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Research Article

Effect of Seasonal Variation on the Levels and Behaviours of Formaldehyde in the Atmosphere of a Suburban Area in Cairo, Egypt

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ABSTRACT Formaldehyde (HCHO) is a carcinogenic pollutant, has an active role in tropospheric photochemistry, and can be affected by seasonal variations. To our knowledge, this is the first comprehensive study of the effect of seasonal variation on the levels and behaviours of HCHO in the atmosphere of a suburban area (15 May City) in Cairo. Daytime and nighttime measurements of HCHO were performed from March 2014 to February 2015. The highest average daily concentrations of HCHO were found in summer and the lowest in winter. The difference was statistically significant ($p \leq 0.001$). Daily average HCHO concentrations in spring, summer, autumn and winter were higher than the corresponding values in many polluted cities in the world. This was true for both weekdays and weekends. HCHO was higher in daytime than nighttime on weekdays and weekends, and the differences in mean concentrations were statistically significant ($p \leq 0.001$), except during the autumn and winter on weekends. Therefore, the contribution of photochemical reactions in the observed levels of HCHO might be greater than that of traffic emissions. This was further proved by the significant positive correlation found between daytime HCHO concentrations and temperature. HCHO concentrations were higher on weekdays than weekends, the differences in mean concentrations were statistically significant ($p \leq 0.001$). This may be attributed to higher emission of HCHO from higher traffic intensity during daytime. Significant positive correlations ($p \leq 0.001$) were found between daytime and nighttime HCHO concentrations, both on weekdays and weekends suggesting that HCHO comes from the same sources.

KEY WORDS Formaldehyde, Seasonal variations, Daytime/nighttime, Weekdays/weekends, Sources, Cairo

1. INTRODUCTION

In urban atmosphere, formaldehyde (HCHO) is an important oxygenated volatile organic compound. It is the most abundant carbonyl compound and recognized as ubiquitous environmental pollutant (Li *et al.*, 2014; Parrish *et al.*, 2012; Lei *et al.*, 2009; Seco *et al.*, 2007). HCHO is a known carcinogenic compound (Zhang *et al.*, 2009; Liu *et al.*, 2006a; IARC, 2004; Molina and Molina, 2002). It plays also an active role in the tropospheric photochemistry, atmospheric chemistry and air quality (Liu *et al.*, 2006b; Possanzini *et al.*, 2002; Viskari *et al.*, 2000;

Müller, 1997; Anderson *et al.*, 1996). HCHO is a major precursor of free radicals through photolysis in the atmosphere (Lin *et al.*, 2012; Dasgupta *et al.*, 2005; Finlayson-Pitts and Pitts, 1999). Degradation of HCHO leads to an enhancing formation of ozone (O_3) (Lui *et al.*, 2017; Luecken *et al.*, 2012; Tilgner and Herrmann, 2010; Olaguer *et al.* 2009). HCHO participates in aqueous chemistry due to its high solubility and interaction with other dissolved species in clouds (Warmeck, 1989; Adewuyi *et al.*, 1984).

HCHO in urban atmosphere originates from both primary and secondary sources. It emits primarily from incomplete combustion of fossil fuel (Ling *et al.*, 2017; Ho *et al.*, 2012; Correa and Arbilla, 2005; Schauer *et al.*, 2002), biomass burning and animal excretion (Li *et al.*, 2014; Lee *et al.*, 1997; Carlier *et al.*, 1986), industrial activities and fugitive industrial emissions (Buzcu Guven and Olaguer, 2011; Viskari *et al.*, 2000), and vegetation (Kaiser *et al.*, 2015; Seco *et al.*, 2007; Villanueva-Fierro *et al.*, 2004). HCHO is produced secondarily from the photochemical oxidation of many volatile organic compounds (VOCs) (Chen *et al.*, 2014; Fortems-Cheiney *et al.*, 2012; Parrish *et al.*, 2012; Fan and Zhang, 2004; Finlayson-Pitts and Pitts, 2000). HCHO via secondary sources will be dependent on the equilibrium position between the photochemical production and removal processes (Sin *et al.*, 2001). The direct emitted primary HCHO accumulates on nighttime and initiates the photochemical reactions on daytime hours (Parrish *et al.*, 2012). The major sinks of HCHO in air are photolysis and reaction with OH radical (Vlasenko *et al.*, 2010; An *et al.*, 2009; Lei *et al.*, 2009; Ervens and Kreidenweis, 2007).

In urban areas, the emissions of HCHO depend on the kind of fossil fuel used, use of catalysts and traffic conditions (Guarieiro *et al.*, 2009; Guarieiro *et al.*, 2008; Zervas, 2008). Diesel fuel, gasoline-related emissions and compressed natural gas (CNG) are important sources of HCHO emission (Nelsona *et al.*, 2008; Martins *et al.*, 2007; Song *et al.*, 2007; Corrêa and Arbilla, 2005). The introduction of ethanol into diesel fuel trigger to increase HCHO levels in diesel emission (Song *et al.*, 2010; Guarieiro *et al.*, 2009; Cheung *et al.*, 2008; Martins *et al.*, 2007; Pang and Mu, 2006; Haupt *et al.*, 2004). Introduction of methyl-tert-butyl ether (MTBE) gasoline to increase the octane index during fuel reformulation leads to 6–73% increase in HCHO emission (Sin *et al.*, 2001).

Air pollution in Cairo is now recognized to be of significant environmental problem due to the presence of intensive anthropogenic activities which lead to an increase in the emission of many primary air pollutants such as VOCs and NO_x. In the presence of high photochemical reactions especially in summer season due to high temperature, intense solar radiation and clear sky, the problem of pollution in Cairo has been shifted towards the so called photochemical pollutants (secondary pollutants) beside the presence of primary pollutants. In urban atmosphere, HCHO emits as primary pollutant from its sources as well as produced from photochemical reactions as secondary pollutants. Study on the atmospheric behaviuor of HCHO can give useful information to identify major sources of HCHO and its role in the tropospheric chemistry and O_3 formation. Previous study on ambient VOCs in Cairo has focused on benzene, toluene, ethyl benzene and xylenes (Khoder, 2007). However, there is a lack of information on the HCHO in Cairo atmosphere. Therefore, the present study aims to evaluate the effect of seasonal variation on the levels and behaviours of HCHO in atmospheric of a suburban area in Cairo. This was achieved through 1) studying the effect of seasonal variation on HCHO during weekdays/weekends, daytime/nighttime in different seasons, 2) tracing the sources variations of HCHO during the different seasons. The results of this study can provide reference data for the evaluation of the status of HCHO that help policy makers to propose control measures for future control strategies.

2. MATERIALS AND METHODS

2.1 Study Area and Sampling Period

A suburban area (15 May City), 29°49′N, 31°22′E, lies approximately 35 km south the center of Cairo with a population of about 300,000 a spread for approximately 50 km^2. It is surrounded by hills and the eastern desert from the east and bounded to the west by a main highway (Heliopolis-Kourimate distinguished with heavy-duty vehicles during the whole year) to Upper Egypt as shown in Fig. 1. The city has been established in the eastern desert to accommodate and redistribute the nation's population away from the fertile Nile Delta region to new desert cities. The main source of air pollutant emissions in the study area originates from traf-

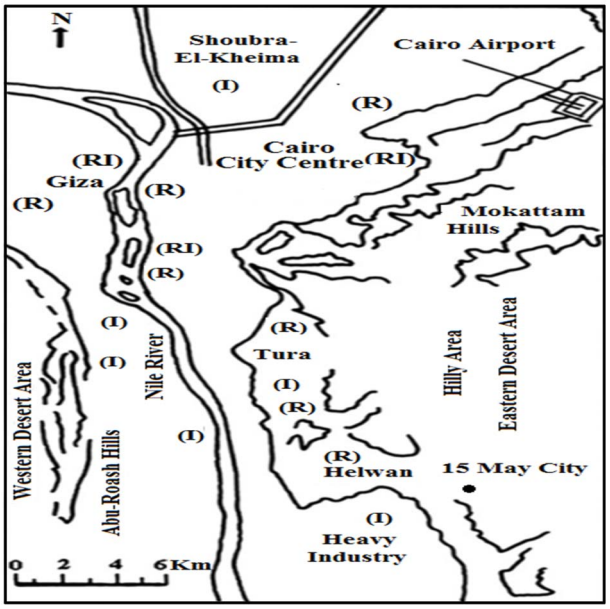

Fig. 1. Map of the Greater Cairo areas showing districts of residential (R), industrial (I), residential industrial (RI) activities and the sampling site (•).

fic activities. Vehicle fuels used in Greater Cairo (Cairo and Giza Governorates and Shoubra El-Khiema city) are mainly unleaded gasoline and diesel, and some vehicles are using compressed natural gas (Hassan and Khoder, 2012). The general climate of Cairo city is cold, moist and rainy in winter, whereas it is characterized by high temperature, high solar radiation, clear sky and rainless during summer. During the period of study, data of the ambient temperature and relative humidity were obtained from Egyptian Meteorological Organization. The daily averages temperature and humidity were 23.2°C and 48.3% in spring, 29.7°C and 56.2% in summer, 24.7°C and 59.0% in autumn and 14.4°C and 62.4% in winter. The daily average wind speeds were 13.13 km/h in spring, 11.25 km/h in summer, 8.71 km/h in autumn and 9.35 km/h in the winter. The mean values of global solar radiation were 11.19 MJ/m^2 in winter and 25.24 MJ/m^2 in summer. North, northeast and northwest were the predominant wind directions during the period of study.

Air samples were collected from a point at approximately 12 m above the ground level, about 100 m faraway the highway. Most of air pollutant emissions in the vicinity of measurement site arise from traffic activities. Daytime and nighttime separately samples were collected in weekdays (working days) and weekends (Friday). Samples were collected twice per week, one every weekend, and in any of the weekdays chosen between Saturday through Thursday. A total of 12 daytime and 12 nighttime HCHO samples in weekdays and also 12 daytime and 12 nighttime samples in weekends during each season were collected. Daytime sampling started from sunrise to sunset (from 7 a.m. to 5 p.m. (winter), 6 a.m. to 6 p.m. (spring), 5 a.m. to 7 p.m. (summer) and 6 a.m. to 5 p.m. (autumn)), while nighttime sampling started from sunset to sunrise (from 5 p.m. to 7 a.m. (winter), 6 p.m. to 6 a.m. (spring), 7 p.m. to 5 a.m. (summer) and 5 p.m. to 6 a.m. (autumn)) Cairo local time during the period of study starting from March 2014 to February 2015.

2.2 Air Sampling and Chemical Analysis

The aldehydes in air were collected in a 0.05% aqueous solution of 3-methyl-2-benzothiazolone hydrazone hydrochloride (MBTH) (Harrison and Perry, 1986). This applied method is relatively free from interference and its collection efficiency is 84%. Air samples were collected in glass bubblers with a coarse fritted inlet containing 35 mL of 0.05% MBTH solution, using a pump calibrated to draw 1 L/min. After each sampling time, the volume of absorbing solution was made up with distilled water to exactly 35 mL (to compensate for evaporation losses) and allowed to stand for 1 h. Ten milliliter of the sample solution were transferred into a clean gas stoppered tube washed with distilled water. An equal volume of unexposed reagent was placed in a second clean tube as a blank. To oxidize the azines of the sample, 2 mL of an oxidizing solution consisting of 1.6 g sulfamic acid (Fluka) and 1.0 g ferric chloride (Sigma) dissolved in 100 mL distilled water was added to sample solution and blank and mixed well. After allowing to stand for at least 12 min, the absorbance of the sample was measured at 628 nm spectrophotometrically against the reagent blank. The aldehyde content (expressed as μg/mL HCHO) was determined directly from the calibration standard curve, and then the air concentration of total aliphatic aldehyde (as HCHO) in ppb was calculated. Replicate field samples and blanks were handled and analyzed in the same manner as mentioned previously. The relative standard deviation (RSD) for replicate analyses of the field samples was 5%. However, the RSD for replicate analyses of the calibration standard was 2%.

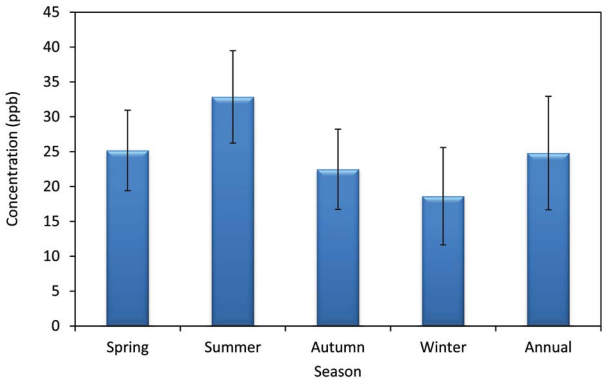

Fig. 2. Seasonal variations and annual mean daily concentrations of HCHO during the period of study at the study area.

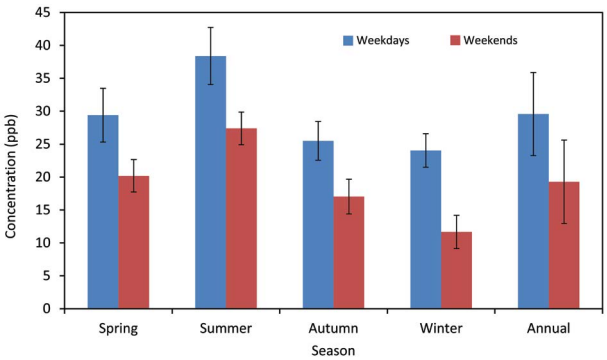

Fig. 3. Seasonal variations in daily HCHO concentrations on weekdays (working days) and weekends (Fridays) during the period of study at the study area.

2.3 Statistical Analysis

SPSS Statistical program version 10 was used to investigate the daytime/nighttime relationship of HCHO concentrations through which 10 regression equations at 95% confidence level were conducted and examined on HCHO concentrations that measured in each season to select the actual relationship between them. The accurate and predominant relationship was selected and operated on the seasonal concentration of HCHO. Student's t-test was used to estimate the significant difference between the mean concentration in different seasons, between weekdays and weekends, and also between daytime and nighttime concentrations.

3. RESULTS AND DISCUSSION

3.1 Seasonal Variation of HCHO Concentrations

HCHO levels in the urban area are greatly influenced by many factors such as direct and indirect sources, photochemical oxidation, meteorological conditions, and its sinks through reaction with OH radical and photodecomposition processes (Duan *et al.*, 2012; Pang and Lee, 2010; Pang *et al.*, 2009; Pang and Mu, 2006). So the trend of seasonal variations in HCHO levels was found to vary from one place to another. In the present study, the seasonal variation of daily mean concentrations of HCHO during the period of study are graphically presented in Fig. 2. The highest daily average HCHO concentration was found in summer and the lowest daily level in winter season. The difference was statistically significant ($p \leq 0.001$). The average concentrations were 25.2 ± 5.8 ppb in spring, 32.9 ± 6.6 ppb in summer, 22.5 ± 5.7 ppb in autumn and 18.6 ± 6.9 ppb in winter. The summer/winter daily concentration ratio of HCHO was 1.77. During the weekdays and weekends, the highest average daily HCHO concentrations were also observed in summer, whereas the lowest concentrations were found in winter (Fig. 3), and the differences in mean concentrations were statistically significant ($p \leq 0.001$). The summer/winter daily concentration ratios of HCHO were 1.59 in weekdays and 2.34 in weekends. These results are consistent with those reported by Possanzini *et al.* (1996), Viskari *et al.* (2000), Feng *et al.* (2005), Grutter *et al.* (2005), Pang and Mu (2006), Seo and Baek (2011) who reported that the highest concentration of HCHO were found in summer. The summer/winter concentration ratio of formaldehyde was 1.47 in Xi'an, China (Dai *et al.*, 2012).

HCHO in the urban atmosphere originates from direct emissions of traffic sources and secondarily from the photochemical reactions. In the present study, the higher HCHO in summer indicates that the contribution of its production from photochemical activity in the observed levels of HCHO might be greater than that of traffic emissions. Ling *et al.* (2017) reported that the half of ambient HCHO in Guangzhou during summer was from photochemical reactions (secondary formation).

Previous investigators (Li *et al.*, 2010; Tago *et al.*, 2005) reported that the similar diurnal patterns of HCHO and O_3 concentrations and the relationship between them indicated that photo-oxidation of nonmethane hydrocarbons (NMHCs) during photochemical activity may be the major source of HCHO. In the

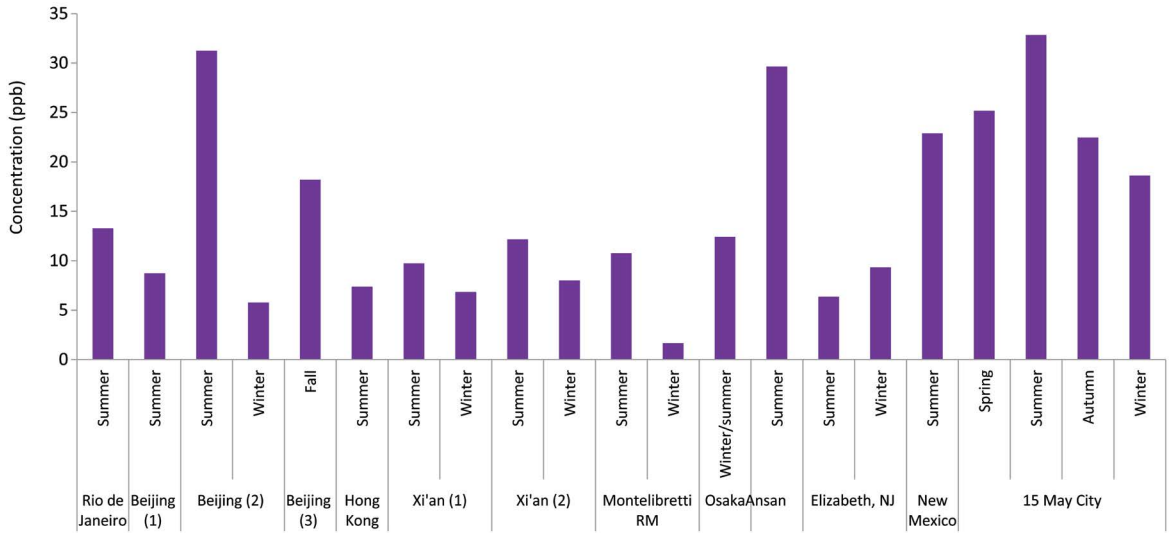

Fig. 4. Comparison of HCHO concentrations for various cities including study area (15 May City), Cairo.

present study, although the concentration of O_3 which can be used as indicator for the intensity of photochemical activity in the atmosphere of Cairo was not measured, previous studies reported that the highest levels of O_3 in Cairo atmosphere were found in summer due to the higher photochemical activity under the effect of favourable meteorological conditions, such as higher temperature, higher solar radiation intensity as well as the longer sunlight hours (Khoder, 2002; Khoder, 2009). In the present study, the higher photochemical reactions in summer leads to an increase the production of secondary HCHO from the photochemical oxidation of hydrocarbons. This is in agreement with Huang *et al.* (2008), Fortems-Cheiney *et al.* (2012), Parrish *et al.* (2012), Dai *et al.* (2012), Chen *et al.* (2014), Cheng *et al.* (2014), Wang *et al.* (2017) who reported that significant amount of atmospheric HCHO was mainly produced from the intense photooxidation of VOCs with OH radicals in the presence of higher temperature and stronger solar radiation during summer. Increased HCHO concentration in summer is attributable not only to the increased volatile emissions, but to the secondary formation of HCHO as a byproduct of photochemical reactions (Moussa *et al.*, 2006; Altshuller, 1993).

The average seasonal concentrations of HCHO in the study area were compared with those found in urban areas in other cities and are shown in Fig. 4 (Dai *et al.*, 2012; Xu *et al.*, 2010; Pal *et al.*, 2008; Possanzini *et al.*, 2007; Wang *et al.*, 2007; Liu *et al.*, 2006; Pang and Mu, 2006; Guo *et al.*, 2004; Grosjean *et al.*, 2002; Nguyen *et al.*, 2001; Gaffney *et al.*, 1997). The Figure reveals that the HCHO levels during spring, autumn and winter in the study area were much higher when compared with those reported for Rio de Janeiro, Beijing (1), Beijing (2), Beijing (3), Hong Kong, Xi'an (1), Xi'an (2), Montelibretti RM, Osaka, Elizabeth, NJ and New Mexico. Moreover, the average HCHO level in summer was much higher than those found in Rio de Janeiro, Beijing (1), Beijing (3), Hong Kong, Xi'an (1), Xi'an (2), Montelibretti RM, and Elizabeth, NJ. The average HCHO levels in summer was similar to that reported for Beijing (2) and relatively higher than that found in Ansan. Generally, HCHO concentrations profile described in Fig. 4 shows that 15 May City is at high ranges among the 12 cities.

3.2 Weekdays/Weekends Variations of HCHO Concentrations

Road traffic density and different anthropogenic activities vary substantially between weekdays (working days) and weekends in urban areas. The difference between air pollutants concentration levels and their chemical composition on weekdays and weekends allows to discriminate the contribution of different sources, especially road vehicles, to the atmospheric load (Khoder and Hassan, 2008; Blanchard and Tanenbaum, 2003). In the present study, in order to investigate the actual impact of traffic emissions on HCHO levels it was essential to put into consideration the

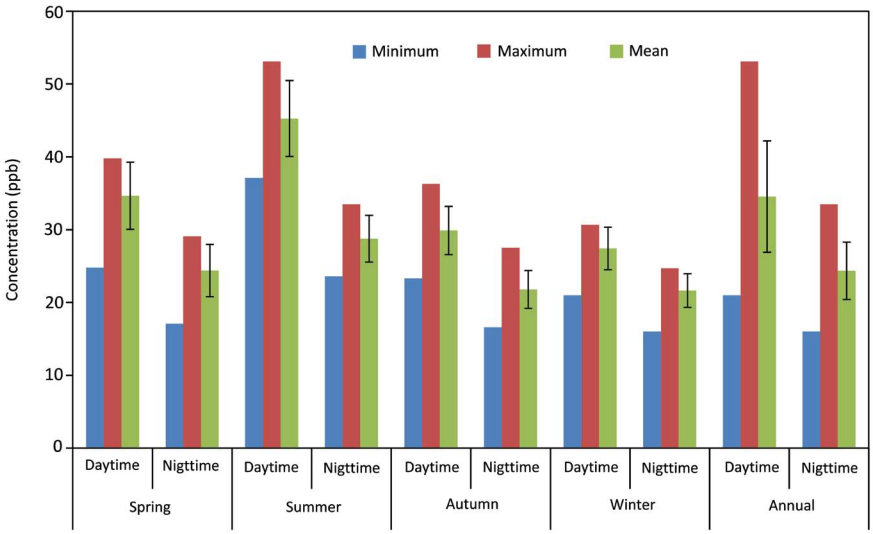

Fig. 5. Daytime and nighttime concentrations of HCHO on weekdays (working days) during the different seasons and the whole period of study at the study area.

weekend effect, by comparing between its levels on weekdays and weekends. The seasonal variations in daily HCHO concentrations during weekdays and weekends during the period of study is represented graphically in Fig. 3. The average HCHO concentrations were higher during weekdays than weekends in all seasons, and the differences were statistically significant ($p \leq 0.001$). The average concentrations of HCHO were 29.4 ppb, 38.39 ppb, 25.5 ppb and 24.05 ppb on weekdays and 20.19 ppb, 27.39 ppb, 17.03 ppb and 11.67 ppb on weekends, during spring, summer, autumn and winter seasons, respectively. During the whole period of study, its concentrations were 29.57 ppb on weekdays and 19.28 ppb on weekends. The weekdays/weekends HCHO concentration ratios were 1.45 on spring, 1.04 on summer, 1.50 on autumn, 2.05 on winter, and 1.53 on the whole period of study. The reduction of HCHO on weekends could be attributed to the decrease in traffic density due to the official days- off of government institutions, schools and colleges. The effect of decreasing traffic density during weekends does not only cause low exhaust HCHO emission (primary source), but also reduces the emission of VOCs which are important in the photochemical production of HCHO (secondary source).

3.3 Daytime/Nighttime Concentrations of HCHO

Studying of the daytime/nighttime variations of air pollutants concentrations can reflect and provide information about the influences of sources, transport and chemical reactions on this pollutants. In urban areas, HCHO concentrations in ambient air are greatly influenced by several factors such as primary and secondary emission sources, meteorological conditions, and their destruction and removal from the atmosphere. In the present study, the minimum, maximum, daytime and nighttime concentrations of HCHO in weekdays and weekends during the different seasons and the whole period of study is graphically presented in Figs. 5 and 6. The average concentrations of HCHO on weekdays and weekends were significantly higher ($p \leq 0.001$) in daytime than nighttime during the different seasons, except on weekends during the autumn and winter seasons. The higher daytime concentrations of HCHO may be attributed to the higher traffic intensity and human activities during daytime and the absence of photochemical activity during nighttime on contrary during daytime. The photochemical reactions during daylight hours contribute approximately 87% to the secondary aldehyde production in Los Angeles city (Kawamura *et al.*, 2000).

During the period of the present study, daytime and nighttime HCHO concentrations ranged respectively from 21 ppb (winter) to 53.1 ppb (summer) and from 16 ppb (winter) to 33.5 ppb (summer) on weekdays (Fig. 5) and from 8.8 ppb (winter) to 35.8 ppb (summer) and from 7.2 ppb (winter) to 25.2 ppb (summer) on weekends (Fig. 6). The highest daytime and night-

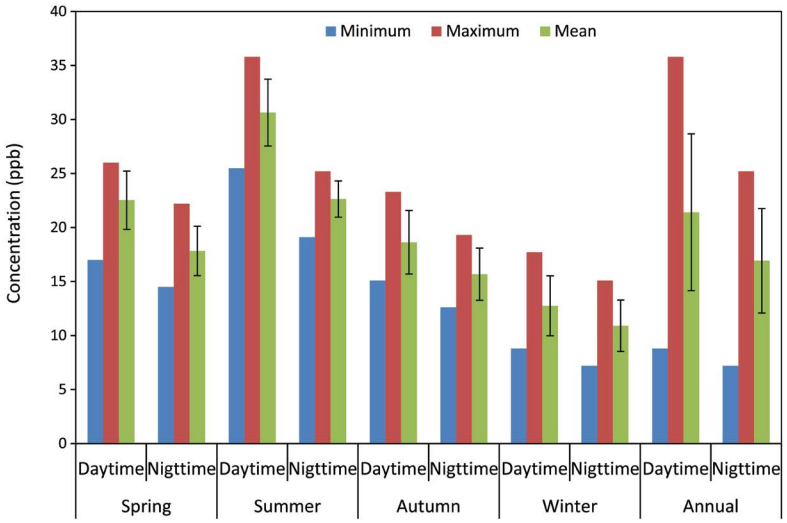

Fig. 6. Daytime and nighttime concentrations of HCHO on weekends (Friday) during the different seasons and the whole period of study at the study area.

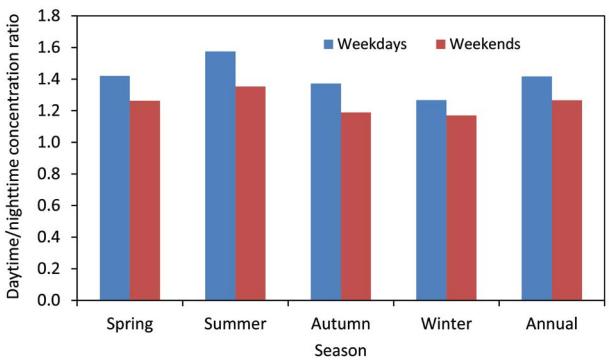

Fig. 7. Daytime/nighttime concentration ratios of HCHO during different seasons and the whole period of study at the study area.

time HCHO concentrations were found on weekdays. During daytime, the weekdays/weekends concentration ratios of HCHO were 1.54 (spring), 1.48 (summer), 1.61 (autumn) and 2.15 (winter). While during nighttime, the ratios were 1.37 (spring), 1.27 (summer), 1.39 (autumn) and 1.99 (winter).

The highest daytime and nighttime concentrations of HCHO on both weekdays and weekends were found in summer, whereas the lowest concentrations were detected in winter, and the differences in mean concentrations were statistically significant ($p \leq 0.001$). Daytime/nighttime concentration ratios of HCHO were 1.42 (spring), 1.57 (summer), 1.37 (autumn), 1.27 (winter) and 1.42 (annual) on weekdays and 1.26 (spring), 1.35 (summer), 1.19 (autumn), 1.17 (winter) and 1.27 (annual) on weekends (Fig. 7). The highest daytime/nighttime ratio in summer suggests that the higher daytime production of secondary HCHO from local photo-oxidation of VOCs might be the dominant source of HCHO in summer beside its primary emission from human activities during the daytime. On the other hand, the lowest daytime/nighttime ratio in winter indicates a lower production of secondary HCHO in daytime due to lower photochemical activity and the primary emission of HCHO was more dominant in winter. Previous studies reported that the secondary formations of aldehydes in summer are larger than their primary emission (Altshuller, 1993), and the photochemical source contributed up to a maximum of 80–90% in summer and 30–35% in winter to the total burden of HCHO in urban air (Possanzini *et al.*, 2002). Dai *et al.*, (2012) concluded that the higher daytime/nighttime HCHO concentration ratio in summer than winter suggests a faster photochemical decomposition and oxidation of other carbonyl compounds such as acetaldehyde leading to formaldehyde.

Data illustrated daytime and nighttime HCHO concentrations had a significant relationship through strong correlation coefficients (R^2). The value of R^2 determined in winter, spring, summer and autumn was respectively in order of 0.95 ($p < 0.001$), 0.97 ($p < 0.001$), 0.87 ($p < 0.001$) and 0.99 ($p < 0.001$) on weekdays. On weekends its value was respectively 0.96 ($p < 0.001$), 0.83 ($p < 0.001$), 0.92 ($p < 0.001$) and 0.97 ($p < 0.001$). In order to investigate the daytime/night-

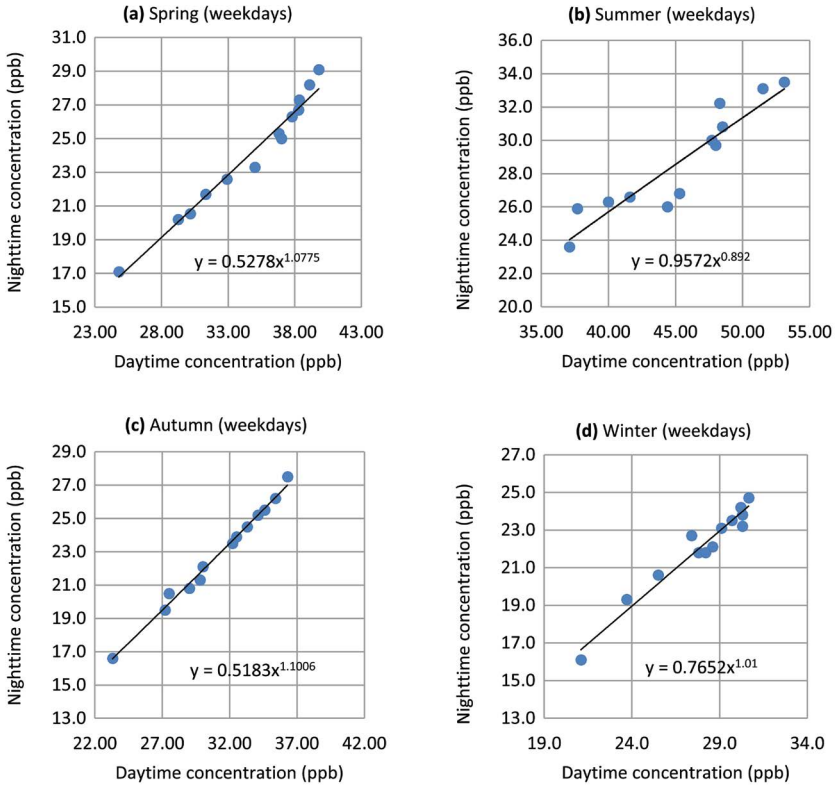

Fig. 8(a-d). Daytime/nighttime relationship of HCHO concentrations on weekdays (working days) during the four seasons at the study area.

time relationship of HCHO concentrations, 10 regression equations at 95% confidence level were conducted and studied for the detected HCHO concentrations to select the actual relationship between them through each season. The perfect and prevalent relationship was chosen and applied on the seasonal concentration of HCHO.

Fig. 8(a-d) shows overviews of the daytime and nighttime relationship of HCHO concentrations on weekdays through winter, spring, summer and autumn, respectively. Whereas Fig. 9(a-d) shows the same relationship on weekends through the four seasons. The Figures clarify obviously there was a similarity in this relationship on weekdays through the four seasons but the same relationship was different from season to other on weekends. The significant correlation coefficients between daytime and nighttime HCHO concentrations among this study imply that HCHO comes from the same pollution sources.

The statistical analysis of obtained data revealed significant positive correlations ($p \leq 0.001$) between daytime HCHO concentrations and the ambient temperature during weekdays and weekends. The correlation coefficients (R^2) ranged from 0.84 to 0.94 on weekends and from 0.92 to 0.99 on weekdays, suggesting that high temperature leads to an increase in the formation of HCHO. Higher temperatures are often associated with intense solar radiation, which are key factors that control the photochemistry processes (Wang *et al.*, 2009), and consequently on the photochemical formation of HCHO (secondary source). Moreover, the favourable meteorological conditions (clear skies, warm temperature and soft winds) have a great influence on O_3 levels (Vecchi and Valli, 1999). O_3 concentrations are positively correlated with temperature (Khoder, 2009; Pudasainee *et al.*, 2006; Vukovich and Sherwell, 2003). This indicates that higher temperatures are associated with high photochemical reactions and O_3 formation, which would have a significant effect on the increasing of HCHO production. The significant positive correlation between HCHO and temperature in the present study is in agreement with a previous investigator (Dutta *et al.*, 2010). Formaldehyde concentrations were significantly higher in warmer than cooler months (Tago *et*

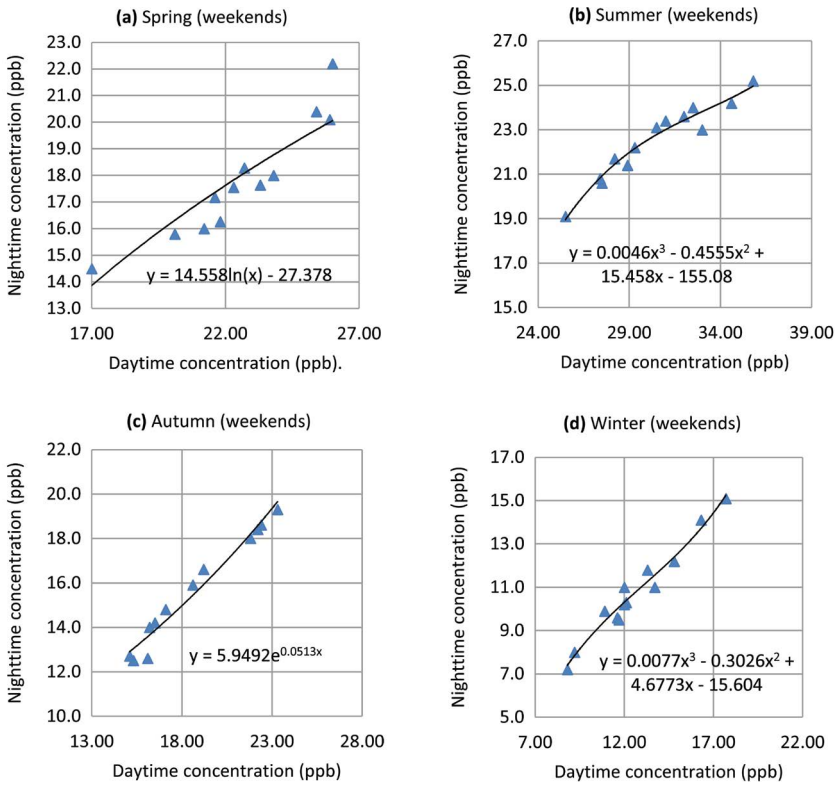

Fig. 9(a-d). Daytme/nighttime relationship of HCHO concentrations on weekends (Friday) during the four seasons at at the study area.

al., 2005). In the present study, insignificant weak correlation coefficients were found between HCHO concentrations and the humidity.

4. LIMITATIONS

Our observations in the present study were made from only one measurement site in a suburban area in Cairo (Egypt) and the results may not reflect the overall situation for Cairo city. Furthermore, only daytime/nighttime and weekdays/weekends variations of the average HCHO concentrations were investigated during the study period. Study the diurnal variations of HCHO and its relation with O_3 are very essential to understand the sources of HCHO and their contributions to photochemical pollution in the atmosphere of Cairo for effective O_3 control measures.

5. CONCLUSIONS AND RECOMMENDATIONS

The present study describes the level, behaviour and sources of HCHO in the atmosphere of a suburban area in Cairo (Egypt), during March 2014–February 2015. Our results showed that HCHO levels in the atmosphere of 15 May City in Cairo were higher than the corresponding values in some cities over the world. Higher levels of HCHO were found on summer, on weekdays, and on daytime. Significant positive correlations were found between daytime and nighttime HCHO concentrations. Daytime HCHO concentrations were significantly positive correlated with ambient temperature. Therefore, the contribution of photochemical activity in the levels of HCHO is clear through the high summer and daytime levels. On the other hand, the high levels of HCHO during weekdays and daytime confirm the contribution of motor vehicles in the HCHO levels.

There is a great tendency for the government to increase the number of vehicles powered by CNG, with a remarkable rise in HCHO emission, as a local alternative fuel substitution of gasoline and diesel. Therefore, monitoring of HCHO is necessary to evaluate the impact of traffic emission (primary source) on its ambient levels and its role in tropospheric photochemistry.

Strategies for controlling the emission of volatile organic compounds from vehicles in order to reduce secondary HCHO formation are also needed.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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