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(RESEARCH ARTICLE)

Impact of traffic densities on indoor air quality

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Abstract

In the last few decades air pollution in general and indoor air pollution in particular represents a danger for the human health. The impact of traffic density on indoor air quality was evaluated. Indoor and outdoor concentrations of particulate matter (PM_{10}), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) were estimated in 30 homes during the winter and summer seasons of 2016. The results showed that the impact of traffic on indoor concentration was evident in moderate and high traffic areas. PM_{10} recorded the highest values in winter while both NO_2 and SO_2 were slightly higher in the summer for all the studied areas. PM_{10} is one of the most commonly used criteria for determining air quality indices (AQI). Among the different studied sites, the highest traffic density showed the worst air quality (AQI>395). The other sites showed very poor air quality (AQI>224) which showed that these areas were also polluted. In winter, the levels of indoor bacteria at all sites were lower than the threshold value (TLV), 50 CFU/m^3 according to the WHO, but the opposite was observed in the summer. It was also found that the counts of indoor Gram-negative bacteria were less numerous than Gram-positive bacteria. The quality index for each individually studied site and AQI in this region of Cairo was higher than the allowable value of the air quality standard set by the US Environmental Protection Agency and the Egyptian Ministry of Environment.

Keywords: Indoor air quality; Traffic density; Particulate matter; Nitrogen dioxide; Sulfur dioxide; Airborne Gram negative bacteria; Airborne Gram positive bacteria

1. Introduction

It is well known since 1952 that outdoor air pollution is a serious problem for human health. Harrison (1997) [1] stated that indoor air pollution is also a critical problem for human health. Indoor or outdoor air quality is associated with incidence and death from respiratory, cardiovascular, and vascular diseases. Therefore, indoor air pollution is an important source influence on the public health of humans. This was evident in the past decades by several studies [2]. It was found that the concentration of many indoor air pollutants was higher than that of outdoor air [3]. The world record of disease rate from indoor air pollution is higher than the recorded number of outdoor air pollution [4]. This is because people spend more time indoors, with a large number of pollutants sources and a significant concentration of indoor pollutants compared to outdoor air.

Airborne particles (PM) are closely related to morbidity and mortality, mainly due to respiratory, cardiovascular and vascular diseases [5]. Many studies have been conducted in densely populated cities due to high levels of PM concentrations. Vehicle traffic is one of the most sources of air pollution. Therefore, PM is affected by both indoor and outdoor sources of pollution. Since most people, especially children and the elderly spend more time in indoors, they are more susceptible to different pollutants. PM formation in indoor air is closely related to human activities such as cooking, cleaning, walking, and smoking [6]. However, little data is available on indoor air pollution compared to outdoor environments.

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Transport and energy production is a major source of outdoor PM_{10} [7], while human activities inside homes contribute primarily to indoor PM concentrations [8]. Road paving, transport density and brakes are the main sources of particles formation [9]. The traffic releases a wide range of particles and reduces air quality in urban areas [10]. Ventilation and closed windows are among the sources of particles that reach the indoor environment [11]. Many researchers have recorded particles concentrations related to traffic [12].

The main outdoor sources of NO are mobile and stationary combustion sources [13], while indoor sources include gas cookers, wood stoves, stoves and smoking [14]. Approximately 80% of SO emissions and 55% of NO emissions are emitted from diesel light and heavy vehicles [15].

The objective of this study was to determine the quality of indoor air in different traffic density locations in Cairo. To study the effect of traffic density on indoor air quality in homes located in different traffic areas in Cairo; this study was carried out to achieve the following: (1) Characterization of air pollutants related to the traffic density in the residential environment through measurements of PM_{10}, NO_2 and SO_2 in indoor and outdoor air during the winter and summer of 2016 and (2) study of indoor air quality in the studied areas and compares it with the levels set by the World Health Organization (WHO).

2. Material and methods

To study the impact of air traffic pollution on the Greater Cairo area, Egypt, 30 homes were selected in the streets with a different traffic density. The homes were classified into three groups according to the traffic density nearby, which are a high traffic density represented by Helwan, moderate traffic density represented by Shubra area and the low traffic density area represented by Maadi area. The particulates matter (PM_{10}) were collected and measured in 30 households living on the first floors of residential buildings distributed in the three areas under studied 10 families in each area during the winter and summer of 2016. All sampling sites are located 50 meters from the main road of the Nile River with high traffic density most of the time. Helwan area differs from other areas under study since it contains a number of different factories. A survey questionnaire was conducted to identify some characteristics of the population living in the housing units under the study. The questionnaire included the number of inhabitants of each dwelling unit; the area of the living room, the number of cigarettes smoked daily, the frequency of cleaning per month and the presence or absence of air conditioning in living room.

The indoor and outdoor concentrations of PM_{10}, NO_2 and SO_2 were estimated in 30 homes under study during the winter (January to February) and the summer seasons (July and August) of 2016. Samples were taken from homes that were usually occupied during the sampling period because most households had young children. Indoor and outdoor samplers were placed at the breathing level for a typical adult (1.5 m). The measurements were completed along with an application form asking about housing characteristics and possible indoor sources of pollution. The questionnaire form shows a difference in ventilation systems by season. The use of air conditioning in the living room was irregular. Most homes under study use cooking gas and indoor air pollution mainly occurs through cooking, smoking and cleaning activities.

The 24-hour sampling time was used in the current study as 24-hour measurements are the standard in most air pollution guidelines [16]. The concentrations of particulate matters (PM_{10}) were measured using the filtration method [17]. The particles matters (PM_{10}) were collected on the 37 mm Whatman Fiberglass filter. The filter cassette was located about 1.5 meters from the ground with an open face pointing to 45 degrees down. The filters were weighed at constant temperature and relative humidity (RH) of about 20 °C and 45% RH. Weighing method is detailed by [18]. NO_2 was determined calorimetrically at 540 nm using sodium arsenate method [17]. West and Gaeke Method (Pararosaniline Method) was applied to determine calorimetrically SO_2 at 548 nm [19].

Airborne bacteria were collected by influencing the agar medium using the portable Mini-Patrisol Air Sampler PM_{10}, at about 10 L/m^3 for 2 to 8 minutes, with frequency around once a week and placed at a height of about 1.5 meters above the surface to simulate the human breathing area. Before or after each sample, the sampler surface was disinfected using a 70% ethanol solution. Sampling was conducted for all the three sampling areas each day of sampling during daylight hours. Nutrient agar plates were incubated at 30 °C and aerobic bacteria were enumerated 48 hours later [20]. Cycloheximide, final concentration of 0.5 mg/ml, which previously showed no effect on bacterial counts [21], was added to the media to prevent the growth of fungi. Approximately 50% of the entire colonies were isolated for partial identification by light microscopy based on Gram reaction and bacterial morphology.

3. Results

Data presented in Table 1 showed that the average amount of indoor PM_{10} ranged between 316 and 711 µg/m^3. On the other side, the average of PM_{10} concentrations in the outdoor air ranged between 224 and 675 µg/m^3. In winter, PM_{10} was higher than the summer average. The results showed that the heaviest traffic area at Helwan has the highest PM_{10} values with indoor PM concentrations reached 528 and 711 µg /m^3 in summer and winter, respectively. The moderate traffic density area at Shubra was found to have moderately low PM_{10} values with mean indoor PM_{10} concentrations reached 498 and 592 µg /m^3, while the least traffic density area at Maadi had the lowest PM_{10} levels and the mean indoor PM_{10} concentrations reached 316 and 395 µg /m^3 in summer and winter, respectively.

Table 1 showed that indoor PM concentrations were higher than outdoor concentration while NO_2 and SO_2 indoor concentrations were lower than outdoor ones in both seasons. Among the concentrations of measured gaseous pollutants in the three areas, the NO_2 concentration was highest, followed by sulfur dioxide. It is clear that the concentrations of both nitrogen dioxide and sulfur dioxide in the summer were higher than those recorded in winter in all traffic areas.

To study the relationship between the related pollutants of indoor and outdoor air, the (I/O) ratios were calculated. The I/O ratio presented in Table 1 is indicative of whether indoor levels are due to outdoor particles concentrations or if indoor levels are affected by large indoor sources of particles. As shown in Table 1, the average I/O ratios of PM_{10}, NO_2 and SO_2 in summer are higher than those recorded in winter in all traffic areas.

3.1. Airborne bacteria

The concentration of airborne bacteria ranged from 19 to 77 CFU/m^3 for the three different traffic density areas in winter and summer (Table 2). Among the areas examined, Helwan showed the highest level (77 CFU/m^3) of the bacterial count. Shubra recorded moderate numbers of bacteria, while the lowest levels of bacteria were shown in Maadi area. The counts of airborne Gram positive bacteria were higher than airborne Gram negative bacteria. As shown from the results recorded in (Table 2), it is clear that Gram negative bacteria were present at a high concentration in Maadi District (39%) followed by Shubra (28%) and Helwan (13%) in winter and be lower than these levels in summer. The opposite is occurred in the summer season in the case of Gram positive bacteria.

Table 1 Average of indoor and outdoor traffic related pollutants (PM_{10}, NO_2, and SO_2) at different traffic density areas in both summer and winter

Pollutant	Season	Category	Mean values			Indoor/outdoor ratio		
			H	M	L	H	M	L
PM_{10} (µg/m^3)	Winter	Indoor	711	592	395	1.053	1.256	1.386
		Outdoor	675	471	285			
	Summer	Indoor	528	498	316	1.091	1.328	1.411
		Outdoor	484	375	224			
NO_2 (µg/m^3)	Winter	Indoor	342	217	174	0.713	0.661	0.817
		Outdoor	480	328	213			
	Summer	Indoor	434	363	284	0.793	0.846	0.879
		Outdoor	547	429	323			
SO_2 (µg/m^3)	Winter	Indoor	193	157	138	0.894	0.835	0.841
		Outdoor	216	188	164			
	Summer	Indoor	322	239	208	0.902	0.919	0.889
		Outdoor	357	287	234			

PM_{10}: particulate matter H: high traffic density M: moderate traffic density L: traffic density low

Table 2 Indoor average of total bacteria (CFU/m^3) and the percentage of Gram positive & negative bacteria at each studied location of Cairo

Location	Winter			Summer		
	Total bacterial counts (CFU/m^3)	% of Gram$^+$ bacteria	% of Gram$^-$ bacteria	Total bacterial counts (CFU/m^3)	% of Gram$^+$ bacteria	% of Gram$^-$ bacteria
Helwan	49	87	13	77	90	10
Shubra	38	72	28	64	77	23
Maadi	19	61	39	34	65	35

L.S.D. for bacterial type at 5 %: 18.74

4. Discussion

The outdoor PM_{10} concentration ranged from 224 to 675 µg /m^3, exceeding the standard of air quality (230 µg /m^3) recommended by the ministry of Egyptian Environmental 1994. This is because the selected sites are close to high traffic routes in addition to the existence of industrial and commercial activities. All of the studied houses showed that PM_{10} concentration in indoor air was higher than in outdoor air and I/O ratio ranged between 1.053 and 1.411. Previous studies [22] have reported that an increase in the value of I/O ratio occurs during the time of children activity due to the re-suspension of deposited particulates matter. In addition, indoor sources of human activities can play an important role in increasing the concentration of PM_{10} in the studied sites. The concentration of particulates matter in the indoor air depends in depth on the level of these particles in the outdoor air due to increased ventilation in the summer season [23].

The studied homes are normally ventilated by open windows and therefore are more susceptible to pollutants from outdoor air. In this case the concentration of particulates matter PM_{10} may be increased in homes close to roads with high traffic density [23]. For homes that rely on air conditioning, particulates matter PM_{10} are pulled from the outdoor air into the homes and filtered through the filtration process of air conditioning systems. These results are in harmony with the previous data of [24]. Air conditioning filters are used to reduce the amount of PM entering homes. Therefore, it can be concluded that high concentrations of PM in some homes under study which used air conditioning systems were probably associated with the existence of some indoor sources of human activities and so the I/O ratio was high [24-25]. Clearly, the cumulative effect of indoor sources, in the absence of good ventilation of clean air with the surrounding air, could contribute to increase PM concentrations in indoor and therefore I/O ratios would be higher. These results are in line with results found in Damietta, Egypt by [23]. Future plans should be developed to reduce and test indoor PM concentrations in order to increase their effectiveness in reducing human exposure and health risks.

The obtained results showed that in the winter, particulate concentrations PM_{10} are higher due to prevailing weather conditions. In this season, weather conditions are stable and restrict air dispersion, especially in large cities as it was mentioned previously by [26]. In contrast, greater dispersion leads to low particulate concentrations are occurred in summer. The small room size and a large number of children were found to be associated with increased indoor PM_{10} concentrations.

Chemical reactions in the atmosphere play a large role in seasonal variation. Seasonal variation of NO_2 from the traffic sector may be affected by the high traffic density during the summer and by the secondary formation of NO_2 via NO interaction with O_3 [27]. Direct oxidation from NO to NO_2 significantly increases NO_2 during the summer season when O_3 concentrations are high. On the other hand, the oxidation of sulfur dioxide is increased by increasing the presence of the hydroxyl group with increasing temperature and relative humidity [28]. Janssen et al. (2001) [29] reported that the increase of PM_{10}, SO_2, and NO_2 concentrations in both indoor and outdoor air is closely related with increasing traffic density. Mao et al. (2009) [30] found that aerosol levels in high density areas were about twice in areas with low traffic density. Rijnders et al. (2001) [31] showed that NO_2 concentrations in indoor and outdoor areas were significantly affected by traffic density followed by distance to the highway. Several studies have shown that outdoor nitrogen dioxide levels could be higher due to increased emissions from vehicles [32]. Shakour et al. (1992) [33] reported that the average of sulfur dioxide levels in new residential areas in Cairo ranged from 13.28 to 19.10 µg /m^3 over the four seasons, with the highest concentrations recorded in summer and fall. Ingle et al. (2005) [34] in India, observed an increase in the concentration of sulfur oxides during the summer season.

It is observed from Table 1 that the average of I/O ratio for each of particulate matter, nitrogen dioxide and sulfur dioxide was higher in summer than in winter in all traffic areas under study. In a previous study, Gupta et al. (2007) [35] observed a relative increase in I/O ratio with increasing temperature as it helps in the transfer of particles to the inside. When ventilation is high during summer, the differences between pollutants concentrations are lower than winter due to permeation of the outdoor air through the open windows. Since most I/O ratios of NO_2 and SO_2 are less than one, this indicates that sources associated with outdoor traffic have contributed more to indoor air quality. However, the average I/O ratios of the PM10 were higher than one especially in homes with strong indoor activities. Abt et al. (2000) [36] found that indoor activities especially cleaning, contributed 50% to 80% of the concentrations of indoor particles. On the other hand, the cooking activities increased the indoor air particles as it released large quantities of oil vapors from kitchens.

The abundance of bacteria in Helwan area of high traffic density may be due to the presence of many factors, the amount of suspended dust and the density of people carrying germs. In winter, the levels of bacteria at all sites are significantly lower than the threshold value (TLV), 50 CFU/m^3 according to the WHO, however the opposite was observed in the summer season. The obtained bacterial counts were in line with the previous results of [37], where airborne bacteria varied between 10-100 CFU/m^3. In the present study, the concentration of airborne Gram-positive bacteria was significantly higher than airborne gram-negative bacteria. Several reports stated that gram-negative bacteria were less than 10% [38]. Gram positive bacteria have been shown to have greater resistance and more viability than gram-negative bacteria under strong sunlight; and they can only be found in spore form.

4.1. Assessment of indoor pollution

Air quality index (AQI) shows how clean or polluted air is, and what associated health affects might be a concern for human beings (Environmental Protection Agency). PM_{10} is one of the most commonly identified criteria for air quality indicators (AQI). These indicators enable us to evaluate air quality at each location and can also be used to compare with each other. The greater the value of the air quality index the higher the level of air pollution and thus the greater the health concern. The Air Quality Index (AQI) of 100 corresponds to national air quality standards for pollutant, is the specific level of public health protection. It is generally believed that values of air quality index of less than 100 are satisfactory as reported by WHO. When AQI values are higher than 100, air quality is considered unhealthy especially for certain groups of sensitive persons, and therefore for every one as AQI values get higher. The AQI for each studied location individually and the overall AQI for Cairo are found to be higher the permissible value (Table 1). Helwan area showed the worst air quality (AQI > 395) and all other locations showed very bad quality of air (AQI > 224).

5. Conclusion

The contribution of traffic related air pollution to the indoor air quality in homes located on areas of different traffic density in Cairo was apparent, especially in the high traffic ones. The concentrations of all pollutants in the different traffic density areas varied significantly in both seasons. There was a general pattern of increasing summer I/O ratios of PM_{10}, NO_2 and SO_2 at all traffic areas. The most I/O ratios were less than one indicating that the outdoor traffic-related sources contributed more to indoor air quality. The indoor nitrogen and sulfur oxides might be the cause of the penetration of traffic-related aerosols to indoor environment while PM not only attributed to traffic exhaust, but also to other local outdoor sources as the cement factories located adjacent to many houses in Helwan area. The AQI for each studied location individually and the overall AQI for Cairo are found to be higher the permissible value of air quality standard established by US-EPA and The Egyptian Ministry of the Environment. Various factories in the industrial cities should be transferred outside the scope of residential blocs, especially in cities with high population density. Such studies should be carried out in other regions of Egypt especially in new cities built around the capital.

Compliance with ethical standards

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Disclosure of conflict of interest

All authors have read and approved to submit it to World Journal of Advanced Research and Reviews. There is no conflict of interest of any author in relation to the submission.

Informed consent

The authors obtained informed consent from all fathers of home families before the study is started.

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