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MEASUREMENTS OF $PM_{2.5}$ AND CO_2 CONCENTRATIONS IN RESIDENTIAL HOUSE IN DAMASCUS, SYRIAN ARAB REPUBLIC

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Introduction

This work represents the results of indoor and outdoor air pollution measurements in Damascus, Syria. $PM_{2.5}$ and CO_2 measurements were carried out by an IQ Air - AirVisual Pro Air Quality Monitor in a flat located on the fourth floor in a residential house in the center region of the city, during a two and a half-month period (July, August and September of 2019). The measurements were done in five parts of the house – four in indoor environment, and one in outdoor. In Syria, only very limited air pollution data are available due to the absence of air quality measuring networks, and there is almost no information about indoor air quality. The main aim of this study was to measure the indoor air quality in the capital city of Syria – which is one of the first investigation in this region – and to show the diurnal variation of $PM_{2.5}$ and CO_2 concentration in indoor environment as well as to point out the relationships between indoor and outdoor air pollution.

Background information

Damascus is the capital city of the Syrian Arab Republic, located in the southwest part of Syria. Geographically Damascus located in the border of Anti-Lebanon mountain range to the west and the Syrian desert to the east with altitude 375–650 m above the sea level (Meslmani, 2004). Damascus has a dry climate in general, with a very hot summer and cool winter (Tyson, 2003). Only few studies have addressed the issue of air pollution in Syria and most of these studies have been on outdoor air pollution. It is almost certain that there are no studies have been done for measuring indoor air pollutants, as well-reviewed in (Cornille et al., 1990; Meslmani, 2004; Al-Masri et al., 2006; Ahmad et al., 2020).

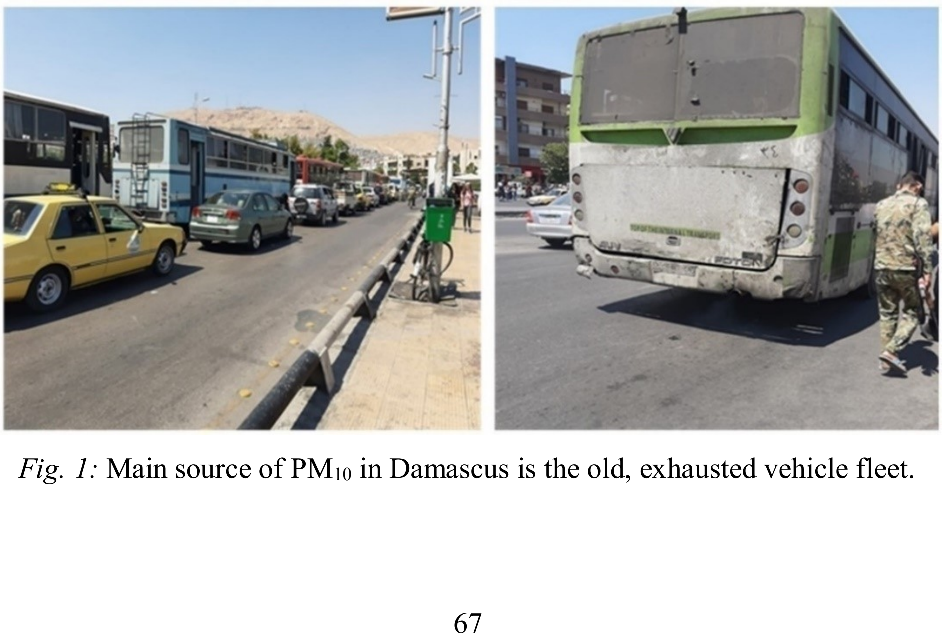

Fig. 1: Main source of PM_{10} in Damascus is the old, exhausted vehicle fleet.

According to Meslmani (2004), the main pollutant in Damascus is PM_{10}. The main source of PM_{10} is vehicles beside the sand particles which is originated from natural sources (Meslmani, 2004). In case of traffic emission, the old fleet of vehicles and traffic jams is also a problem (*Fig. 1*). Waste burning (*Fig. 2*) is a minor source of PM particles, but have a huge impact on other pollutants (75% of Zn and Sb concentrations – Cornille et al., 1990). Another source of air pollution in Damascus is diesel generators used by houses, restaurants and shops, during periods, when there is no electricity (*Fig. 3*). Some houses also use fuel for heating water and the houses during the winter.

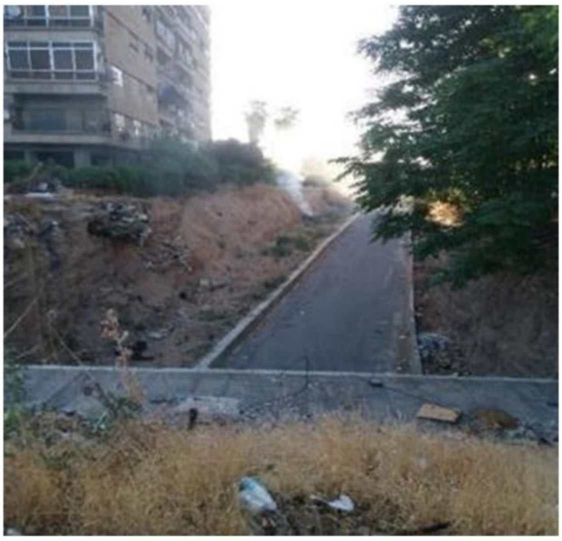

Fig. 2: Random waste burning on the street in the city center at 6.30 AM.

Fig. 3: Diesel generators in the streets. The chimneys of the generators are higher than the level of the houses.

Material and methods

The indoor air quality inside a house in a residential area in the center region of Damascus (Syria) was investigated in the summer of 2019 (from July till September). Measurements were carried out by using an IQ Air – Air Visual Pro Air Quality Monitor. The monitor offers real-time $PM_{2.5}$ concentration but it is also able to measure carbon dioxide (CO_2) concentration, air temperature, and relative humidity that updates in real-time for continuous monitoring (IQ air quality monitor, 2019). The measurements were made in five parts of the house which is located on the highest floor of the building. Indoor air pollution measurements were done in four rooms (saloon, living room, kitchen and bedroom), while outdoor measurements were carried out on the terrace as shown in *Table 1*. Concentration values were registered at every 5 minutes, and hourly average values were calculated each period.

Table 1: Location and brief description of the selected monitoring sites.

Site no.	Site name	Type of measured $PM_{2.5}$	Measurement period (2019)	Description
1	Saloon	Indoor	1 July – 18 July	The height of measurement = 1 m, the saloon is medium size, located near to the kitchen separated by a small corridor.
2	Living room	Indoor	19 July – 15 August	The height of measurement = 1.5 m, the living room located near to the saloon and has a door connected to the balcony.
3	Kitchen	Indoor	16 August – 1 September	The height of measurement = 2.7 m, the kitchen is small and separated by a small corridor from the house door.
4	Terrace	Outdoor	2 September – 8 September	The height of measurement = 2.2 m, the terrace is very big and separated from the house.
5	Bedroom	Indoor	9 September – 13 September	The height of measurement = 0.6 m, the bedroom has a big window connected directly to the street.

Environmental background

There are several restaurants, shops and bars in the quarter surrounding the measuring site. Usually, the electricity cut down without a specific timetable in Damascus, for that each restaurant and shop have its diesel generator on the street. The total number of diesel generators in that alley was 6 (*Fig. 4*).

Fig. 4: Six diesel generators used by restaurants and shops located along the street. These generators operate during the periods, when there is no electricity.

The random operation of these generators can periodically influence the air quality, but we could not detect the exact effects of these emission sources.

Next to the local emission sources, the transport of air pollutants from other regions could also modify the air quality. To analyze this effect, the wind speed and wind direction during the measuring period were investigated. Wind data were only available from Damascus International Airport in three hours resolution (about 30 km from the measuring site). Wind rose, and frequency distribution of wind speed can be seen in *Fig. 5* and *Fig. 6*, respectively.

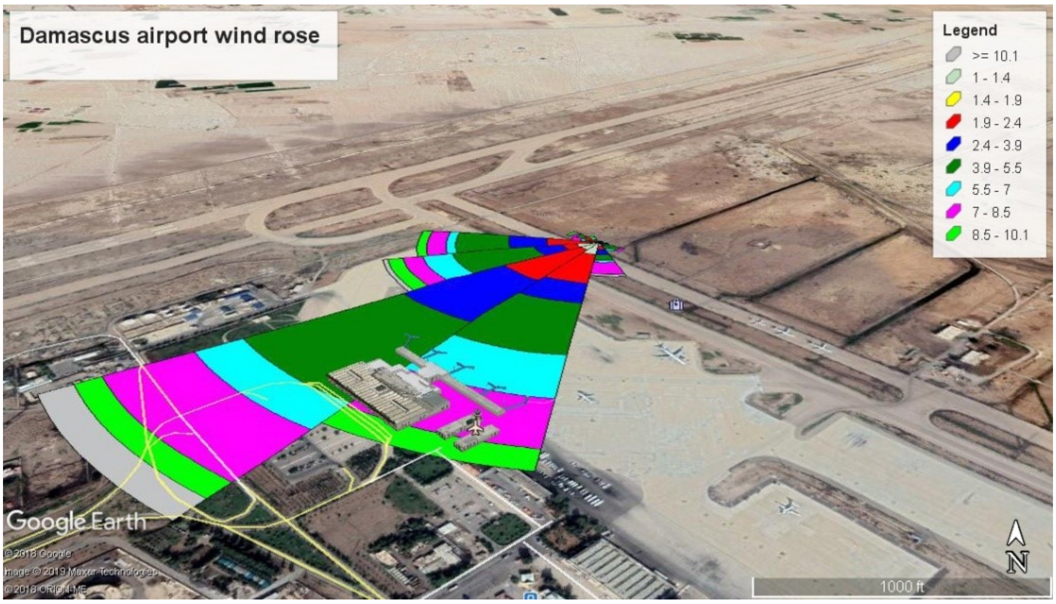

Fig. 5: The wind rose for Damascus International Airport Station for the period 1st July –31th August, 2019 with the frequency of wind speed categories.

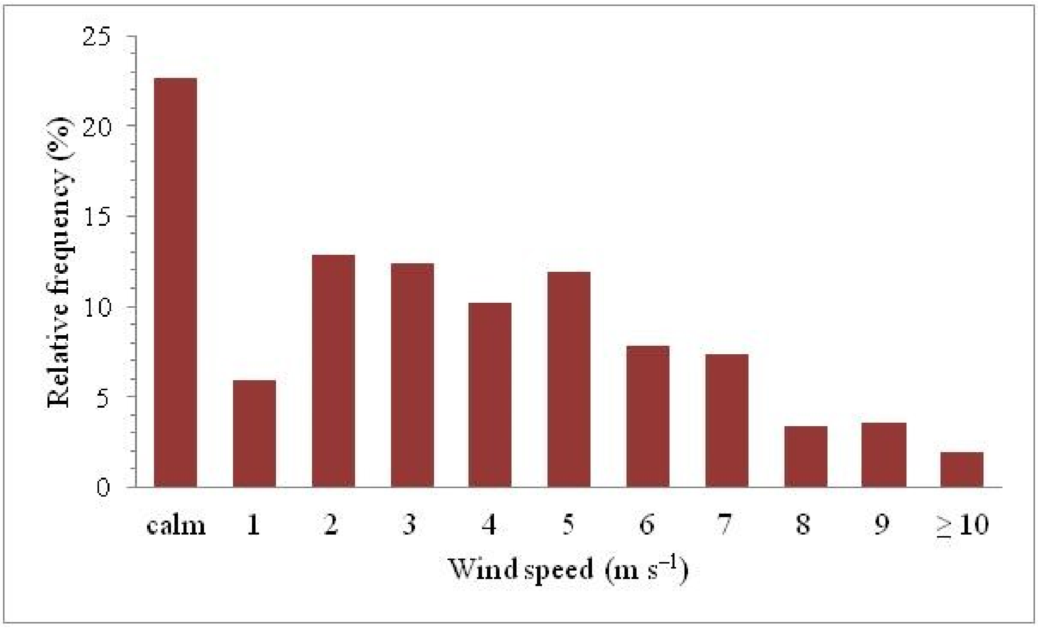

Fig. 6: Frequency distribution of wind speed for Damascus International Airport Station for the period 1st July – 31th August, 2019.

During the whole measuring period the most frequent wind direction was south-westerly. In this case air mass transported from a desert/semi-desert area, which might have increased the outdoor PM concentration. However the wind speed was generally low in this region; the most frequent category was "calm", and wind speed values between 2 and 5 m s^{-1} occurred more frequently. All this information suggests that air quality was affected mainly by local sources during the measuring period.

Results and discussion

Based on the measurements every five minutes, hourly averages and average daily courses of $PM_{2.5}$ concentrations were calculated for each site during five different periods (*Fig. 7*).

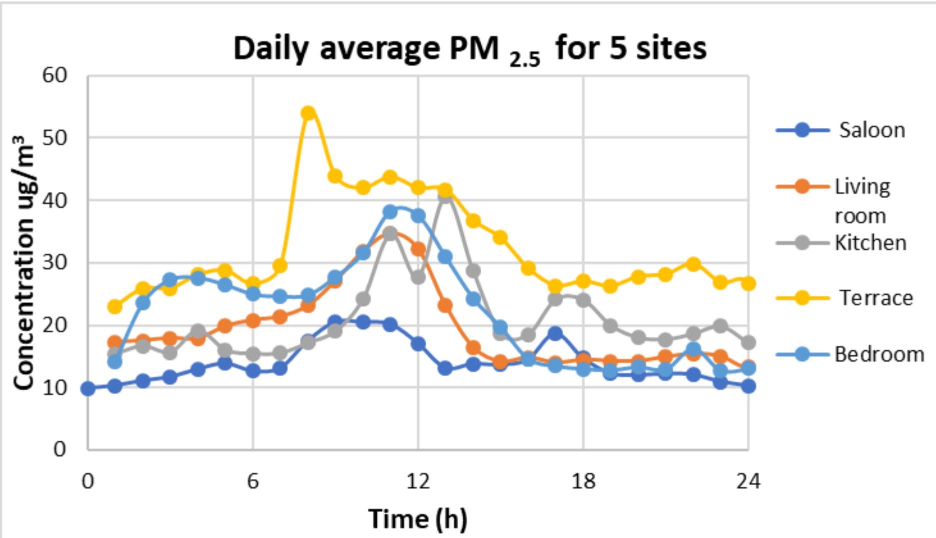

Fig. 7: Average daily courses of indoor and outdoor $PM_{2.5}$ concentrations for 5 locations. Indoor concentrations were measured in a saloon, living room, kitchen and bedroom, while outdoor concentration was measured in a terrace by IQ Air – Air Visual Pro Air Quality Monitor.

Although measurements at different locations were carried out at different periods, the typical daily courses show some clear differences among the measuring sites. Our results show that outdoor concentrations of $PM_{2.5}$ (in the terrace) were higher than indoor values. The better air quality in indoor environment is presumably due to the filters used in air conditioning systems that worked in the summer heat. The morning peak in the course of outdoor measurements most likely due to higher traffic in morning hours. Differences in indoor measurements show the effects of human activities, such as cooking in the kitchen. Higher concentrations in bedroom (especially in nighttime) are probably due to the fact that the window of this room faces the street, so there is a stronger connection to the outdoor air quality.

Next to $PM_{2.5}$ concentration, average daily courses of CO_2 concentration were also investigated. *Fig. 8* shows that CO_2 concentration was higher in all indoor cases, than outdoor environment. Highest values were found in the kitchen and in the bedroom during daytime and nighttime, respectively.

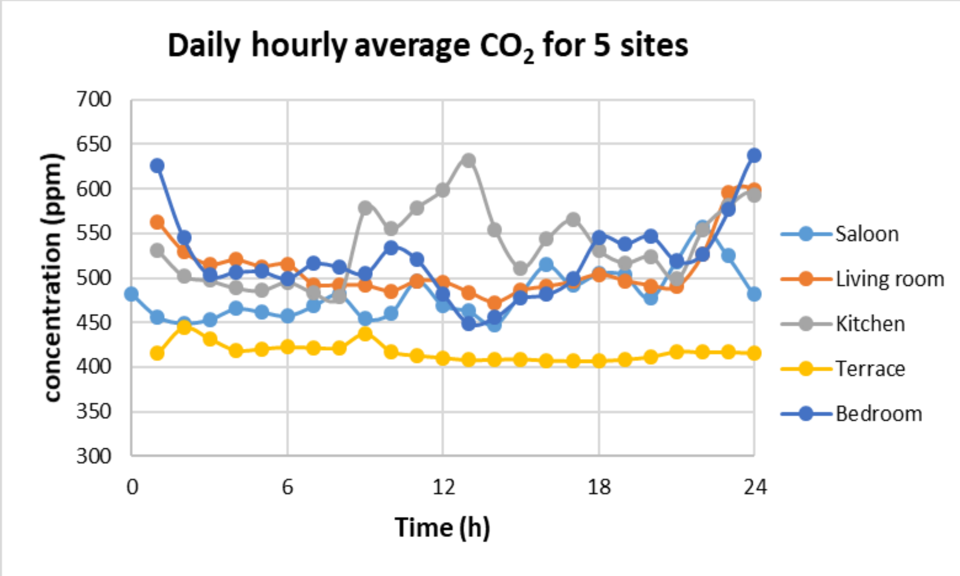

Fig. 8: Average daily courses of indoor and outdoor CO_2 concentrations for 5 measurements locations. Indoor concentrations were measured in a saloon, living room, kitchen and bedroom while outdoor concentration was measured in a terrace by IQ Air – Air Visual Pro Air Quality Monitor.

The air quality can also be characterized by different air quality indices. In this study, we used the US AQI for $PM_{2.5}$, because the applied sensor registers this value. The air quality index (AQI) shows the effects of different pollutants on human health. *Table 2* shows the each category of AQI for $PM_{2.5}$. *Fig. 9* gives a general overview about the air quality for $PM_{2.5}$ at different sites during the measuring periods. Based on these data, the air quality were mainly good and moderate during the measuring campaign, and only for outdoor environment was unhealthy for sensitive groups, or even unhealthy in larger proportion (24% and 4%, respectively).

Table 2: US AQI levels (World air quality report, 2018).

US AQI Level			$PM_{2.5}$ concentration (μg/m³)
1	Good	0–50	0–12.0
2	Moderate	51–100	12.1–35.4
3	Unhealthy for sensitive groups	101–150	35.5–55.4
4	Unhealthy	151–200	55.5–150.4
5	Very unhealthy	201–300	150.5–250.4
6	Hazardous	301+	250.5+

Low cost sensors are widely used tools for measure the indoor air quality. Despite the fact that these devices have a greater uncertainty compared to reference equipment's (Karagulian et al., 2019), low cost sensors can give some useful information about the temporal and spatial variability of air quality.

It is necessary to emphasize that our measurements were only related to a short time period (two and a half months) and for a specific site (a flat in Damascus center). Moreover, in Syria, due to the absence of outdoor air quality monitoring stations and limited meteorological measurements, we could not compare our results with reference values. At the same time, our former investigation (Bushra and Mészáros, 2019) shows, that there is an appropriate correlation between the time series of $PM_{2.5}$ concentration measured by the applied low cost sensor and reference instruments. Some useful information has been obtained about indoor air quality for a region, from which only a very limited former data are available about air pollution. In this work, we presented only our preliminary results of an experiment with a low cost sensor.

Several investigations in different conditions (e.g. winter season) would be necessary in the future.

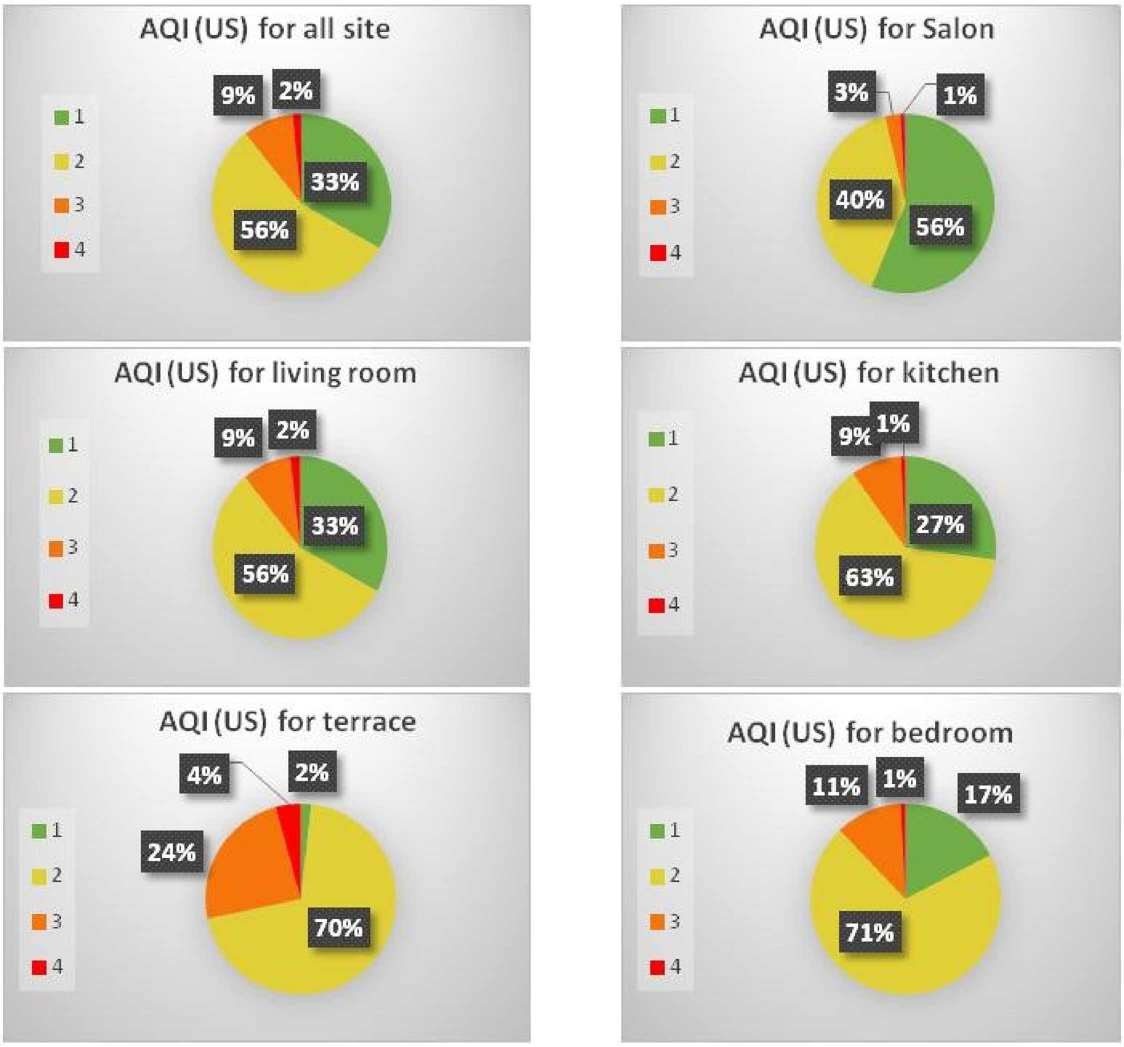

Fig. 9: Proportion of air quality levels for $PM_{2.5}$ (US air quality index)
for all five sites and for individual sites.

Acknowledgement

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