (particulates and gases) were collected by the Egyptian Environmental Affairs Agency (EEAA) branch in Damietta Port Authority 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 CO₂, TEI Model 49i for O₃, and Thermo ESM Andersen, FH 62 I-R for PM₁₀.

3. Results and discussion

3.1 Temporal Variations of CO concentration

Carbon monoxide (CO) is often associated with combustion of fuels, and 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 2.7 mg/m³, and ranged from 0.2 to 6.8 mg/m³. In 2016, the concentration ranged from 0.1 to 11.6 mg/m³, with annual mean 6.2 mg/m³, and ranged from 0.1 to 10.3 mg/m³, with annual mean 3.19 mg/m³ in 2017. According to Table 2, the concentration of CO exceeds the local threshold limit (10 mg/m³ / 8 hours) during the summer months (August, September and October) in 2016 and 2017, and this might have caused hazard effects on human health and the environment in the study area.

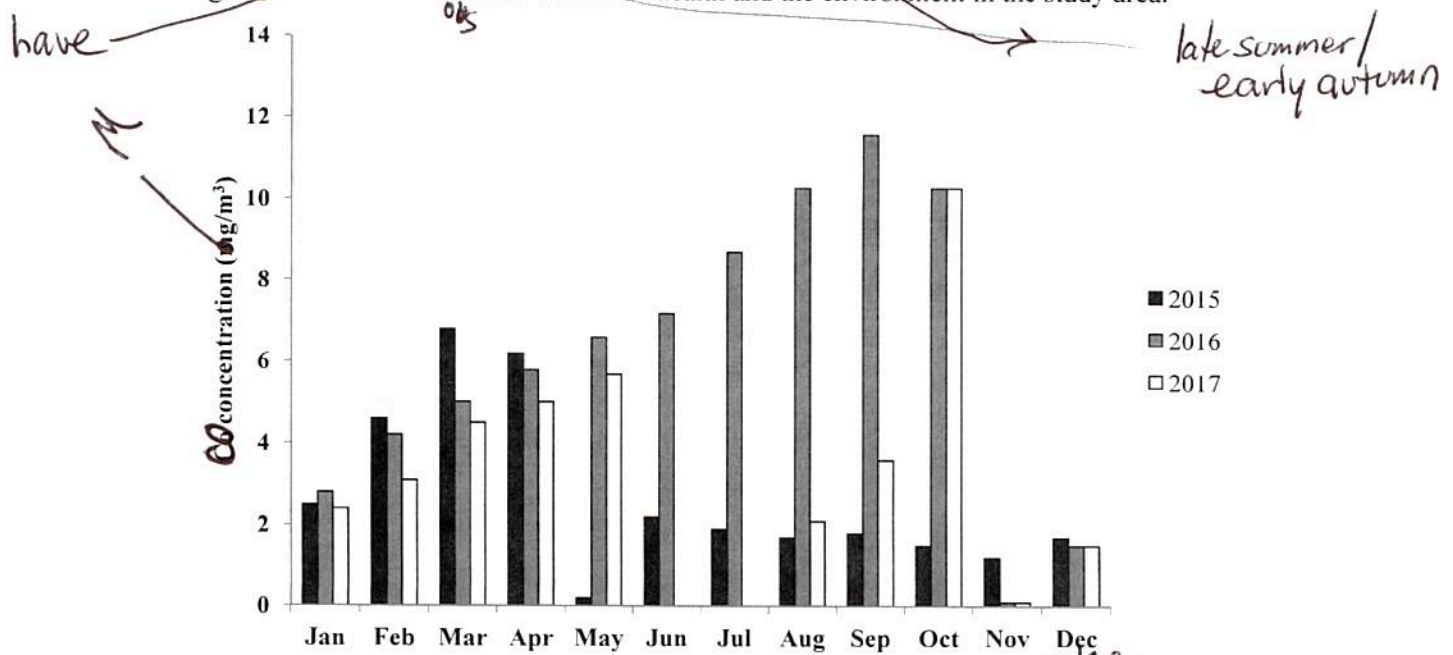


Figure 2. Annual variation of CO concentrations in 2015, 2016 and 2017 at DP site.

Table 1. Summary statistics of the investigated air pollutants; CO, ~~NO₂~~, ~~SO₂~~, ~~O₃~~ and PM₁₀ concentrations in 2015, 2016 and 2017.

Year	Air pollutants	Min.	Max.	Mean	Median	standard deviation	Coeff. of variation	Std. skewness	Std. 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	10 mg/m ³ / 8 hours	9 mg/m ³ / 8 hours	10 mg/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 NO₂ concentration

NO₂ primarily gets in the air from the burning of fuel ~~and from vehicle emissions~~ and from vehicle emissions, power plants, and off-road equipment. NO₂ exposures over short periods cause respiratory diseases, particularly asthma, coughing, wheezing, or difficulty breathing ~~and~~. Longer exposures to high concentrations of NO₂ may increase susceptibility to respiratory infections [20] [21]. In this study, the annual variation of NO₂ concentration from 2015 to 2017 was illustrated in Fig. 3. The annual mean of NO₂ concentration in 2015 ^{was} 27.93 µg/m³, and ranged from 1.8 to 66.8 µg/m³. The annual mean in 2016 ^{was} 28.5 µg/m³, which is slightly higher than in 2015, and ranged from 2.7 µg/m³ to 68.1 µg/m³. In 2017, the annual mean concentration of NO₂ ^{was} 16.5 µg/m³, and ranged from 2.1 to 74.8 µg/m³, which is the maximum value ^{over} the three years (Table 1). ~~NO₂ concentrations~~ NO₂ concentrations ~~do not~~ exceed ^{did} the local threshold limits (150 µg/m³ / 24 hours, Table 2) or international thresholds

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that ~~was~~^{were} shown in (Table 2) and have no any adverse effects on ~~the~~ human health or the environment of the study area.

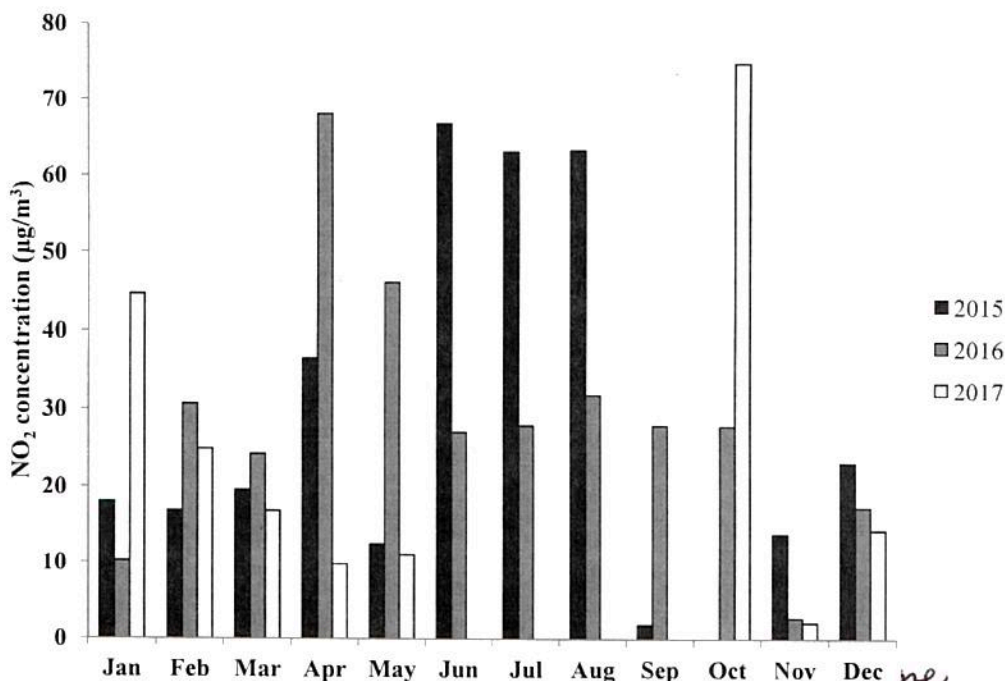


Figure 3. Annual variation of NO₂ concentrations in 2015, 2016 and 2017 at DP site.

3.3 Temporal variation of SO₂ concentration

Sulfur dioxide (SO₂) is derived from natural sources, such as volcanoes, or anthropogenic contributions, which ~~are the greatest concentrations~~^{is} a major air pollutant in many parts of the world [22]. Oxidation of SO₂, especially at the surface of particles in the presence of metallic catalysts, leads to the formation of sulfurous and sulfuric acids. Neutralization of SO₂, by ammonia, leads to the production of bi-sulfates and sulfates. Inhalation is the only route of exposure to SO₂ that is of interest with regard to its effects on health [23]. Short-term exposures to SO₂ 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 SO₂ concentration ~~are~~^{were} 17.52, 22.3, and 11.9 µg/m³ in 2015, 2016, and 2017 respectively. While the annual concentration of SO₂ ranged from 6.2 to 72.4 µg/m³, ~~at 72.4 µg/m³ (the highest value)~~^{at 72.4 µg/m³ (the highest value)} in 2015, from 13.52 to 69.8 µg/m³ in 2016, and from 9.14 to 18.2 µg/m³ in 2017. Based on the above results, ~~the measured SO₂ concentration values do not exceed~~^{did} the local threshold limit (150 µg/m³/ 24 hours, Table 2). Therefore, SO₂ had no adverse effect on human health or the environment in the study area.

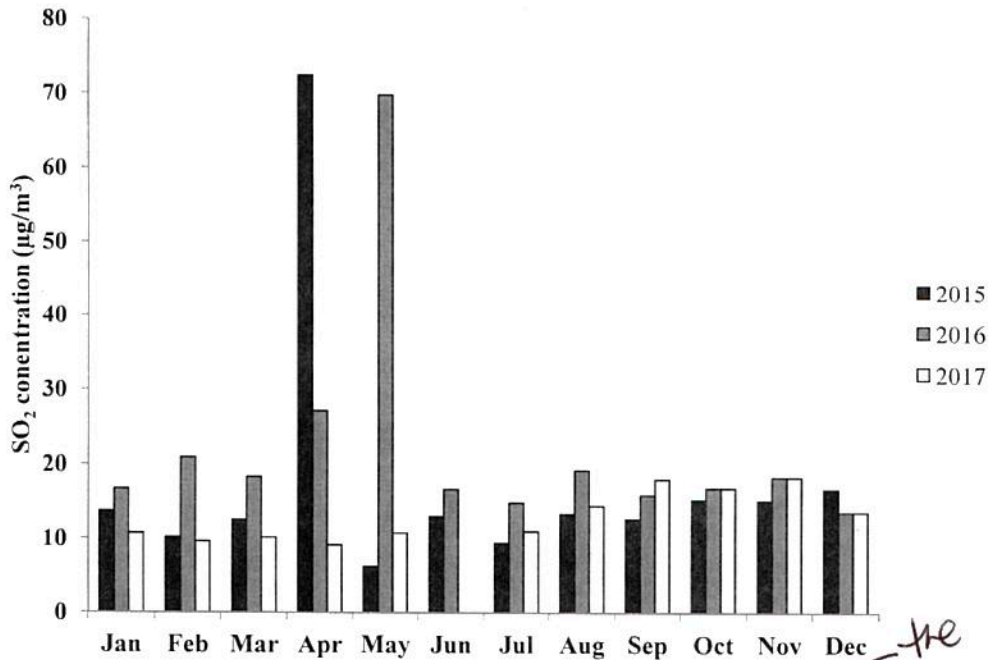


Figure 4. Annual variation of SO₂ concentrations in 2015, 2016 and 2017 at DP site.

3.4 Temporal variation of O₃ 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 ~~low~~ ^{higher} in busy urban centers and ~~higher~~ ^{lower} in suburban and adjacent rural areas [25] [26]. O₃ is also subject to long-range atmospheric transport, and is therefore considered as a trans-boundary problem. Based on its photochemical origin, O₃ displays strong seasonal and diurnal patterns, with higher concentrations in summer, and in the afternoon [27] [28]. The correlation of O₃ with other pollutants varies by season, and location ~~too~~. Epidemiological studies also addressed the effects of short and long-term exposures to O₃, and provided important results. However, the health effects of O₃ 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 O₃ concentration from 2015 to 2017 were illustrated in Fig. 5. In 2015, the mean value of O₃ concentration ^{was} 27.7 µg/m³, and ranged from 11.2 to 35.8 µg/m³. In 2016, the mean value ^{was} 25.1 µg/m³, and ranged from 7.2 to 69.6 µg/m³. While in 2017, the ~~mean~~ ^{was} value ^{is} 16.5 µg/m³, and ranged from 7.2 to 38.4 µg/m³. ~~Overall~~ O₃ values are under the local threshold limit (120 µg/m³/8 hours, Table 2), and with no adverse effects on human health or the environment in the study area.

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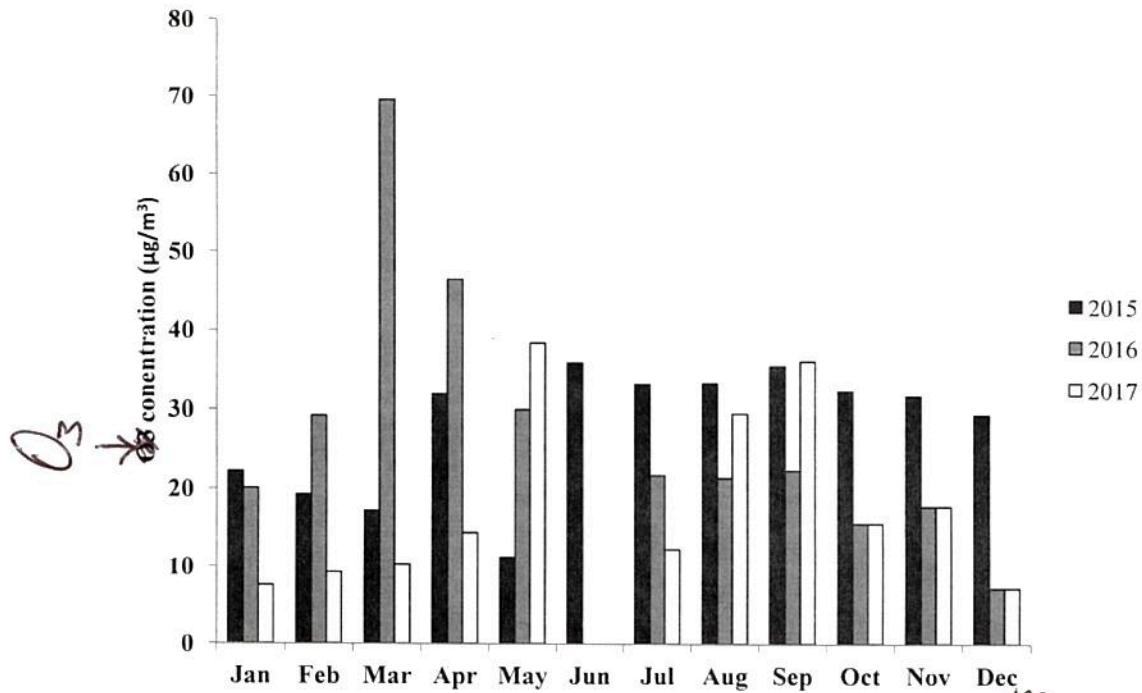


Figure 5. Annual variation of O₃ concentrations in 2015, 2016 and 2017 at DP site.

3.5 Temporal variations of Particulate Matter PM₁₀ concentration

Airborne Particulate Matter (PM₁₀) has a diameter of equal to or less than 10 microns. Exposure to PM₁₀ in particular, poses a definite risk to human health, because it is more likely to be inhaled, and the fine fraction of PM₁₀ (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 SO₂, 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 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 PM₁₀ concentration are shown in Fig. 6. The mean value of PM₁₀ concentration in 2015 was 83.48 µg/m³, and ranged from 29.8 to 130.1 µg/m³. In 2016, the mean value of PM₁₀ was 110.98 µg/m³, and ranged from 63.8 to 250.9 µg/m³, which is the highest value of PM₁₀ in the ~~present~~ study. While in 2017, the mean value of PM₁₀ was 74.4 µg/m³, and the concentration ranged from 11.6 to 126.9 µg/m³. ~~None of the~~ PM₁₀ values ~~exceeded~~ the local threshold limit (150 µg/m³/ 24 hours, Table 2). The maximum value of PM₁₀ concentration was in January, 2016, and it is related to the ~~weather~~ weather condition, ~~which~~ serious effect on the air pollutant concentration. In general, the

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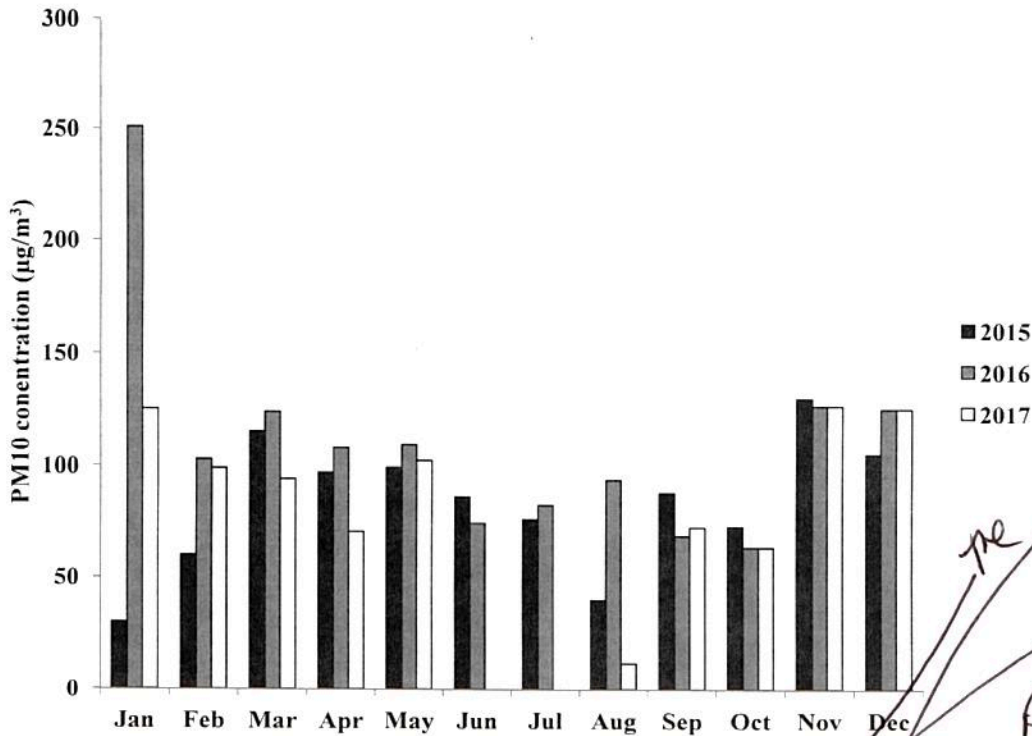


Figure 6. Annual variations of PM₁₀ concentration in 2015, 2016 and 2017 at DP site.

~~Correlation~~ Pearson's correlation has been applied to the ~~correlation~~ air pollutants 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 ~~PM10~~ (0.931)*, ~~NO2~~ and ~~CO~~ (0.964)*, ~~SO2~~ and ~~CO~~ (0.907)*, and ~~PM10~~ and ~~SO2~~ (0.947). Also, there is a medium significant between some other parameters as ~~NO2~~ and ~~PM10~~ (0.724)*, ~~O3~~ and ~~PM10~~ (0.515)*, and ~~CO~~ and ~~SO2~~ (0.763). There is no significant between CO and ~~NO2~~ (0.422), and CO and ~~O3~~ (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

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4. Conclusion

Damietta Port is considered one of the marine ports in ~~Egypt~~ that exposed to ~~various~~ kind of hazards, and this related to ~~different~~ daily activities ~~of~~ diesel trucks, servicing cargo, handling equipment, and fueling of ships. ~~CO concentrations increased~~ CO concentrations increased from 2015 to 2017, due to increased ^{eg} fossil burning ~~and~~ related to the high activity of the port. On the other hand, ozone ~~was~~ 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 concentration~~ some pollutants concentration ~~was~~ exceeded ~~the~~ the threshold limit, ^{eg} CO and PM₁₀ according to the environmental law no. 4/1994. Finally, ~~we~~ ^{we} recommend ~~to~~ monitor and measure the concentration of different air pollutants in the port regularly to assess, analyze, and control ~~the~~ environmental risk to achieve occupational health criteria and safety for the port ~~manpower~~.
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