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Air Pollution Index of Total Suspended Particulates and its Health Concerns at a Heavy Traffic Street in Alexandria, Egypt: Case Study

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ABSTRACT

Background: Air pollution index is not applied in Egypt up till now. **Objectives**: This study is a trial to apply the concept of air pollution index (API) to assess the air quality and its health concerns at one of the heavy traffic streets in Alexandria; Egypt. **Methods**: This was a case study that was conducted over one year, the setting of which was one of the heavy traffic streets. The total suspended particulate matter (TSP) was sampled using "High Volume Air Sampler," for 24 hours/day with simultaneous measurement of local meteorological parameters. **Results**: The total suspended particulates exceeded the National Standards during 78 measurement days out of 84 (92.9%). Application of air pollution index revealed that 19% of the measurement days were of good air quality, 28.6% harmful for sensitive groups, 20.2% unhealthful for the public, 15.5% very unhealthy, and 16.7% hazardous to the public. **Conclusion:** Traffic concentrations of TSP at the streets under study exceeded the Egyptian National Standards during all weekdays and all months throughout the year. The air quality during the working days (Sunday to Thursday) was unhealthy to the general population. The API was the highest during Spring Season. Application of an air pollution control strategy with generalization and communication of air pollution index in Egypt were recommended.

***Key words**: Air pollution index, air quality, total suspended particulate, traffic pollution, sensitive groups.*

INTRODUCTION

Alexandria is the second city in Egypt and the main sea port of the country. The number of private cars within Alexandria streets continuously increases. Consequently, this increases the traffic congestion, with its negative impacts on the City air quality.[1]

Total suspended particulates (TSP) are atmospheric particles smaller than 40-50 µm aerodynamic diameters. They exist as discrete particles (liquid droplets or solids)

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over a wide range of sizes. Particles originate from a variety of stationary and traffic sources and may be emitted directly or formed within the atmosphere by conversion of gaseous emissions. They include dust, dirt, soot, smoke, and liquid droplets. Total suspended particulates have great impacts on human health, and economy. They may cause visibility degradation, smoke and odor nuisance, all of which lead to human discomfort and reduced enjoyment of the environment.[2] Their health effects range from irritation of eye, nose and throat to exacerbation of respiratory diseases and mortality.[3,4] Economic outcomes of TSP comprise potential impact on tourism, and crop damage. The TSP is used as an air pollution indicator in many studies in Kosovo, [5] Hong Kong, [6] India, [7] and Egypt. [8]

The Egyptian standard for TSP in the Environmental Law Number 4-1994 amended by law Number 9-2009, and its executive Law Number 1095-2011 was 230µg/m^3. This limit represents a 24-h average concentration that should not be exceeded more than once in a year. This standard represents the levels of TSP above which exposure may cause adverse health effects. The Egyptian Environmental Law does not contain secondary standard above which may affect comfort of general population and health of the sensitive groups of heart or lung problems.[9]

The air pollution index (API) was developed by the Environmental Protection Agency (EPA). It is a referential scale from 0 to 500 describing air pollution levels, and displays it to the public to enhance their participation and awareness. Its purpose is to help citizens understanding the local air pollution level, and the assumed population affected and is symbolized by a standard color (table-1). The API protects human health by triggering control actions designed to limit or prevent air pollution episodes associated with these contaminants during periods of poor air

quality conditions. For example, API less than or equal to 50 is considered to be for excellent air quality with no health or environmental effects, and it is denoted by the blue color. On the other hand, API of more than 300 is considered heavily polluted with hazardous health impacts on healthy population, and is denoted by the brown color (table-1). [10] In Egypt, the API is not used, until now.

This study is a trial to apply the concept of air pollution index of total suspended particulates to assess air quality and its health concerns at one of the heavy traffic streets in Alexandria; Egypt.

MATERIALS AND METHODS

This was a case study, the setting of which was on Victor Emanuel Al-Thaleth paved street, which connects El-Horreya Avenue in Mostafa Kamel region to Smouha. It is of about 10 meters width, and 1.25 Km length. This street contains schools, a mall, an Alexandria University building, and Smouha Club. It is the main way to the security directorate, Pharos University, computer market, Alexandria-Cairo Highway, some private businesses and industries, including Stia, Al-Nahas, and Al-Nakl & Al-Handassa companies. The location of the sampling station was at 31.22˚ Latitude and 29.95˚ Longitude which was identified using Google Earth 7.0.1.8244 (beta) free software (figure-1).

The data collection period extended for one year from 2008 January 1st to 2008 December 31st. Samples and records were collected over the seven days throughout the week and for one week each month (Seven samples/month and 12 months/year). Samples during dust storms and rainy days were excluded and then compensated by other suitable days in the same month.

The total suspended particulate matter (TSP) was sampled using "GMW TSP High Volume Air Sampler" from Petro-Instruments Corp, Ltd, Bangkok. The sampler was placed on the roadside at about one meter from the roadway and

away from any constraints by two meters. The sampler's inlet height was two meters (at the breathing zone of those crossing the street). Sampling was conducted at a rate of 35 ft^3/minutes for continuous 24 hours according to the Ontario, and Environmental Protection Agency (EPA) reference methods.[11,12] The sample was collected on a pre-conditioned weighed 8×10 inches glass-fiber filter. The collected TSP samples were determined gravimetrically using a four digits analytical balance SERARTORIUS–WERKE- GMBH, Germany.

The weather station was placed and used for measurement of the local barometric pressure, air temperature, air direction using a weather station, WHEATHERMAX, Maximum Inc. The installation and measurements were conducted according to the US-EPA standard method.[13]

For Quality assurance and control, the glass-fiber filters were dried and conditioned before weighing using a desiccator (before & after sampling). The volumes of air samples were corrected for the natural temperature and pressure (25˚C & 1 atm) and then used in calculating the TSP concentrations. In addition, the High Volume Air sampler was calibrated monthly. The local meteorological parameters were recorded automatically each second. Moreover, installation and measurements of meteorological parameters were conducted according to the documented reference methods. [11-13]

Air pollution index was calculated according to the China Environment Series using the following equation. [10, 15]

$$API = \frac{(I_{Hi} - I_{Lo})}{(Bp_{Hi} - Bp_{Lo})} (C - Bp_{Lo}) + I_{Lo}$$

Where: API is the air pollution index of TSP; C is the measured concentration of the TSP; Bp_{Hi} is the breakpoint that is greater than or equal to C; Bp_{Lo} is the breakpoint that is less than or identical to C; I_{Hi} is the sub-index value

matching to Bp_{Hi}; and I_{Lo} is the sub-index value corresponding to Bp_{Lo}. API of particulate matter was calculated and classified into sectors according to Chinese and EPA standard methods as obvious in table-1. [10,16]

Data were statistically analyzed using SPSS-16 Package. The data sheet included TSP concentrations, API, and local air direction. The total suspended particulate concentrations and their corresponding air pollution indices were classified according to days, and months. The statistical tests used were Kolmogrov-Smirove and Shapiro-Wilk Tests of normality, One-Way ANOVA Test followed by LSD Post Hoc Multiple Comparisons Test, and Independent Samples-T-Test. The data were expressed as (mean ± standard deviation). [17]

RESULTS

There were records for totally 84 measurement days during the year, which covered seven days per month, for the twelve months in the year. Kolmogrov-Smirove & Shapiro Wilk Tests indicated the normal distribution of the TSP levels and their corresponding air pollution indices ($p > 0.05$, at 95% C.I.).

The 24-hour TSP concentrations exceeded the Egyptian National Standard in the executive law of the Prime Minister decision Number 1095-2011 at the seven weekdays and twelve months during the year. It exceeded the National Standards during 78 measurement days out of 84 (92.9%). Application of air pollution index revealed that 19% of the measurement days were of good air quality, 28.6% % were unhealthy for sensitive groups, 20.2% were harmful to the public, 15.5% were very unhealthful, and 16.7% were hazardous to the public.

Table -1: Total suspended particulate Breakpoints, its corresponding classes of air pollution indices (API), air quality description, suspected health status and

Breakpoints (Bp_{Lo}-Bp_{Hi}) ($\mu g/m^3$)	Sub-index value of API (I_{Lo}-I_{Hi})	Air Quality Description	Health output description	Color	Accompanying health messages for:	
					Sensitive groups*	General population
0-120	**0-50**	Excellent	No expected health effects	Blue	Enjoy their usual outdoor activities.	
120-300	**51-100**	Good with some visibility reduction		Green		
	101-150	Slightly polluted	Unhealthy for sensitive groups	Yellow	Consider reducing outdoor strenuous physical activities.	Enjoy their usual outdoor activities.
300-500	**151-200**	Lightly polluted	Unhealthy	Orange	- Reduce outdoor strenuous physical exertion. - People with asthma may find they need to use their reliever inhaler more often.	Reducing outdoor activities.
500-625	**201-250**	Moderately polluted	Very unhealthy	Red	- Avoid outdoor strenuous physical activities. People with asthma may find they need to use their reliever inhaler more often use their reliever inhaler more often	Reduce outdoor physical exertion.
	251-300	Moderately-heavily polluted		Light Purple		
>625	**>300**	Heavily polluted	Hazardous	Brown		

*Adults & children with heart or lung problems

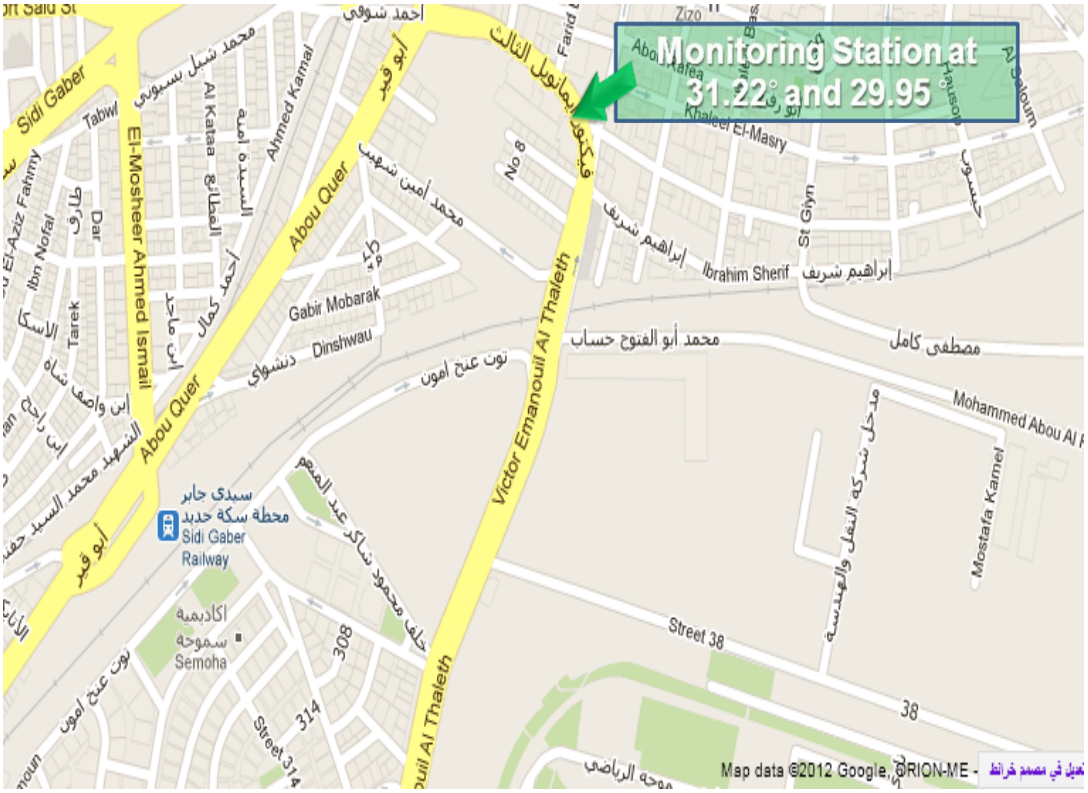

Figure -1: Location of total suspended particulates monitoring station.

Concentrations of TSP and their API were the highest at the South East air direction, and minimum at the North East (table-2). Local air direction showed statistically significant variation in TSP and API (One-Way ANOVA Test). Further analysis using LSD Post Hoc Multiple Comparisons Test revealed that TSP concentrations and API were significantly higher at the SE direction than at each of N, NE, E, S& NW ($P < 0.05$ at 95% C.I.).

Table -2: Concentration of total suspended concentrations (TSP) and its corresponding air pollution index (API) at various prevailing local air direction within the street under study (January 2008- December 2008)

Local Air Direction*	N	TSP Concentrations (µg/m^3)					API				
		Mean	S.D	Min	Max	One-Way ANOVA	Mean	S.D	Min	Max	One-Way ANOVA
N	11	414.8	152.9	224.2	686.4		167.4	83.8	79.0	325.0	
NE	15	361.6	132.0	213.1	743.0		136.7	69.7	76.0	347.0	
E	6	405.8	239.2	200.5	873.4		160.0	120.0	72.0	399.0	
SE	13	581.0	151.8	357.0	786.4	0.009	252.7	99.3	128.0	365.0	0.013
S	6	363.32	160.8	211.8	561.3		144.7	77.2	76.0	249.0	
SW	3	496.1	65.1	421.0	536.6		204.7	37.9	161.0	229.0	
NW	30	450.7	134.9	225.3	715.3		184.1	78.5	79.0	336.0	

*West local air direction was not one of the prevailing directions

Air pollution index of TSP was the highest during Sunday and Wednesday of a moderately polluted very unhealthy red region (table-1). It was the lowest during Friday of good air quality, some visibility reduction and unexpected health effects. During the other days throughout the week, API ranged from the yellow slightly dirty air, which was harmful for sensitive population to orange lightly polluted area that is unhealthy to the public (figure-2). One-Way ANOVA Test indicated the highly significant variation of TSP and API between different days during the week ($p < 0.05$ at 95% C.I). Further analysis using LSD Post Hoc Multiple Comparisons Test clarified that TSP and API during Fridays were significantly higher than that during Sunday to Thursday. In addition, it was significantly lower during Saturday than during Sunday & Wednesday. Independent Samples T-Test

indicated that API during workdays were significantly higher ($p < 0.05$ at 95% C.I) than that during holidays (Friday & Saturday).

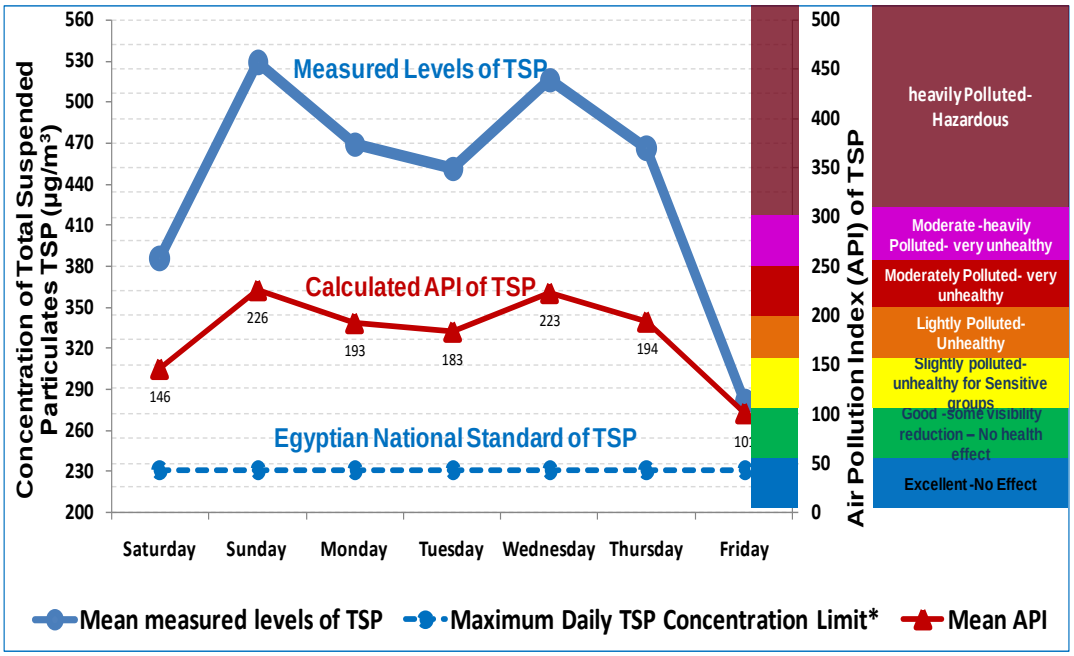

Figure-2: Daily Mean total suspended particulate (TSP) concentrations against its maximum daily Egyptian Limits its corresponding air pollution index in one of the heavy traffic streets in Alexandria Egypt (2008-2009).

The monthly average API ranged from the green area of good air quality and some visibility reduction to the moderately polluted unhealthy red area. The levels of TSP and API were the lowest during February (green area). During the remaining months, the API ranged from slight dirty air that was considered harmful for sensitive groups during January and March (yellow area) to the red moderately polluted very unhealthy air during April, June, and May (figure-3). One-Way ANOVA Test revealed significant variation of both TSP concentrations and their corresponding API with different months ($p < 0.05$, at 95% C.I.). Further analysis using LSD Post Hoc Multiple Comparisons Test clarified

that API during February was significantly lower than those during April to December. In addition, it was significantly higher during April, May, and June than those during January, February, and March ($p < 0.05$ at 95% C.I.). Independent Samples T-Test declared that levels of TSP and API were significantly lower during rainy than non-rainy months ($p < 0.05$ at 95% C.I.).

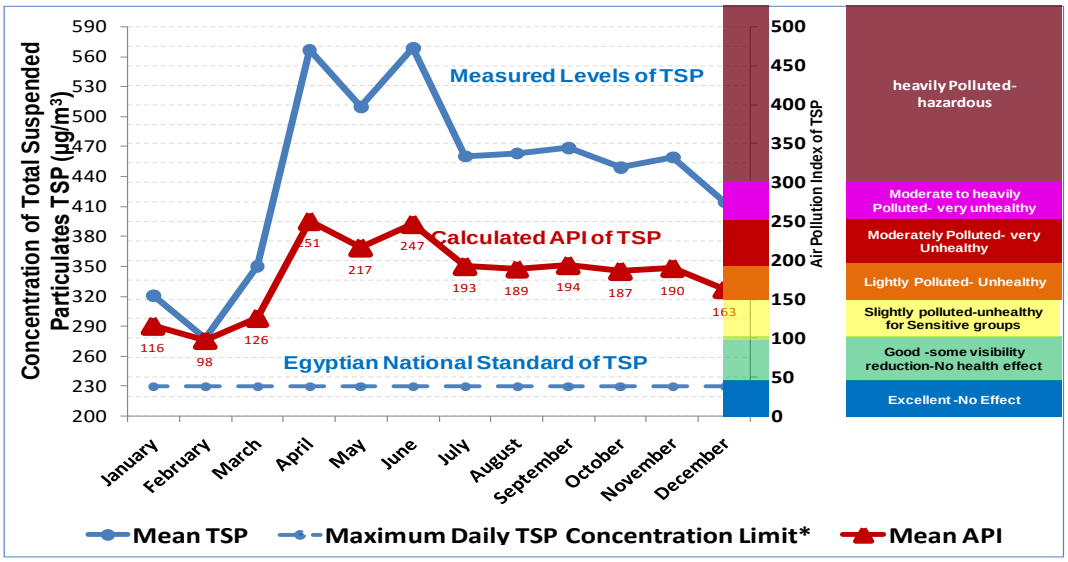

Figure-3: Monthly Mean total suspended particulate (TSP) concentrations against its maximum daily Egyptian Limits and its corresponding air pollution index in one of the heavy traffic streets in Alexandria Egypt (2008-2009).

DISCUSSION

Traffic concentrations of TSP in the street under study exceeded the Egyptian National Ambient Air Quality Standards (NAAQS) during all week days and all months throughout the year. This result was compatible with many studies in Egypt, New Delhi, and Chennai, which stated the increase of TSP above their National Standards in many areas. [18-20] The NAAQS does not include any actions or health messages that must be directed to the affected population or the environmental management authority in

case of poor air quality. So the air pollution index of TSP was used.

South-East air direction recorded the highest average TSP air pollution index (API) of moderately polluted very unhealthy air quality. This may be attributed to the TSP emissions from the tire manufacturing (Al-Nakl & Al-Handasa) company, located South-East the sampling site. The "Poland's Informative Inventory Report 2011," stated that high levels of TSP coming from an automobile tire plant.[21]

The air pollution index (API) was the lowest during Friday (weekends) of the least traffic congestion. This was compatible with the result of the Egyptian study [22] and contradictory with the Japanese one in which TSP did not vary much between weekends.[23] Saturdays were slightly polluted air, and unhealthy for sensitive groups with heart or lung problems. This may be attributed to the closure of schools, and most human activities during Saturdays. Thus, sensitive population must reduce their outdoor strenuous physical activities, while the overall population can enjoy their usual outside activities.[24, 25] The air quality of the other working days (Sunday to Thursday) ranged from lightly to moderately polluted air. So its effect may range from harmful to very unhealthy to the general population. Hence, the public must be informed to avoid their outdoor strenuous physical activities, and the sensitive groups must use their reliever inhaler more often.[24, 25]

The values of air pollution index (API) were the lowest during the rainy months (February, January, March, and December). This may be attributed to the precipitation that supports deposition of particulate matter out of the atmosphere. [26, 27] The highest levels of TSP and API were observed during April, May, and June (Spring Season). This may be due to blowing of Khamaseen wind that carries dust from western desert. [28] This result was well-matched with that of the Egyptian [18] and Brazilian studies. [26] These levels may increase the allergic symptoms among asthmatic and non-asthmatic population as mentioned by Monn 2001,[29] which also may increase hospital admission

with respiratory [30] and cardiopulmonary [31] diseases. So the general population must be advised to reduce or avoid strenuous physical activity and increase the frequency of using a reliever inhaler for sensitive groups. [24, 25] The high levels of TSP and API may explain the lower productivity of the overall Egyptians. Hence, the ministries of environment, health, industry and the interior must develop and apply a strict air quality management system to reduce these oppressive levels.

CONCLUSIONS AND RECOMMENDATIONS

Traffic concentrations of TSP at the street under study exceeded the Egyptian National Ambient Air Quality Standards (NAAQS) at the study location and period. Fridays were of the lowest API. Saturdays were slightly contaminated and harmful for sensitive groups. The air quality of the other working days (Sunday to Thursday) ranged from lightly to moderately polluted air. Hence, their effects varied from harmful to very unhealthy to the general population. The API was the lowest during the rainy months (February, January, March, and December). It was the highest during April, May and June (Spring Season).

It is recommended to apply and generalize air pollution index in Egypt and to ensure community participation by communicating the API triggering control actions through media to prevent air pollution episodes are recommended. In addition, an air pollution control strategy must be applied to reduce traffic pollution such as using cleaner fuels, enhancing public transportation, and limiting private car licensing.

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