# 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, $NO_2$, $O_3$, $SO_2$ and $PM_{10}$) 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/$m^3$ in 2015, 2016 and 2017 respectively. Mean concentration of $NO_2$ was 27.9, 28.5, and 16.5 µg/$m^3$ in 2015, 2016 and 2017. Ozone mean concentraion was 27.7, 25.1, and 16.5 µg/$m^3$ in 2015, 2016 and 2017. $PM_{10}$ mean concentration was 83.5, 111, and 74.4 µg/$m^3$ in 2015, 2016 and 2017. Mean concentration of $SO_2$ was 17.5, 22.3, and 11.9 µg/$m^3$ in 2015, 2016 and 2017. It was showed that CO concentration increased from 2015 to 2017 due to increasing port activiteis as 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 improvement of applied safety and environmental rules and systems in the port. From collected results, it was observed that some pollutants concentraion was exceeded than the threshold limit as CO and $PM_{10}$ accoriding to the environemntal law no. 4/1994. Finally, it was recommended to monitor and measue the concentration of different air pollutants in the port regularly to assess, analysis and control the environmental risk to achieve health surronding environemnt for the port man-power.

*Keywords: Air, contamination, human health, Ozone, $PM_{10}$*

## 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 area 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 has been found that 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

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 for determining the concentration of pollution in the lower atmosphere **[14]**. Poor air qaulity 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 to that 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

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 $m^2$ (Fig. 1). Land area represents about 7.9 million $m^2$ and water area is about 3.9 million $m^2$. Percentage of water to land area is 1: 2. The channel is about 11.3 km long, 300 m wide and 15 m in depth. The river Nile 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. Location 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) are 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 $CO_2$, 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 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 were varied from 2015 to 2017 as illustrated in Fig. 2 and Table 1. The annual mean of CO concentrations in 2015 is 2.7 $mg/m^3$, and ranged from 0.2 to 6.8 $mg/m^3$. In 2016, the concentration ranged from 0.1 to 11.6 $mg/m^3$ with annual mean 6.2 $mg/m^3$ and ranged from 0.1 to 10.3 $mg/m^3$ with annual mean 3.19 $mg/m^3$ in 2017. According to Table 2, the concentration of CO exceeds the local threshold limit (10 $mg/m^3$ / 8 hours) during the summer months (August, September and October) in 2016 and 2017 and this might be caused hazard effects on human health and the environment in the study area.

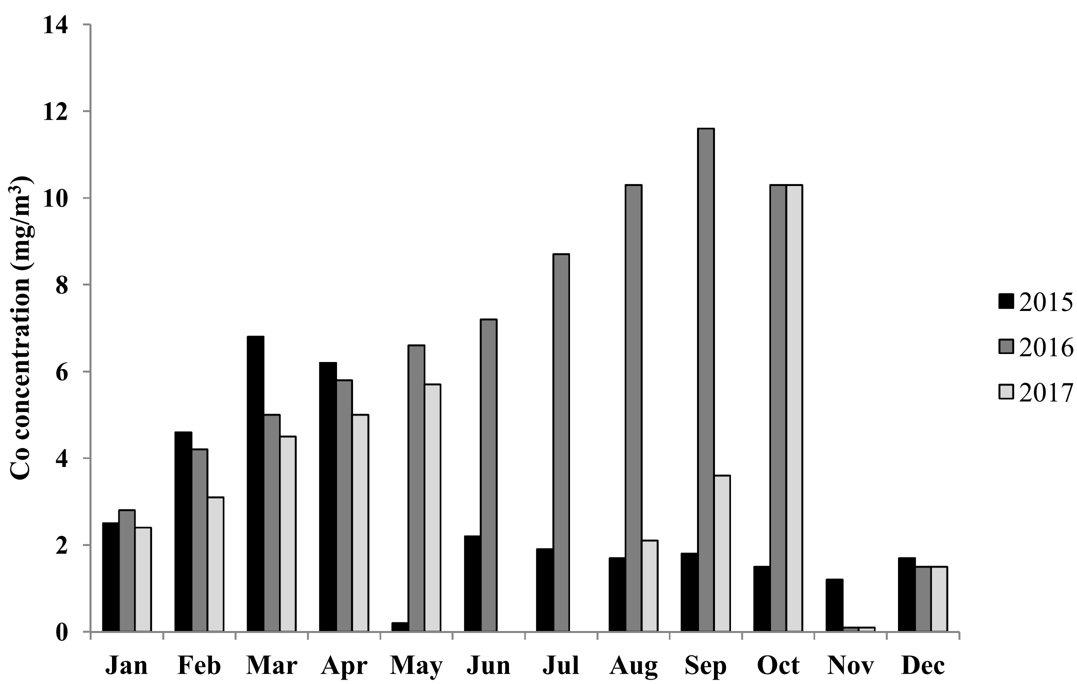


Figure 2. Annual variation of CO concentrations in 2015, 2016 and 2017 at DP site.

Table 1. Summary statistics of the investigated air pollutants; CO, NO2, SO2, O3 and $PM_{10}$ concentrations in 2015, 2016 and 2017.

| Year | Air pollutants | Min. | Max. | Mean | Median | . deviation | Coeff. variation | Stnd. skewness | Stnd. kurtosis |
|---|---|---|---|---|---|---|---|---|---|
| | **CO** | 0.2 | 6.8 | 2.69 | 1.85 | 2.053 | 76.26% | 1.707 | 0.274 |
| | **NO2** | 1.8 | 66.8 | 27.93 | 18.8 | 23.920 | 85.66% | 1.104 | -0.609 |
| **2015** | **SO2** | 6.2 | 72.4 | 17.52 | 13.15 | 17.513 | 99.98% | 4.666 | 7.926 |
| | **O3** | 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 |
| | **CO** | 0.1 | 11.6 | 6.18 | 6.2 | 3.651 | 59.13% | -0.180 | -0.674 |
| | **NO2** | 2.7 | 68.1 | 28.47 | 27.85 | 16.635 | 58.44% | 1.444 | 1.707 |
| **2016** | **SO2** | 13.52 | 69.75 | 22.33 | 17.515 | 15.332 | 68.67% | 4.481 | 7.374 |
| | **O3** | 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 |
| | **CO** | 0.1 | 10.3 | 3.19 | 2.75 | 2.963 | 92.84% | 1.672 | 1.361 |
| | **NO2** | 2.1 | 74.8 | 16.53 | 10.4 | 22.647 | 137.05% | 2.648 | 2.448 |
| **2017** | **SO2** | 9.14 | 18.23 | 11.87 | 10.9 | 4.959 | 41.79% | -1.370 | 1.499 |
| | **O3** | 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 |
| O3 | 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 the air from the burning of fuel combustion, and from vehicles emissions, power plants, and off-road equipment. $NO_2$ exposures over short periods cause respiratory diseases, particularly asthma, coughing, wheezing or difficulty breathing issues. Longer exposures to high concentrations of $NO_2$ may increase susceptibility to respiratory infections [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 is 27.93 µg/m$^3$, and ranged from 1.8 to 66.8 µg /m$^3$. The annual mean in 2016 is 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 $NO_2$ is 16.5µg /m$^3$ and ranged from 2.1 to 74.8 µg /m$^3$ which is the maximum value in the three years (Table 1). It is concluded that $NO_2$ concentrations were not exceeded the local threshold limits (150 µg/m$^3$/ 24 hours, Table 2) or International thresholds that was shown in ( Table 2) and have no any adverse effects on the human health or the environment of the study area.

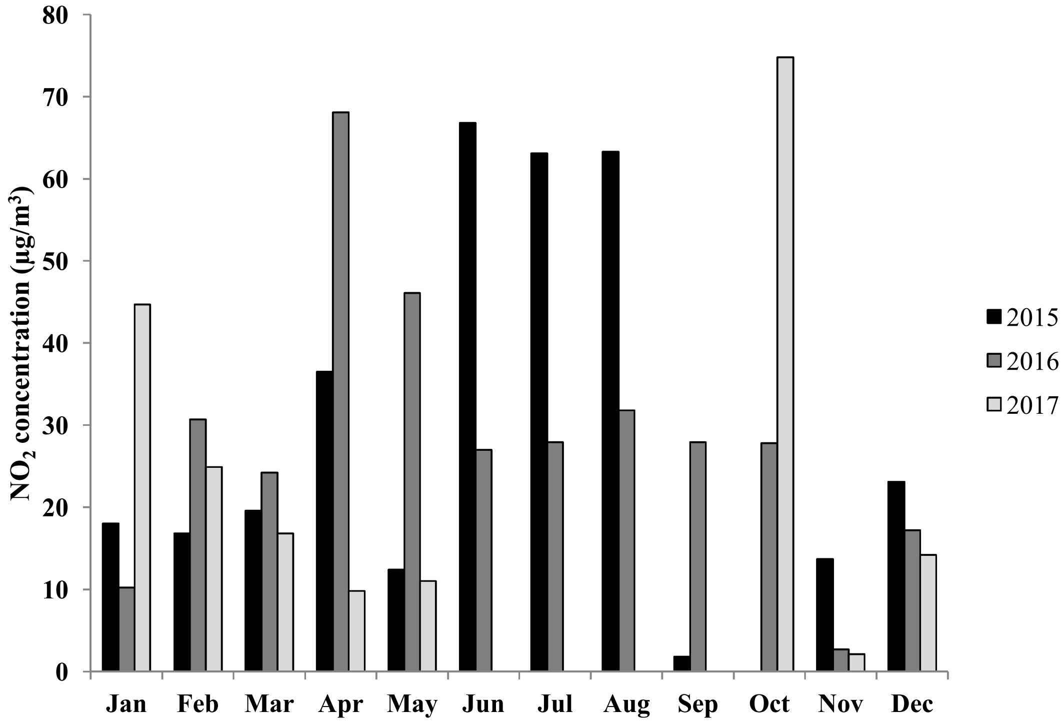


Figure 3. Annual variation of $NO_2$ concentrations in 2015, 2016 and 2017 at DP site.

### 3.3 Temporal variation of $SO_2$ concentration

Sulfur dioxide ($SO_2$) is derived from natural sources such as volcanoes or anthropogenic contributions which take the greatest concern and are 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 are 17.52, 22.3 and 11.9 µg/m$^3$ in 2015, 2016 and 2017 respectively. While the annual concentration of $SO_2$ ranges from 6.2 to 72.4 µg/m$^3$ which is the highest value 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, it is noticed that $SO_2$ concentration values are not exceeded the local threshold limit (150 µg/m$^3$/ 24 hours, Table 2). Therefore, $SO_2$ has no adverse effect on human health or the environment in the study area.

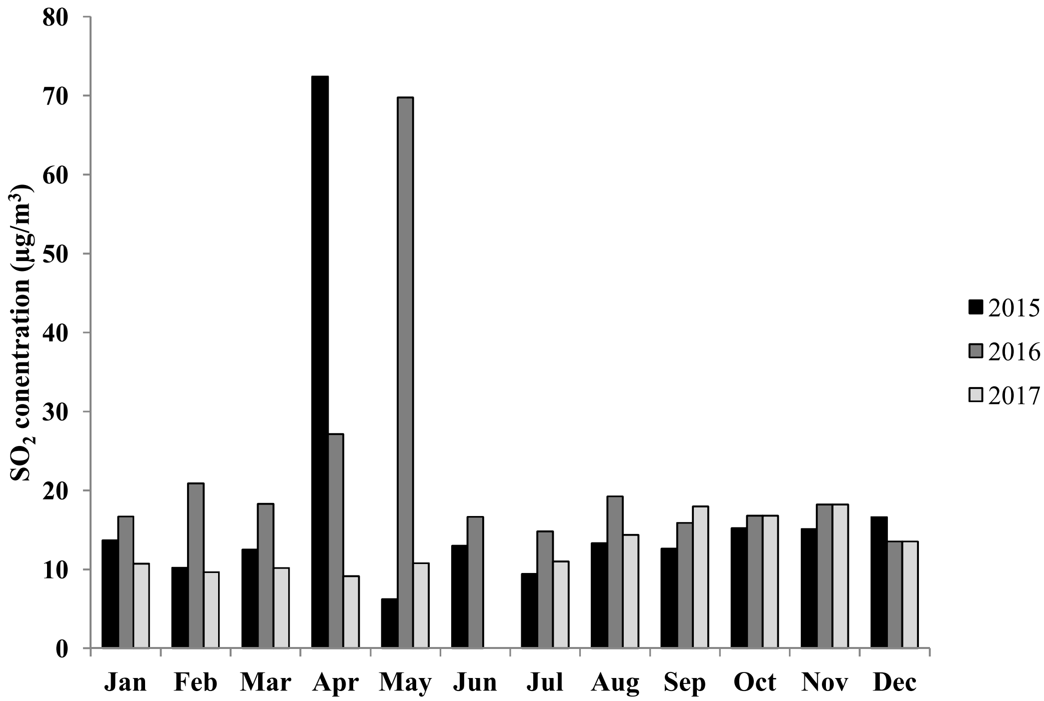


Figure 4. Annual variation of $SO_2$ concentrations in 2015, 2016 and 2017 at DP site.

### 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 low in busy urban centers and higher 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 have Epidemiological studies also addressed the effects of short and long-term exposures to $O_3$ and provided important results. 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 is 27.7 $\mu g/m^3$ and ranges from 11.2 to 35.8 $\mu g/m^3$. In 2016, the mean value is 25.1 $\mu g/m^3$ and ranges from 7.2 to 69.6 $\mu g/m^3$. While in 2017, the main value is 16.5 $\mu g/m^3$ and ranges from 7.2 to 38.4 $\mu g/m^3$. It is noticed that $O_3$ values are under the local threshold limit (120 $\mu g/m^3$/8 hours, Table 2) and with no adverse effect on human health or the environment in the study area.

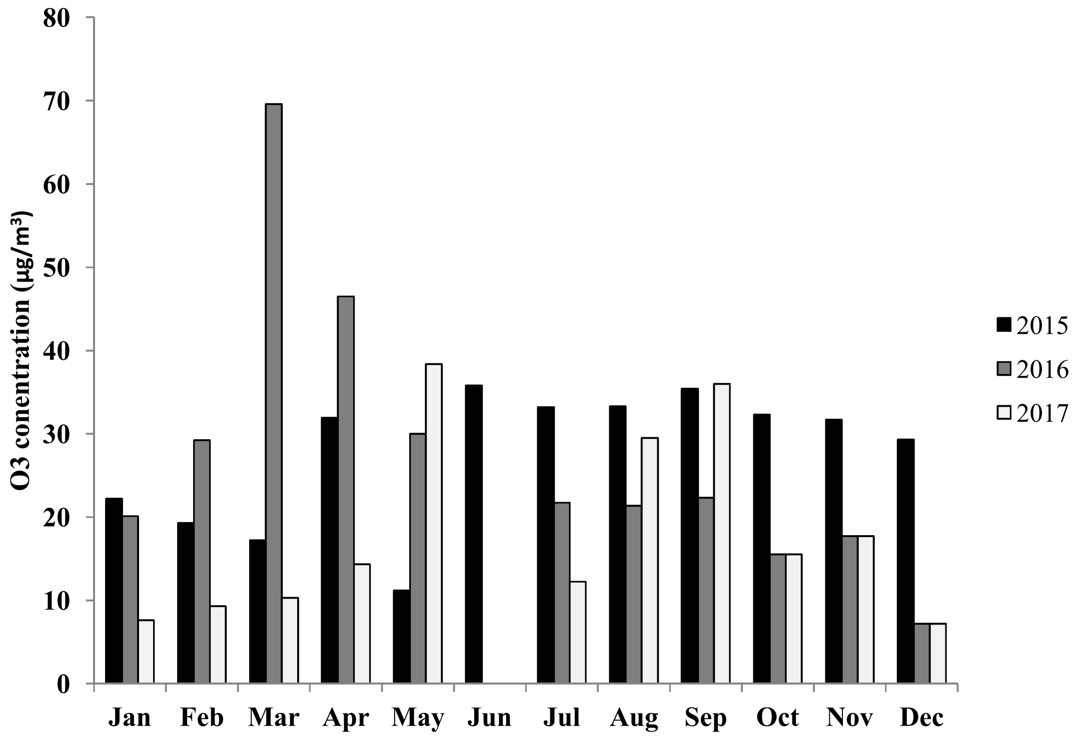


Figure 5. Annual variation of $O_3$ concentrations in 2015, 2016 and 2017 at DP site.

### 3.5 Temporal variations of Particulate Matter $PM_{10}$ concentration

Air 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 petrol), 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 $PM_{10}$ concentration are shown in Fig. 6. The mean value of $PM_{10}$ concentration in 2015 is 83.48 µg/m$^3$ and ranges from 29.8 to 130.1 µg/m$^3$. In 2016, the mean value of $PM_{10}$ is 110.98 µg/m$^3$ and ranges from 63.8 to 250.9 µg/m$^3$ which is the highest value of $PM_{10}$ in the present study. While in 2017, the mean value of $PM_{10}$ is 74.4µg/m$^3$and the concentration ranges from 11.6 to 126.9 µg/m$^3$. It is noticed that $PM_{10}$ values are exceeded than 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 heavy weather condition with serious effect on the air pollutants concentration. In general, the concentrations of $PM_{10}$ during winter are higher than summer, resulting in a higher risk to health during winter and this can causes adverse effect on the human health in the study area.

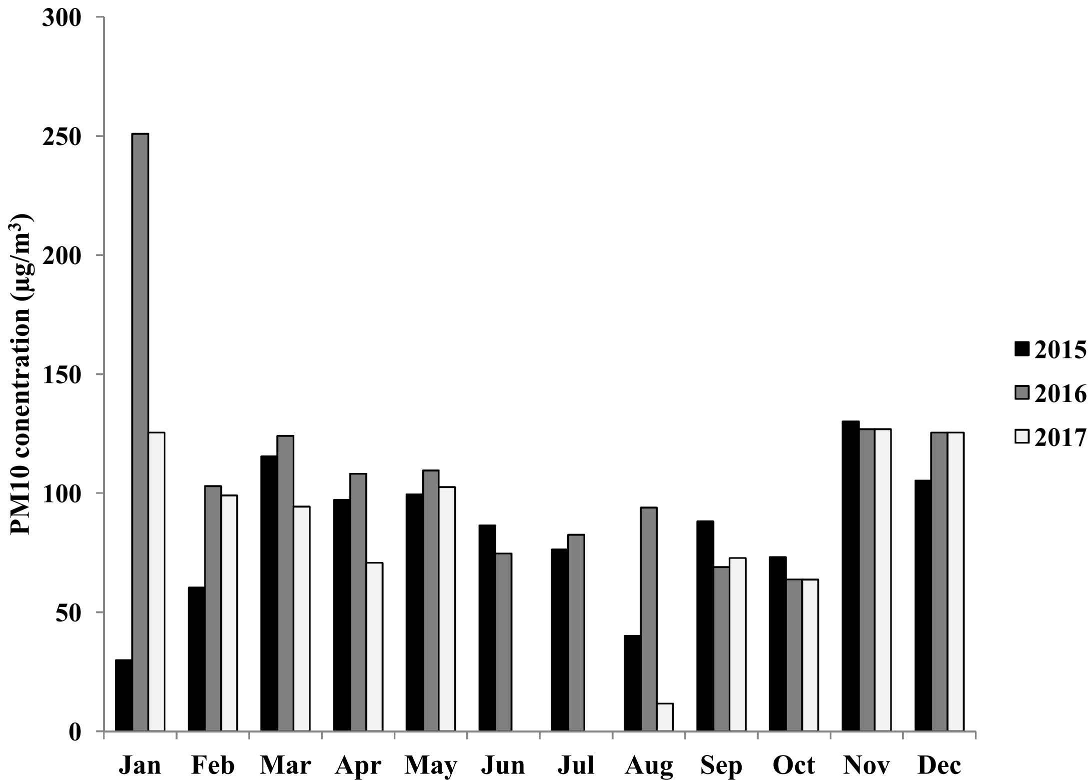


Figure 6. Annual variations of $PM_{10}$ concentration in 2015, 2016 and 2017 at DP site.

Statistical Pearson's correlation has been applied to the investigated data of 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 O3 (0.964), NO2 and SO2 (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 O3 and SO2 (0.763). There is no significant between CO, NO2 (0.422) and CO, 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 | | | |
| O3 | 0.167 | 0.964** | 1 | | |
| PM10 | 0.931** | 0.724* | 0.515* | 1 | |
| $SO_2$ | 0.765* | 0.907** | 0.763* | 0.947** | 1 |

## 4. Conclusion

Damietta Port is considered one of the marine ports in Egypet that exposed to varied kind of hazards and this related to differnet daily activities as diesel trucks, servicing cargo, handling equipments, and fueling of ships. It was showed that CO concentrations increased from 2015 to 2017 due to increasing of fossils burining that 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 collected results, it was observed that some pollutants concentraion was exceeded than the threshold limit as CO and $PM_{10}$ according to the environemntal law no. 4/1994. Finally, it was recommended to monitor and measure the concentration of different air pollutants in the port regularly to assess, analysis and control the environmental risk to achieve occupational health criterias and safety for the port man-power.

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