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Original Article

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Abstract

The objective of this study is to assess the influence of particulates generated by traffic on air quality of the urban area in Damietta City, Egypt. In this study, particulate concentrations had demonstrated in the atmosphere of seven locations in the city, through year 2018 and comparing with the data of year 2009. The chemical characteristics of particulate components (SO_4^{2-}, NH_4^+, NO_3^-, NO_2^- and Cl^-) had also investigated for the sampling locations. It indicated that about 100 % of the measured samples exceeded Egyptian ambient air quality standard (90 µg/m^3/year). The air quality index (AQI) of traffic and residential areas in Damietta City with respect to suspended particulate matter (SPM) shows a significant improvement of air quality during the period of 2018, compared with the concentrations during the period of 2009, which indicated extreme air pollution at that period. Whereas the main compounds in SPM in the city follow the order: $(NH_4)_2SO_4$> NH_4NO_3. These results clarify that the reaction between NO_x, SO_2 and ammonia gases might be emitted from auto-exhaust.

1. Introduction

Air pollution emitted from transportation contributes immediate and long-term effects on the environment, which has negative impacts on human health, acid rain, and harming the environment. Pollutants that contribute to poor air quality include nitrogen oxides (NO_x), volatile organic compounds (VOCs) and particulate matter (PM) **(EPA, 2017)**. The atmospheric particulates have suggested being responsible for climatic effect due to their capability to modify the solar or terrestrial infrared radiation **(Frey *et al.*, 2017 and Al-Thani *et al.*, 2018),** and other environmental effects such as visibility reduction, acidic precipitation and the transport of pollutants from industrial regions to remote and pristine areas **(Marshall *et al.*, 2005)**. The atmospheric deposition of the trace elements from urban areas effects on water bodies **(Wright *et al.*, 2018)**.

Airborne PM is composed of an extensive class of chemical and physical diverse substances, which is erratic in size, chemical composition, formation, origin, and concentration. Particulate species related to vehicle emissions derived from incomplete fuel combustion, lubricant volatilization, brake lining dust, tire debris, and road dust, which categorized according to its mode of formation; however, there are a number of other processes, involving mechanical abrasion and corrosion, which can result in PM directly released to the atmosphere. The most important processes include road surface wear, and brake wear. Other possible processes are clutch wear and corrosion of vehicle components. The direct emissions can also cause the deposition of particles on the road surface **(Xu *et al.*, 2014)**.The PM components of air pollution consist of carbonaceous particles, and may include a wide range of chemical species, ranging from metals to organic and inorganic compounds. Particulates contain a wide diversity of water-soluble and insoluble components. Soluble components of particulates include the common cations as NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, protons as well as Cl^-, SO_4^{2-} and NO_3^- **(Yadav and Satsangi, 2013)**. Common components of PM include

nitrates, sulfates, polycyclic aromatic hydrocarbons, endotoxin, and metals **(Hamanaka and Mutlu, 2018)**. Suspended particulate matter (SPM) are particulate having aerodynamic diameter less than 100 microns which tend to remain suspended in the atmosphere for a long period of time. SPM is one of the major air pollutants responsible for degradation of the ambient air quality and may have adverse effects on human health because they can penetrate deep into the respiratory system **(Lamare and Chaturvedi, 2014)**.

High concentrations of particulate air pollution have been associated with adverse health effects to the population exposed **(Chen *et al.*, 2010; Saud and Paudel, 2018)**. The chemical composition (e.g. acidity, sulfate, nitrate, etc.) of particles can induce health-related effects **(Monn, *et al.*, 1995).** The health risks of air pollution are extremely serious. Poor air quality increases respiratory ailments like bronchitis and asthma, heightens the risk of life-threatening conditions like cancer, and burdens our health care system with substantial medical costs. PM is singlehandedly responsible for up to 30,000 premature deaths yearly.

Motor vehicles now include petrol and diesel engine cars, motorcycles, light vans, passenger service vehicles (buses and coaches) and heavy goods vehicles (HGVs). Petrol is the major fuel type used for cars and light vans, with diesel and other fuel sources making up the remaining 1%, HGVs, light goods vehicles, motorcycles and passenger service vehicles **(Kawashima *et al.*, 2006)**.

Since, air pollution generated from a number of various sources, the concentrations of atmospheric pollutants will always be a sum of the interactions from its sources. It is therefore air pollution in Damietta city, which is categorized as urban site, comes from a great variety of the different activities of workshops (furniture and painting workshops), light industries; such as sweets, diary, shoes, and textile industries, as well as from fuel combustion in motor vehicles. Consequently, heavy commercial activities and motorized vehicles emissions are major contributors of air in many urban areas of the city because of no heavy industries in the city **(El Gammal *et al.*, 2005)**.

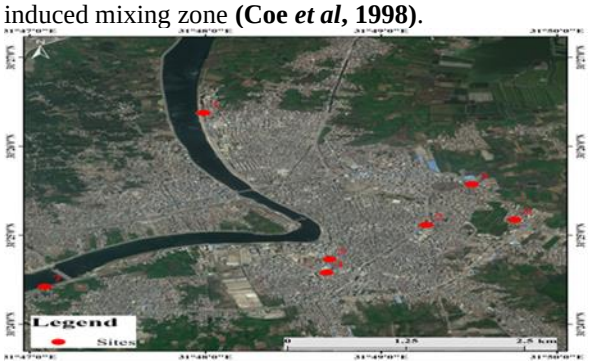
The monitoring of particulate concentrations and the related chemical components (SO_4^{2-}, NH_4^+, NO_3^-, NO_2^- and Cl^-) for the year 2018 were evaluated the atmospheric quality at different sites scattered in Damietta City. Thus, the comparing between SPM of the year 2018, with particulates results in 2009 at the same locations, were very important for estimation and following the status of air quality generated in traffic and residential areas in the city with respect to SPM.

Therefore, the aim of this study was to estimate the situation of particulates pollution in year 2018 by comparing it with SPM of 2009. Subsequently, it could be assessing the impact of atmospheric particulates generated by traffic on air quality of Damietta city.

2. Materials and Methods

The particular conditions of the city and especially the limited funding make the use of a traditional methodology to estimate and evaluate the road traffic emissions is difficult. Therefore, it noticed that the high demand for transport in the city, and all the advantages offered by motorcycles made them the main mode of transport in Damietta City.

In the present study by using Global Positioning System (GPS), PM had collected at the seven locations in Damietta city (Map 1) over a period of year during 2018 and then comparing with our previous study of year 2009 **(El-Henawy, 2011)**. The locations of samples had selected by their strategic positions with the traffic density and commercial activities. Samples were collected from: Al-Harby Street (location 1), Bab Al-Haraas (location 2), El-Matary Bridge (location 3), Abd Al-Raheem Nafea Street (location 4), Souror Square (location 5), Gheit El-Nasara (location 6), and Damietta Lock and Gates Bridge (location 7). Locations (6 and 7) had selected because they were outside the potential influence of high traffic; Gheit El-Nasara and Damietta Lock and Gates Bridge. Sampling Locations were located on both sides of a street at a distance of ≥3m from the traffic lanes, in order to be outside of the traffic induced mixing zone **(Coe *et al*, 1998)**.



Map (1): Samples Locations of the Investigated Sites at Damietta City, Damietta Governorate, Egypt.

Site Locations:
1- Al-Harby Street, 2- Bab Al-Haraas, 3- El-Matary Bridge, 4- Abd Al-Raheem Nafea Street, 5- Souror Square, 6- Gheit El-Nasara, and 7- Damietta Lock and Gates Bridge.

2.2. SPM: The concentration of SPM matter had calculated in microgram per cubic meter ($\mu g/m^3$) **(Katz, 1986)**. The air sampler of a flow meter (1 L/min) was placed at two heights; of 1.5m height above ground level (street level, A) to characterize pollution near the standing breathing zone and of 6 ±2 m height above ground level, rooftop (ambient air, B). Average sampling time was about 24-h periods at least once a week/sampling location. SPM sampler was employed using cellulose membrane fiber filters (Whatman: pore size: 0.45 µm; diameter: 47 mm) **(Harrison and Perry, 1986)**.

2.3. Total Water-Soluble Matter and SO_4^{2-}, NH_4^+, NO_3^-, NO_2^- and Cl^- in Water-Soluble Portion: Turbidimetric Method was applied for determination

of sulfate (SO_4^{2-}) at λ= 500 nm **(Lodge and Editor, 1998)**. Nitrates were measured by Colorimetric Method at λ= 540 nm. Nitrite (NO_2^-) was determined by the modification of Saltzman method and measured calorimetrically at λ = 540 nm. Ammonium salts (NH_4^+) was determined by catalyzed indophenol-blue method calorimetrically at λ = 630 nm **(Harrison and Perry, 1986)** and Chloride (Cl^-) was determined by Mohr's method **(American Public Health Association, *et al.*, 1992)**.

2.4. Calculation of Air Quality Index (AQI): according to **Air Quality Communication Workshop (2012)**, where AQI has calculated by the equation:

$$AQI = \frac{(AQI_{Hi}) - (AQI_{Lo})}{(Conc_{Hi}) - (Conc_{Lo})} \times ((\mathbf{Conc_i}) - (Conc_{Lo})) + (AQI_{Lo})$$

Where:

AQI = Air Quality Index	**AQI_{Lo}** = The AQI value corresponding to $Conc_i$
Conci = Input concentration for a given pollutant	**AQI_{Hi}** = The AQI value corresponding to $Conc_i$
$Conc_{Lo}$ = The concentration breakpoint (that is less than or equal to $Conc_i$)	**$Conc_{Hi}$** = The concentration breakpoint (that is greater than or equal to $Conc_i$)

Statistical Analysis: The statistical analysis had performed using Microsoft Excel 2010. This represents the descriptive statistics. Correlation coefficients as well as the derived equations from the relationships between the related parameters were also calculated.

3. Results and Discussion

3.1. Evaluation of Annual Concentration of SPM

From Table 2 and Figure 1, it is seen that the annual SPM concentration of sampling locations at heavily trafficked roads (Al-Harby street, site 1) in Damietta City atmosphere for the year 2018 was 104.96±23.83 µg/m^3 and for year 2009 was 1065.01±411.75 µg/m^3 at ground level (street level A). These concentrations were very higher than the maximum allowable concentration that given by the Egyptian Environmental Low No. 4, 1994, as amended by Law No. 9, 2009 (90 µg/m^3/year) **(EEAA, 2010)**. For the year 2018, roof level (B) was lower than that recorded at street level (A) with about 30.75%. The annual mean of enrichment factor of SPM was 70.39 %. Comparing with the year 2009**,** reduction ratio (44.56 %) of SPM, and the enrichment factor was 67.08 %.

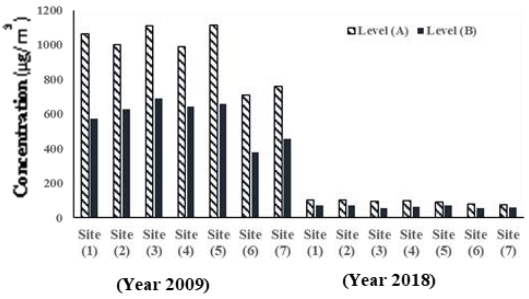


Figure (1): Annual Mean Conc. of SPM over the Sites under the Investigation at Damietta City During Years 2009 and 2018.

Whereas the annual SPM concentration of Bab Al-Haraas (Site 2) during the year 2018 was 101.87±33.02 µg/m^3 at level (A), with reduction ratio (29.82 %) of SPM that recorded at roof level (B), and the annual mean of enrichment was 62.10 %. Comparing with the year 2009, annual SPM concentration was 1000.20±279.92 µg/m^3 at level (A), with reduction ratio of SPM (36.03 %) for roof level (B) and the enrichment factor was 55.38 %.

For the Site 3 (El-Matary Bridge), the annual SPM concentration during the year 2018 was 95.08±43.64 µg/m^3 at level (A), with reduction ratio (39.89 %) that recorded at roof level (B), and with about annual mean of enrichment factor of SPM (56.18 %). Comparing with the year 2009, annual SPM concentration was 1108.96±361.59 µg/m^3 at level (A), with reduction ratio of SPM (36.34 %) for roof level (B) and the enrichment factor was 54.42 %.

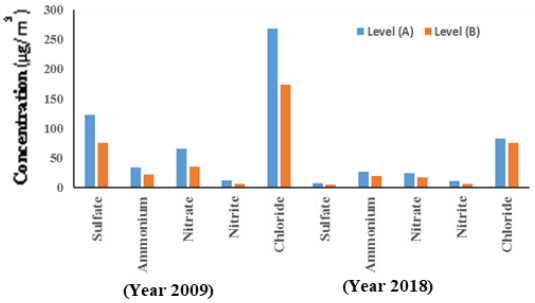


Figure (2): Annual Mean of the Percentage Concentrations of Sulfate, NH_4^+, Nitrate, Nitrite and Chloride in SPM During Years 2009 and 2018.

It is also evident that the annual SPM concentration at Abd Al-Raheem Nafea Street (Site 4) for year 2018 was 100.19±33.77 µg/m^3 at level (A), with reduction ratio (22.10 %) that recorded at roof level (B) and annual mean of enrichment factor of SPM was 62.48 %. Comparing with the year 2009, the annual SPM concentrations was 988.11±354.41 µg/m^3 at level (A), with reduction ratio of SPM (36.84 %) at roof level (B) and the enrichment factor was 56.47 %.

Table (1): EPA's Table of Air Quality Index (AQI) and Concentration Breakpoints by Pollutant (US EPA 2018).

PM10 (µg/m^3)	Air Quality Index (AQI) AQI Value	AQI	
$Conc_{Lo}$ - $Conc_{Hi}$ (avg)	AQI_{Lo} - AQI_{Hi}	Category	AQI Color
0-54 (24-hr)	0-50	Good	Green
55-154 (24-hr)	51-100	Moderate	Yellow
155-254 (24-hr)	101-150	Unhealthy for Sensitive Groups	Orange
255-354 (24-hr)	151-200	Unhealthy	Red
355-424 (24-hr)	201-300	Very Unhealthy	Purple
425-504 (24-hr)	301-400	Hazardous	Maroon
505-604 (24-hr)	401-500		

AQI values above 500 are considered Beyond the AQI. Follow recommendations for the Hazardous category.

For Souror Square (Site 5), the annual SPM concentration during the year 2018, was 91.58±20.34 µg/m^3 at level (A), with reduction ratio (26.90 %) at roof level (B). The annual mean of enrichment factor of SPM was 52.00 %. Comparing with the year 2009, the annual SPM concentration was 1114.54±235.12 µg/m^3 at level (A), with reduction ratio (42.15 %) of

SPM at roof level (B), and the enrichment factor was 58.29 %.

Table (2): Annual Mean Conc. ± S. D. (µg/m^3), Mean Reduction Ratio and Enrichment Factor (%) of SPM at the Investigated Sites at Damietta City, Egypt at levels (A) and (B) during Years 2009 and 2018.

Site	2009				2018			
	A	B	Reduction Ratio	Enrichment Factor	A	B	Reduction Ratio	Enrichme Factor
(1)	1065.01±411.75	573.19±192.88	44.56	67.08	104.96±23.83	72.69±11.91	38.15	70.39
(2)	1000.20±279.92	626.45±162.61	36.03	55.38	101.87±33.02	71.49±22.52	35.82	62.10
(3)	1108.96±361.59	691.30±204.36	36.34	54.42	95.08±43.64	58.10±11.08	33.89	56.18
(4)	988.11±354.41	641.68±265.04	36.84	56.47	100.19±33.77	62.60±6.29	30.52	62.48
(5)	1114.54±235.12	660.82±254.92	42.15	58.29	91.58±20.34	71.34±24.30	36.02	52.00
(6)	708.75±219.08	377.30±150.93	46.11	66.41	77.99±3.37	57.01±19.06	30.97	65.28
(7)	760.99±127.69	456.42±172.93	41.51	58.29	74.09±3.95	59.09±2.44	27.11	60.42
Mean ±S. D.	963.79±203.922	575.31±147.86	40.51	59.48	92.25±11.96	64.61±6.98	33.21	61.26
A.Q.S.	The Egyptian Environmental Low No. 4, 1994 =90 µg/m^3 /Year (EEAA, 2010).							

A = Street Level, B = Roof (Second Floor) "6 ± 2 m above Ground Level", A.Q.S. = Air Quality Standard (EEAA, 2010), and S. D.= Standard Deviation.

These results might be attributed to that these sites are heavily trafficked streets, which explain the high enrichment factor recorded. The obtained results of SPM in Damietta City, Egypt in the year 2009 were above or nearly similar with previous results by **El-Gammal (2001)** and **El-Gammal *et al.*, (2005)** demonstrated that SPM concentrations in years 2001 and 2005 ranged from 572 - 1016.5 µg/m^3 and 284.72 - 1708.68 µg/m^3, respectively. They added that the commercial and traffic are significant contributors to air pollution in Damietta City, beside the soil re-suspension and sea spray. Whereas these results were higher than that recorded in the year 2018.

Table (3): Air Quality Index (AQI) at the Investigated Sites at Damietta City, Egypt at levels (A) and (B) during Years 2009 and 2018.

Site		(1)		(2)		(3)		(4)		(5)		(6)		(7)		Mean for Level (A)	Mean for Level (B)
		A	B	A	B	A	B	A	B	A	B	A	B	A	B		
AQI	2009	961.01	469.19	896.2	522.45	1004.96	587.3	884.11	537.68	1010.54	556.83	604.75	241.22	656.99	352.43	859.79	471.31
Category	2009	hazardous	hazardous	hazardous	hazardous	hazardous	hazardous	hazardous	hazardous	hazardous	hazardous	hazardous	Very Unhealthy	hazardous	Very Unhealthy	hazardous	hazardous
AQI	2018	0.96	-31.31	-2.13	-32.51	-8.92	-45.9	-3.81	-41.4	-12.42	-32.66	-26.01	-46.99	-29.91	-44.91	-11.75	-39.39
Category	2018	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good

A = Street Level, B = Roof (Second Floor) "6 ± 2 m above Ground Level, and AQI = Air Quality Index Rating for PM

Guttikunda *et al.*, (2013) recorded that vehicular activity-based emissions (from direct vehicular exhaust and indirect fugitive dust) in Hyderabad, India were the main sources of increasing SPM pollution problems. Furthermore, **Giovanis (2018)** concluded that traffic congestion is one of the foremost problems confronted by the urban and suburban tenants of today, which increases vehicle emissions and degrades air quality. Urban planners and policy makers have consequently been always investigating choices to reduce traffic congestion and to enhance air quality.

However, the annual SPM concentration at Gheit El-Nasara (Site 6) for year 2018, was 77.99±3.37 µg/m^3 at ground level (street level A), with reduction ratio (20.25 %) of SPM at roof level (B). The annual mean of enrichment factor of SPM was 65.28 %. Comparing with the year 2009, annual SPM concentration was 708.75±219.08 µg/m^3 at ground level (street level A), with reduction ratio (46.11 %) of SPM at roof level (B), and the enrichment factor was 66.41 %. In addition, the annual SPM concentration at Damietta Lock and Gates Bridge (Site 7) with low population density for year 2018, was 74.09±3.95 µg/m^3 at ground level (street level A), with reduction ratio (29.96 %) at roof level (B). The annual mean of enrichment factor of SPM was 60.42 %. Comparing with the year 2009, the annual SPM concentration was 760.99±127.69 µg/m^3 at ground level (street level A), with reduction ratio (41.51 %) of SPM, and the enrichment factor was 58.29 % (Table 2).

According to the above-mentioned results, the following conclusions must be detailed; the obtained concentrations of SPM decrease from level (A) to level (B) in all studied sites and show a reduction of the ratio (%). For the year 2018, SPM among all studied samples, ranged from 72.15 to 100.48 µg/m^3 for street level (A) and ranged from 55.07 to 70.44 µg/m^3 for ambient air level (6 m above the ground level, B) (Figure (1). On the other hand, during the year 2009, SPM among all studied samples ranged from 400.37 to 1961.81µg/m^3 for street level (A) and ranged from 187.04 to 1058.52 µg/ m^3 for ambient air level (6 m above the ground level, B)

As expected, the greatest PM concentrations observed at roadside locations where the contribution from vehicles was high **(Rajé *et al.*, 2018)**. **Abdelbagi (2018)** indicated that traffic emission is the major source of atmospheric SPM, beside natural dust and sea spray. Whereas, no industrial emissions affect these sites, as there are no heavy industry or power generation plants in the city. These results agreed with some studies related to Auto-exhaust particulates measurement and estimations, which conducted by different researchers and recorded in Beijing, China **(Malaguti *et al.*, 2015; Shao *et al.*, 2019)**.

3.2. Estimation of AQI*:*

Air Quality Index has used to specify the extent of purity or pollution of the air and to identify the associated health effects of local air quality on human health. AQI focuses on health affects the human may experience within a few hours or days after breathing polluted air (US EPA 2018). Thus, AQI had estimated in this study to evaluate the air quality status of traffic areas and residential areas in Damietta City during the year 2018 and comparing it

with the results of 2009 in respect to SPM. EPA's table of AQI and concentration breakpoints by pollutant, divided into six categories (Table 1), according to **Air Quality Communication Workshop (2012)**.

Table (4): Annual Mean Conc. ± S. D. (μg/m^3), Mean Reduction Ratio and Enrichment Factor (%) of SO_4^{2-} in SPM at Damietta City, during Years 2009 and 2018.

Site	2009				2018			
	A	B	Reduction Ratio	Enrichment Factor	A	B	Reduction Ratio	Enrichment Factor
(1)	133.36±47.52	50.9±13.43	57.51	72.08	58.61±29.48	7.02±4.63	46.09	65.02
(2)	125.81±70.12	71.78±53.54	40.57	48.50	27.80±12.06	9.33±2.25	33.72	43.61
(3)	149.58±98.19	101.53±91.75	40.00	62.92	44.30±12.86	24.70±9.83	59.81	61.33
(4)	157.07±82.81	111.34±104.48	45.66	66.03	69.52±32.84	16.01±11.47	53.44	56.13
(5)	112.07±95.11	86.18±89.03	30.88	50.84	26.08±12.58	5.46±3.00	47.89	50.42
(6)	76.09±52.76	39.12±36.13	50.18	67.15	15.22±3.50	8.15±5.91	37.72	49.60
(7)	106.39±61.54	68.97±51.95	41.08	60.52	16.21±8.22	5.88±2.45	44.70	52.94
Mean ±S. D.	122.91±27.62	75.69±26.02	43.70	61.15	36.82±21.17	10.94±7.03	46.20	54.15
A.Q.S.	The USA Air Quality Standards = 4 μg/m^3 (Stern, 1986).							

Based on AQI values, air pollution level at each location can rated. AQI values among all studied samples during the year 2009, for street level (A) and for level (B) were in a hazardous level of air pollution, while its value for level (B) of sites (6 and 7) was categorized as very unhealthy air quality. Otherwise, SPM during the year 2018 showed improvement of the air quality status of traffic and residential areas in Damietta City (Table 3).

3.3. Evaluation of Water-Soluble SO_4^{2-}, NH_4^+, NO_3^-, NO_2^- and Cl^- Conc. in SPM

Results of SO_4^{2-} represent in Table 4. For year 2018, the annual mean of water-soluble sulfate (SO_4^{2-}) concentrations of SPM at sites 1, 2, 3, 4, 5, 6 and 7 in Damietta city atmosphere, were 58.61, 27.80, 44.30, 69.52, 26.08, 15.22, and 16.21 μg/m^3, respectively at ground level (street level A). Sulfate concentrations decrease from level (A) to level (B) in all sampling sites, with a reduction ratio (%) of 46.09, 33.72, 59.81, 53.44, 47.89, 37.72 and 44.70 %, respectively. In addition, enrichment factor (%) of SO_4^{2-} in SPM were 65.02, 43.61, 61.33, 56.13, 50.42, 49.60 and 52.94 %, respectively. Comparing with the year 2009, the annual SO_4^{2-} concentrations of SPM at sites 1, 2, 3, 4, 5, 6 and 7 for year 2018, were 133.36, 125.81, 149.58, 157.07, 112.07, 76.09 and 106.39 μg/m^3, respectively at level (A). SO_4^{2-} of SPM decrease from level (A) to level (B) in all sampling sites, with a reduction ratio (%) of 57.51, 40.57, 40.00, 45.66, 30.88, 50.18 and 41.08 %, respectively, and the enrichment factor (%) of SO_4^{2-} in SPM were 72.08, 48.50, 62.92, 66.03, 50.84, 67.15 and 60.52 %, respectively. Auto-exhaust is the main source of sulfate especially those resulting from diesel oil **(Resitoğlu *et al.*, 2015)**.

It is also seen that the annual mean of water-soluble ammonium (NH_4^+) concentrations of SPM at sites 1, 2, 3, 4, 5, 6 and 7 in Damietta city atmosphere for year 2018, were 37.22, 15.77, 33.40, 31.19, 23.06, 15.38 and 27.11 μg/m^3, respectively at level (A). Ammonium concentrations decrease at level (B), with a reduction ratio (%) of 38.22, 44.70, 38.26, 20.36, 49.61, 17.36, and 40.64 %, respectively. In addition, enrichment factor (%) of NH_4^+ in SPM were 69.57, 65.83, 52.34, 25.56, 62.45, 21.01, and 57.26 %, respectively. Comparing with the year 2009, the annual (NH_4^+) concentrations of SPM at sites 1, 2, 3, 4, 5, 6 and 7 for year 2018, were 42.22, 26.12, 39.42, 39.91, 35.26, 24.38 and 32.26 μg/m^3, respectively at level (A). Ammonium in SPM decrease at level (B), with a reduction ratio (%) of 37.23, 70.55, 27.75, 26.42, 39.93, 45.57 and 37.45 %, respectively, and the enrichment factor (%) of NH_4^+ were 61.15, 85.94, 48.09, 41.34, 57.79, 56.41 and 60.61 %, respectively. According to the above-mentioned results, which are presented in Table 5, the maximum annual enrichment factor of (NH_4^+) at Bab-Al-Haraas Road (site 2) recorded during the year 2018 and for the year 2009, which is also a heavily trafficked street, located at the eastern direction of the city and classified as one of the most favorite business zones. Both sides of the street are sandwiched by clothing stalls and different parking garages for buses and cars, so it is a congested street with heavy traffic density. These results confirm the role of human activities and vehicular traffic in contribution of soluble sulfate concentrations **(Ali-Mohamed and Ali, 2001)**.

Table (5): Annual Mean Conc. ± S. D. (μg/m^3), Mean Reduction Ratio and Enrichment Factor (%) of NH_4^+ in SPM at Damietta City, during Years 2009 and 2018.

Site	2009				2018			
	A	B	Reduction Ratio	Enrichment Factor	A	B	Reduction Ratio	Enrichment Factor
(1)	42.22±19.7	25.51±10.13	37.23	61.15	37.22±15.82	24.06±18.37	38.22	65.83
(2)	26.12±8.44	6.93±4.41	70.55	85.94	15.77±6.90	9.51±5.64	44.70	69.57
(3)	39.67±15.19	30.44±17.68	27.75	48.09	33.40±17.25	27.30±10.42	38.26	52.34
(4)	39.91±17.08	31.14±15.73	26.42	41.34	31.19±21.05	24.84±9.75	20.36	25.56
(5)	35.26±20.83	23.86±16.58	39.93	57.79	23.06±8.47	11.62±5.49	49.61	62.45
(6)	24.38±10.92	13.78±10.1	45.57	56.41	15.38±6.82	12.71±8.23	17.36	21.01
(7)	32.26±15.83	19.79±8.49	37.45	60.61	27.11±10.46	10.67±3.19	40.64	57.26
Mean ±S. D.	34.26±6.99	21.64±8.84	40.70	58.76	26.16±8.51	17.24±7.75	35.59	50.57
A.Q.S.	The Standard Limit Value of Ammonium = 50 μg/m^3. (Malaguti *et al.*, 2015).							

NO_3^- results are presented in Table 6. It is also evident that the annual mean of water-soluble nitrate (NO_3^-) concentrations of SPM at sites 1, 2, 3, 4, 5, 6 and 7 in Damietta city atmosphere for year 2018, were 63.50, 84.22, 66.81, 44.80, 37.62, 18.55 and 27.39 μg/m^3, respectively at level (A). Nitrate concentrations decrease at level (B), with a reduction ratio (%) of 45.80, 38.72, 43.06, 37.58, 38.23, 41.77 and 35.28 %, respectively. In addition, enrichment factor (%) of NO3- were and 77.45, 63.19, 75.61, 60.21, 61.89, 71.73 and 54.51 %, respectively. Comparing with the year 2009, the annual concentrations of (NO_3^-) of SPM at sites 1, 2, 3, 4, 5, 6 and 7, were 83.18, 115.83, 88.73, 63.06, 51.36, 22.06 and 31.96 μg/m^3, respectively at level (A). Nitrate decrease at level (B), with a reduction ratio of 53.03, 33.44, 50.33, 33.58, 62.52, 46.81 and 40.80%, respectively, and the enrichment factor (%) of NO_3^- were 82.12, 41.32, 64.62, 58.09, 62.52, 46.81 and 40.80%, respectively. Furthermore, **Kundu and**

Stone (2014) documented that higher NO_3^- concentrations in the urban atmospheres are associated with a higher amount of NO_x emissions from the combustion sources, particularly automobiles. This finding is in agreement with **Hand *et al.*, (2012)**, in addition to **Ali-Mohamed and Ali (2001)**.

Table (6): Annual Mean Conc. ± S. D. (µg/m^3), Mean Reduction Ratio and Enrichment Factor (%) of NO_3^- in SPM at Damietta City, during Years 2009 and 2018.

Site	2009				2018			
	A	B	Reduction Ratio	Enrichment Factor	A	B	Reduction Ratio	Enrichment Factor
(1)	83.18±51.28	37.90±24.00	53.03	82.12	63.50±13.05	42.22±22.53	45.80	77.45
(2)	115.83±54.78	70.93±40.22	33.44	41.32	84.22±17.90	57.49±11.27	38.72	63.19
(3)	88.73±77.22	51.09±51.76	50.33	64.62	66.81±18.31	39.50±14.52	43.06	75.61
(4)	63.06±65.54	35.63±31.42	33.58	58.09	44.80±9.14	30.46±15.03	37.58	60.21
(5)	51.36±35.87	21.88±20.32	62.52	62.52	37.62±8.81	22.33±12.24	38.23	61.89
(6)	22.06±9.96	10.74±3.84	46.81	46.81	18.55±5.06	9.27±22.98	41.77	71.73
(7)	31.96±16.56	18.69±9.00	40.80	40.80	27.39±7.15	16.57±12.23	35.28	54.51
Mean ±S. D.	65.17±33.17	35.27±20.76	45.79	56.61	48.98±23.48	31.12±16.61	40.06	66.37

Whereas the annual mean of water-soluble nitrite (NO_2^-) concentrations of SPM at sites 1, 2, 3, 4, 5, 6 and 7 in Damietta city atmosphere for year 2018, were 11.42, 9.33, 14.28, 11.56, 7.14, 5.91 and 7.43 µg/m^3, respectively at level (A). Nitrite concentrations decrease at level (B), with a reduction ratio (%) of 36.97, 42.02, 35.64, 39.10, 37.39, 44.67 and 43.20 %, respectively. In addition, enrichment factor (%) of NO_3^- were 69.25, 57.30, 55.92, 64.37, 62.61, 55.33 and 56.80 %, respectively. Comparing with the year 2009, the annual concentrations of (NO_2^-) of SPM at sites 1, 2, 3, 4, 5, 6 and 7, were 14.98, 12.00, 17.96, 15.58, 9.51, 6.39 and 9.09 µg/m^3, respectively at level (A). Nitrite decreased at level (B) with a reduction ratio of 59.96, 65.00, 43.77, 48.04, 54.98, 52.70 and 36.72 %, respectively, and the enrichment factor (%) of NO_2^- were 85.18, 78.13, 60.17, 69.62, 54.98, 52.70 and 36.72 %, respectively. This clearly indicates that traffic emission is the main source of atmospheric soluble nitrites.

Table (7): Annual Mean Conc. ± S. D. (µg/m^3), Mean Reduction Ratio and Enrichment Factor (%) of NO_2^- in SPM at Damietta City, during Years 2009 and 2018.

Site	2009				2018			
	A	B	Reduction Ratio	Enrichment Factor	A	B	Reduction Ratio	Enrichmer Factor
(1)	14.98±9.68	5.79±4.97	59.96	85.18	11.42±4.02	7.20±2.95	36.97	69.25
(2)	12.00±7.75	3.76±2.12	65.00	78.13	9.33±1.77	5.41±5.89	42.02	57.30
(3)	17.96±15.52	9.02±5.90	43.77	60.17	14.28±2.60	9.19±3.70	35.64	55.92
(4)	15.58±2.30	7.99±3.58	48.04	69.62	11.56±3.05	7.04±2.67	39.10	64.37
(5)	9.51±7.34	4.56±3.79	54.98	54.98	7.14±2.68	4.47±2.71	37.39	62.61
(6)	6.39±3.37	3.31±2.33	52.70	52.70	5.91±1.82	3.27±1.27	44.67	55.33
(7)	9.09±4.55	6.04±4.69	36.72	36.72	7.43±2.25	4.22±2.56	43.20	56.80
Mean ±S. D.	12.22±4.14	5.78±2.13	51.60	62.50	9.58±2.99	5.83±2.07	39.86	60.23

This is coinciding with **Hand *et al.*, (2012)**. On the other hand, the lowest mean concentration of water-soluble nitrites detected at very low population density sites. NO_2^- results are shown in Table 7.

Results of Cl^- are presented in Table 8. The annual mean of water-soluble chloride (Cl^-) concentrations of SPM at sites 1, 2, 3, 4, 5, 6 and 7 in Damietta city atmosphere for year 2018, were 175.22, 177.70, 180.63, 185.46, 172.00, 85.57 and 83.16 µg/m^3, respectively at level (A). Chloride concentrations decrease at level (B), with a reduction ratio (%) of 28.27, 50.15, 55.84, 48.71, 62.32, 30.76 and 30.57 %, respectively. In addition, enrichment factor (%) of Cl^- were 50.55, 72.43, 78.12, 70.99, 84.60, 53.04 and 52.85 %, respectively. Comparing with the year 2009, the annual concentrations of (Cl^-) of SPM at sites 1, 2, 3, 4, 5, 6 and 7, were 202.48, 318.19, 338.52, 390.51, 401.44, 103.96 and 118.99 µg/m^3, respectively at level (A). Chloride decreases at level (B), with a reduction ratio of 30.84, 37.47, 43.96, 50.76, 27.53, 43.71 and 34.35 %, respectively, and the enrichment factor (%) of (Cl^-) were 69.34, 48.19, 51.26, 59.22, 32.00, 56.19 and 55.17 %, respectively.

Table (8): Annual Mean Conc. ± S. D. (µg/m^3), Mean Reduction Ratio and Enrichment Factor (%) of Cl^- in SPM at Damietta City, during Years 2009 and 2018.

Site	2009				2018			
	A	B	Reduction Ratio	Enrichment Factor	A	B	Reduction Ratio	Enrichment Factor
(1)	202.48±137.72	152.84±119.07	30.84	69.34	175.22±37.74	120.44±31.08	55.27	87.55
(2)	318.19±187.47	202.49±147.50	37.47	48.19	177.70±32.88	129.78±41.31	50.15	72.43
(3)	338.52±105.62	203.96±120.04	43.96	51.26	180.63±42.03	119.78±30.21	55.84	78.12
(4)	390.51±152.15	206.84±120.27	50.76	59.22	185.46±21.83	153.18±58.87	48.71	70.99
(5)	401.44±157.82	313.93±177.35	27.53	32.00	172.00±25.32	134.78±36.24	62.32	84.60
(6)	103.96±34.97	60.05±26.49	43.71	56.19	85.57±19.36	56.78±19.40	30.76	53.04
(7)	118.99±58.96	78.75±37.38	34.35	55.17	83.16±14.85	60.75±11.34	30.57	52.85
an ±S. D.	267.73±124.97	174.12±86.48	38.37	53.05	151.39±45.99	110.78±37.26	47.66	71.37

This may be attributed to that Damietta City is a coastal area and influenced by the northern winds from Mediterranean Sea. This is consistent with **Ali-Mohamed and Ali (2001)** who reported that the main source of Cl^- had expected to be sea-salt particles or sea spray at the locations that surrounded by sea. On the other hand, the lowest annual mean concentration of water-soluble chloride has detected at low population density in street, site (6). Chloride at Souror Square (site 5) might originate from natural sources such as sea spray, besides those originated from human activities, and might be due to the high density of motor vehicles. These results are in agreement with **Chang *et al.*, (2016)**.

Obviously, it is clearly that the maximum annual mean of enrichment factor of water-soluble SO_4^{2-}, NO_3^-, NO_2^- and Cl^- at Al-Harby Street (site 1) were 65.02, 77.45, 69.25 and 87.55 %, respectively for the year 2018 and 72.08, 82.12, 85.18 and 69.34 %, respectively recorded during the year 2009. This might be attributed to that site (1) is a heavily trafficked street, which explain the high enrichment factor recorded. As expected, the greatest PM concentrations observed at roadside locations where the contribution from vehicles was high **(Rajé *et al.*, 2018)**. **Abdelbagi (2018)** indicated that traffic emission is the major source of atmospheric SPM,

beside natural dust and sea spray. Whereas, no industrial emissions affect these sites, as there are no heavy industry or power generation plants in the city.

The two main pathways formed the secondary particulate sulfates and nitrates; (1) Photochemical oxidation of SO_2 and NO_x precursors in the gas phase to highly soluble acids and followed by uptake into pre-existing aerosols or cloud droplets. (2) Oxidation in the aqueous phase, which followed by evaporation of cloud droplets **(Wang *et al.*, 2012)**.

Auto-exhaust also emits chloride particles into the urban atmosphere in the form of lead bromochloride and ammonium lead chloride. These particles can remain suspended for long time in the atmosphere before they settle down under gravity or transported by wind to the other locations **(Bondy *et al.*, 2017)**.

It is obvious that the concentration of soluble components follows the order: $Cl^- > SO_4^{2-} > NO_3^- > NH_4^+ > NO_2^-$ for the year 2009, while it follows the order $Cl^- > NH_4^+ > NO_3^- > NO_2^- > SO_4^{2-}$ for the year 2018, as shown in figure 2. **Wen and Fang (2007)** documented the mean percentage of ionic species concentrations of total suspended particulates were: SO_4^{2-} (34.22%) > NH_4^+ (15.16%) > NO_3^- (12.02%) > Cl^- (11.78%) and SO_4^{2-} (33.95%) > NO_3^- (14.67%) > NH_4^+ (11.90%) > Cl^- (10.34%), respectively, during 2004 - 2005 at Taichung Harbor (TH) and WuChi Traffic (WT) sampling sites near Taiwan Strait.

Table (9): Correlation Coefficients between Water-Soluble Matter at the Investigated Sites at Damietta City.

	Site (1)						Site (2)				
	SO_4^{-2}	NH_4^+	NO_3^-	NO_2^-	Cl^-		SO_4^{-2}	NH_4^+	NO_3^-	NO_2^-	Cl^-
SO_4^{-2}	-	0.30	0.95	0.68	0.87	SO_4^{-2}	-	-0.87	0.22	0.98	0.76
NH_4^+		-	0.02	-0.13	-0.20	NH_4^+		-	0.22	-0.81	-0.67
NO_3^-			-	0.67	0.97	NO_3^-			-	0.67	0.49
NO_2^-				-	0.74	NO_2^-				-	0.86
Cl^-					-	Cl^-					-
	Site (3)						Site (4)				
	SO_4^{-2}	NH_4^+	NO_3^-	NO_2^-	Cl^-		SO_4^{-2}	NH_4^+	NO_3^-	NO_2^-	Cl^-
SO_4^{-2}	-	0.34	0.85	0.55	0.73	SO_4^{-2}	-	0.43	0.95	-0.40	0.44
NH_4^+		-	0.05	-0.60	-0.38	NH_4^+		-	0.44	-0.68	-0.17
NO_3^-			-	0.70	0.14	NO_3^-			-	-0.17	0.14
NO_2^-				-	0.96	NO_2^-				-	-0.53
Cl^-					-	Cl^-					-
	Site (5)						Site (6)				
	SO_4^{-2}	NH_4^+	NO_3^-	NO_2^-	Cl^-		SO_4^{-2}	NH_4^+	NO_3^-	NO_2^-	Cl^-
SO_4^{-2}	-	0.41	0.92	-0.18	0.07	SO_4^{-2}	-	0.46	0.85	0.37	0.60
NH_4^+		-	0.03	-0.87	-0.33	NH_4^+		-	0.60	-0.41	-0.42
NO_3^-			-	0.12	0.12	NO_3^-			-	-0.16	0.24
NO_2^-				-	0.75	NO_2^-				-	0.84
Cl^-					-	Cl^-					-
	Site (7)										
	SO_4^{-2}	NH_4^+	NO_3^-	NO_2^-	Cl^-						
SO_4^{-2}	-	0.63	0.95	-0.04	0.62						
NH_4^+		-	0.52	-0.68	-0.12						
NO_3^-			-	-0.12	0.54						
NO_2^-				-	0.75						
Cl^-					-						

3.4. Association between Soluble Matters

From Table (9), the correlation between ions, indicates that the main compounds in SPM in Damietta City follow the order: $(NH_4)_2SO_4$> NH_4NO_3. This might be explained because of the reaction between nitrate, sulfate and ammonia gases emitted from auto-exhaust, and that Damietta City is located at the north coast and affected by sea salt (Cl^-). It has noticed that the main compounds in the present study follow the order: $(NH_4)_2SO_4$> NH_4NO_3. NH_4NO_3 may formed by the reaction of ammonia with acid gas NO_2 that resulted from combustion processes.

Ammonium sulfate is the most common and abundant sulfate species in ambient aerosol samples at site 7, formed through the atmospheric reactions, which involve ammonia and sulfuric acid. This is confirmed by the correlation coefficient (r=0.63) that is found between ammonium and sulfate concentrations in SPM at Damietta atmosphere at site 7. Meanwhile, no correlation coefficient (r = -0.02) was found between nitrate and ammonium concentrations in SPM. This might be because ammonium nitrate is relatively unstable compound compared to ammonium sulfate **(Godish, 1997)**.

Furthermore, **Stockwell, *et al.*, (2000)** documented that ammonium nitrate formation is favored under conditions of high relative humidity and low temperature. These conditions are common during the winter in Damietta City. **Tsitouridou and Samara, (1993)** showed also a significant correlation of SO_4^{2-} with NH_4^+ and NO_3^-. The contribution of the sea spray has estimated to be 47 % of aerosol chlorides but only 1.5 % of aerosol sulfates. Aerosol sulfates are neutralized by atmospheric ammonia to form $(NH_4)_2SO_4$.

Ammonia when formed initially in the atmosphere, nitrate and sulfate are in the form of nitric and sulfuric acids, which has progressively neutralized by atmospheric ammonia forming ammonium salts **(Harrison and Yin, 2000)**. Sulfate has a good association with nitrate at all the investigated sites except for site (2) where it has a bad association with NO_3^-. Moreover, sulfate has a good association with NO_2^- at all the investigated sites except for sites (4, 5, 6 and 7). Sulfate and chloride were having a good association in the samples collected from all sites except for sites (4 and 5) and this is due to that the major sources at this location are motor vehicles. However, NH_4^+ has a negative association with NO_2^- and Cl^- at all the investigated sites. This could be attributed to the fact that NH_4^+ in atmosphere of these sites were mainly emitted from fermentation of organic matters while NO_2^- and Cl^- source is motor vehicles distributed in these areas. This is very clear from the high correlation coefficient, which has found to hold NO_2^- and Cl^- at all the investigated sites except for site (4). On the other hand, NO_3^- has a good association with NO_2^- at sites (1, 2, and 3), a low association with Cl^- at sites (2, 3, 4, 5 and 6), and a negative association with NO_2^- at sites (4, 6 and 7).

Primary aerosols may be directly emitted into the atmosphere from sources such as vehicles, factories, seas, and the earth's crust, while secondary inorganic aerosols that contain nitrogen or sulfur species (such as NH_4^+, NO_3^-, and SO_4^{2-}) are generated in the atmosphere in reactions with gaseous precursors.

In a correlation between ions, the main compounds in suspended particulate matter in Damietta City follow the order: $(NH_4)_2SO_4$> NH_4NO_3. This could explain as because of the reaction between NO_x, SO_2 and ammonia gases that might be emitted from auto-exhaust.

It has concluded that sulfate has shown a good correlation with most of the investigated emissions at all sites at street level except for NO_2^-. This indicates that the source profile and its variation in atmospheric levels do not match with other exhaust emissions. SO_2 from car exhausts could oxidize to SO_4^{2-} when the conditions (dust particles, relative humidity and light). On the other hand, the lowest mean concentration of water-soluble sulfate has detected at very low population density sites. Where, NO_2^- shows a good correlation with Cl^-.

Obviously, it is clearly that this study showed that the maximum annual enrichment factor of water-soluble **SO_4^{2-}, NO^{3-}, NO_2^- and Cl^-** at Al-Harby Street (site 1) recorded for the year 2018 and during the year 2009. This might be attributed to that site (1) is a heavily trafficked street which explain the high enrichment factor recorded. While the lowest enrichment factor of water-soluble recorded at locations; Gheit El-Nasara and, Damietta lock and Gates Bridge (6 and 7) because they were outside the potential influence of high traffic for the years 2018 and 2009. It has noticed that the main compounds in the present study follow the order: $(NH_4)_2SO_4$> NH_4NO_3. NH_4NO_3 may formed by the reaction of ammonia with acid gas NO_2 that resulted from combustion processes.

According to the above-mentioned results indicated that traffic emission is the major source of atmospheric SPM in Damietta City, since the lack of environmental knowledge, awareness and culture could trace back to the reasons of air pollution and its effects on human health, as well as how the concern of governments and the importance of environmental attention. Therefore, it is an important public health task in the future to reduce car exhausts such as soot installing paper end of pipe control technologies at industrial facilities such as electrostatic precipitators and bag houses.

It is clearly noticed that the obtained results and according to this comparison, the results of particles over the period of the year 2018 and their chemical components showed a significant improving the air quality related vehicle emissions during the period of the year 2009. These results may relate to the concern of governments and the importance of environmental attention, development of alternative fuels that may produce low concentration of pollutants upon combustion, replacing the progressive substitution of fuel oil for natural gas, reducing sensitively particulates. Nerveless, great attention must be pay to environmental protection in planning future social and economic development and continuous emission monitoring systems have utilized.

Conclusion and recommendation

The focus of this study was to make detailed characterization and quantification of motor vehicle related air pollutants along an urban street in Damietta City over the year 2018 and then comparing it with SPM of year 2009. The chemical characteristics of particulate components (SO_4^{2-}, NH_4^+, NO_3^-, NO_2^- and Cl^-) also had investigated for the sampling locations, to quantify the emissions of particulate pollutants from traffic and its effects.

It is clear from the study that the main source of suspended particles in the air of Damietta city is the exhaust of vehicles especially since most of the cars are old and require maintenance. Although, the study showed improvement of air quality related vehicle emissions during the period of 2018 in comparing with the obtained results during the year 2009. Further study should conduct with a view to estimate the actual contribution of particulate deposits and in order to characterize and follow up more precisely the situation of atmospheric pollution generated by traffic in this city.

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