Measurement of Fines Particle Concentrations and estimation of Air Quality Index (AQI) over Northeast Douala, Cameroon

Cyrille A. Mezoue (mezoueadiang@yahoo.fr)
National Higher Polytechnic School of Douala, University of Douala P.O. Box: 2701, Douala
Yannick C. Ngangmo
Faculty of Science, University of Douala, P.O. Box: 24157, Douala
Arti Choudhary
Centre of Environment Climate Change and Public Health, Utkal University Bhubaneswar Odisha, 751004,
Severin Nguiya
National Higher Polytechnic School of Douala, University of Douala P.O. Box: 2701, Douala
Andre Lenouo
Faculty of Science, University of Douala, P.O. Box: 24157, Douala
David Monkam
Faculty of Science, University of Douala, P.O. Box: 24157, Douala

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Abstract

The paucity of data regarding air quality monitoring and pollutant emissions from various sources in the city of Douala, allowed us to initiate a measuring campaign at the main road entrance of the university campus. Using the OC 300 Laser Dust Particle, fines particles concentrations are monitored during one week from Monday to Sunday. The instrument used detects four (04) different sizes of particles: PM_{10}, PM_5, $PM_{2.5}$, and PM_1. The daily average concentrations measured ranged from 9.47 ± 0.26 to 50.14 ± 2.42 μg.m^{-3} for $PM_{1.0}$; 13.13 ± 0.38 to 86.65 ± 3.96 μg.m^{-3} for $PM_{2.5}$; 13.60 ± 0.40 to 100.56 ± 4.20 μg.m^{-3} for PM_5 and 14.52 ± 0.42 to 114.59 ± 4.60 μg.m^{-3} for PM_{10}. Exceptions made from PM_5 and $PM_{1.0}$ which were not in relation to the WHO (World Health Organization) guideline values, the level of PM_{10} and $PM_{2.5}$ are higher than the WHO standards. The air quality index (AQI) is between very poor and poor during this measurement campaign, indicating that residents of the study region are highly exposed. Through the use of correlation studies, it has been demonstrated that the predominant source of fine particles in the studied region is vehicular activity. As a result, traffic density is the most significant factor causing the different air pollution levels seen in the tested areas.

1. Introduction

A significant risk factor for endangering human health is air pollution. Due to the increased growth of the economy and population, there is a tremendous demand for environmental resources in urban areas (Leem et al., 2015). An estimated 7 million people die from air pollution each year, accounting for 12.5% of all fatalities globally. By 2050, air pollution is predicted to overtake all other environmental causes of mortality (OECD, 2012; WHO, 2014). Airborne particles are regarded as one of the biggest hazards to human health in urban environments because they considerably contribute to poor air quality (El Raey, 2006; Graff et al., 2009; McKenzie et al., 2011; Tang et al., 2014). The size of airborne particles ranges widely, from a few nanometers (nm) to around 100 micrometers (μm). All particles up to 50 micrometers (μm) in diameter that may float in the atmosphere for extended periods of time are referred to as total suspended particulate matter (TSP) (Cao and Orrù, 2014; Vallero, 2014).

Particularly, particulate matter (PM) is typically identified by a number that indicates its aerodynamic diameter. PM10 (breathable) and PM2.5 (fine), for instance, refer to particles with nominal mean aerodynamic diameters of 10 m and 2.5 m, respectively (Schleicher, 2012). The fact that particulate matter from sources other than exhaust gases also significantly contributes to concentrations in the air has been brought to light by reductions in exhaust emissions. Other than exhaust gases, abrasive sources such as tire wear, road surface abrasion, home heating, household waste combustion, and printing plants are the main contributors of particulate matter (Antonel and Chowdhury, 2014). In metropolitan areas, brake and tire wear are a substantial source of trace metals, and in areas with high traffic, they may even be more significant than industrial emissions.

Additionally, particularly in drier regions, the re-suspension of particles from the road surface can be crucial (Abu-Allaban et al., 2003). Numerous studies on the health impacts of particulate matter have revealed a significant relationship between human mortality and particulate matter concentration (Dockery et al., 1993). The same author also affirmed that, an increase in PM2.5 concentration of 10 g/m^3 was associated with an increase of up to 3.3% in elderly patients admitted for cardio-respiratory conditions. According Berico et al., 1997, PM2.5 was substantially connected with fatalities from lung cancer and cardiopulmonary disease as well as declines in lung function and deaths from respiratory and cardiovascular disorders. This damage frequently occurs, when the guidelines established by regulatory bodies for air quality, such as the WHO, are exceeded. There are, in fact, mass concentrations ascribed to particles based on their sizes: $50µg.m^{-3}$, $25µg.m^{-3}$ respectively PM_{10}, $PM_{2.5}$ for daily exposure, and $20µg.m^{-3}$, $10µg.m^{-3}$ respectively PM_{10}, $PM_{2.5}$ for annual exposure) (WHO, 2006). Any organization regulating air quality has pushed for research that might create limits exceeding PM5 and PM1.0 dust levels.

The World Bank's "clean Air Initiative in Sub-Saharan African Cities" program was responsible for the first studies on air quality in Cameroon. This was follow by few study on air quality mainly on gaseous pollutants such as CO (Mezoue A. et al., 2017; Mezoue et al., 2017). The first studies on PMs in Cameroon are those carried out by Antonel and Chowdhury, 2014, in three cities for during 9 days every 24 hours, in the dry season. The daily average concentrations at Bafoussam, Bamenda and Yaoundé for $PM_{2.5}$ were: 67 ± 14, 132 ± 64 and 49 ± 12 $µg.m^{-3}$ and for PM_{10}: 105 ± 29, 141 ± 107 and 65 ± $21µg.m^{-3}$ respectively. Insufficient equipment is available in Central Africa to control air quality by tracking particulate matter concentrations over a long period of time. Recently Gravimetric analyses were carried out in the city of Yaoundé and compared to WHO limits, the annual mean was slightly lower for PM2.5 (9 ± 3 µg/m3) and exceedingly higher for PM10 (30 ± 8 µg/m3) (Nducol et al., 2020). Similar studies are carried out in some significant West African capitals, for instance, the average PM2.5 concentration in Cotonou, Benin, is approximately 463.25 ± 66.21 $µg.m^{-3}$ at a junction and 264.75 ± 50.97 $µg.m^{-3}$ beyond the junction (Houngbégnon et al., 2019). The average $PM_{2.5}$ concentration in Nigeria, and more specifically in Enugu State, ranges from 1.67 to 12.16 $µg.m^{-3}$. In Dakar, Senegal, the concentrations of PM_{10} and $PM_{2.5}$ range from 120 to $180µg.m^{-3}$ and 25 to 48 $µg.m^{-3}$, respectively (Sow et al., 2021).

The city of Douala continues to be one of the most heavily urbanized and populous cities in central Africa, not to mention having a booming industrial sector. These indicators are elements that may have an impact on the rise in air pollution concentration thresholds in metropolitan areas (Houngbégnon et al., 2019; Kumar et al., 2015). However, the town's PM pollution is still not well understood. The purpose of the paper is to estimate the PM concentration on a major road that leads to the university area and a semi-urban zone with a significant rate of population growth.

Pollutants measured using OC 300 Laser Dust Particle is particulate: PM_{10}, PM_5, $PM_{2.5}$ and $PM_{1.0}$.The measurement campaign was carried out for 7 days from 02 August to 08 August 2021, between 6–10 am and 4-8pm. The choice of time slots is justified by the fact that several works locate the heavy traffic during these periods, which correspond to the hours when people leave the house and the times of return (Houngbégnon et al., 2019; Mezoue et al., 2017; Onyeka et al., 2020). This data will also allow us to evaluate the Air Quality Index (AQI) to get an idea of the air quality in our study area.

2. Materials And Methodology

Our investigation of changes in the elemental concentrations of PM1.0, PM2.5, PM5, and PM10 in Douala, Cameroon began on August 2nd and will conclude on August 8th, 2021.

2.1. Study areas

Cameroon is situated near the Gulf of Guinea in Central Africa (Fig. 1). It lies between latitudes 1° 40'–13° 05' N and longitudes 8° 30'–16° 10' E, and covers a surface area of about 475,650 km^2. It is divided into two climatic regions: the humid tropical region in the south, and the semi-arid region in the north (Ndarwe et al., 2019; Ngongang et al., 2021). Douala is the economic capital of the country and located at 9.7° E and 4.0° N at the Atlantic coast, by the Wouri River. The weather is very hot and the town has significant rainfall (Lenouo et al., 2009; Sighomnov et al., 1993; Tanessong et al., 2017). The average temperature in douala is 26.2°C and the average annual precipitation is 3,702 mm; with 39 mm of precipation, december is the driest month of the year. August, with an average of 681 mm, shows the higth rainfall (Ngongang et al., 2021). It is subjected to an equatorial climate, and influenced by the West African monsoon flux deviated to the east. It is uplifted by the Mount Cameroon Mountain, located at 60 km west and culminating at 4070 m (Ndarwe et al., 2019). The measuring point geolocalized by Latitude: 4.0922 Longitude: 9.8019 is on the major road that leads to the university area and a semi-urban zone with a significant rate of population growth (Fig. 1).

2.2. Study Site and Data Collection

Data collection is a necessary stage in every study, whether applied or fundamental. Data are a vital requirement for a study's quality. The data utilized in this study originates from measurements taken using an OC 300 Laser dust particle detector (Oceanus, 2016). The latter is a computerized instrument that monitors the concentrations ($\mu g.m^{-3}$) of four (04) fine particle sizes at the same time (PM10, PM5, PM2.5, and PM1.0). The device was situated around five (05) meters from a road at a height of approximately 1.50 m.

2.3. AQI calculation

An Air Quality Index (AQI) is produced on a daily basis to determine pollutant concentrations and has become an essential tool for characterizing pollution and sending alerts in the event of significant air quality degradation (Sharma et al., 2020; Sow et al., 2021). The AQI ranges from 0 to 500 (Table 1). The higher the value, the greater the risk to public health. When the contamination level is less than or equal to 50, the air quality is considered satisfactory and poses no health hazards. An index higher than or equal to 100, on the other hand, poses health dangers, and when the level of 200 is reached, a health alert is issued. In such instances, each individual may suffer catastrophic health consequences. When the index rises above 300, a general alarm is issued, along with emergency actions (Hashim et al., 2021; Sow et al., 2021).

Table 1
AQI Standard values and Quality Index category (Sow et al., 2021)

Air Quality Index(AQI)	**Air Quality Index category**
0–50%	Good
51–100%	Moderate
101–200%	Bad
201–500%	Very Bad

The approach provided in the following equation was used to estimate AQI (Sow et al., 2021):

$$AQI = \frac{Pollutant\ Concentration}{Limit\ Value} \times 100$$

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Four particle matters were measured (PM_{10}, PM_5, $PM_{2.5}$, and PM_1). Because Cameroon lacks laws governing the concentration thresholds of air contaminants, the WHO's suggested values (Table 2) are utilised (particulate matter and gaseous pollutants). It should be noted, however, that threshold values are only known for two particles in this scenario, PM_{10} and $PM_{2.5}$.

Table 2
Air quality limit values for WHO (WHO, 2014).

Pollutants	Time average	Limit values ($\mu g.m^{-3}$)
		WHO guidelines
PM_{10}	Daily	50
	Annual	20
PM_5	Daily	–
	Annual	–
$PM_{2.5}$	Daily	25
	Annual	10
PM_1	Daily	–
	Annual	–

3. Results And Discussion

3.1. Hourly variation of fine particle concentrations

Figure 2 was generated by analyzing data from the 07-day measurement campaign that took place from August 2nd to August 8th, 2021, utilizing the OC 300 Laser Dust Particle. The meteorological data are obtained from the OGIMET database via satellite (OGIMET, 2022). Because it has previously been utilized in multiple scientific papers, the OGIMET database is a credible source of data. August is Cameroon's rainiest month, with rainfall of up to 700 or even 900 mm (Ndarwe et al., 2019). The air quality is monitored twice a day, between 06 am to 10 am and 4 pm to 8 pm because, according to the literature, multiple investigations Adiang et al., 2017; Houngbégnon et al., 2019; Onyeka et al., 2020, identified these time slots as having very high pollutant concentration thresholds. As a result of the selection of these varied time periods, Fig. 2 usually shows the different fluctuations in fine particle concentrations in $\mu g.m^{-3}$ throughout the course of the seven-day campaign. The peaks in Fig. 2 represent the hourly-daily variations in the concentrations of fine particles, these different peaks of concentrations are greater than the guidelines set by the World Health Organization (50 $\mu g.m^{-3}$ for PM_{10}, 20 $\mu g.m^{-3}$ for $PM_{2.5}$).The resulting curves represent the peaks of hourly variation in mass concentrations ($\mu g.m^{-3}$) of fine particulate matter (PM_{10}, PM_5, $PM_{2.5}$ and $PM_{1.0}$) as a function of time. Each particle is materialized by a color on the different curves: PM_{10} are materialized by the green color, PM_5 by the yellow color, $PM_{2.5}$ by the red color and $PM_{1.0}$ by the blue color.

The average daily change in PMs is determined using Fig. 2 (Fig. 3). The obtained PM mass concentrations range between: $9.47 \pm 0.26–50.14 \pm 2.42$ $\mu g.m^{-3}$ for $PM_{1.0}$; $13.13 \pm 0.38–86.65 \pm 3.96$ $\mu g.m^{-3}$ for $PM_{2.5}$; $13.60 \pm 0.40–100.56 \pm 4.20$ $\mu g.m^{-3}$ for PM_5 and $14.52 \pm 0.42–114.59 \pm 4.60$ $\mu g.m^{-3}$ for PM_{10} (see Table 3).

Table 3
Hourly average change in data obtained from the measurement campaign (± SD):(a) First day, (b) Second day, (c) Third day, (d) Fourth day, (e) Fifth day, (f) Sixth day, Seventh day.

(a)	**Particulate Matter (µg.m^{-3})**			
Time (hour)	**$PM_{1.0}$**	**$PM_{2.5}$**	**PM_5**	**PM_{10}**
6–7 am	43.17 ± 1.85	64.31 ± 2.57	69.84 ± 2.52	75.92 ± 2.49
7–8 am	46.25 ± 2.07	68.79 ± 3.23	73.88 ± 3.34	79.52 ± 3.45
8–9 am	36.01 ± 1.68	54.31 ± 2.64	59.49 ± 2.64	65.13 ± 2.79
9–10 am	37.01 ± 1.90	57.29 ± 2.85	63.24 ± 3.02	69.64 ± 3.19
4–5 pm	32.70 ± 2.24	54.47 ± 4.47	63.69 ± 4.74	73.27 ± 5.01
5–6 pm	34.68 ± 2.13	57.29 ± 3.18	67.74 ± 3.38	78.74 ± 3.61
6–7 pm	39.52 ± 1.92	65.14 ± 3.18	76.22 ± 3.50	87.81 ± 3.87
7–8 pm	40.52 ± 1.63	64.05 ± 2.65	72.42 ± 2.85	81.21 ± 3.05

(b)	**Particulate Matter (µg.m^{-3})**			
Time (hour)	**$PM_{1.0}$**	**$PM_{2.5}$**	**PM_5**	**PM_{10}**
6–7 am	9.47 ± 0.26	13.13 ± 0.38	13.60 ± 0.40	14.52 ± 0.42
7–8 am	34.01 ± 2.84	50.18 ± 4.80	52.84 ± 5.00	56.11 ± 5.21
8–9 am	44.03 ± 2.42	60.10 ± 3.36	67.58 ± 3.38	72.58 ± 3.41
9–10 am	29.45 ± 2.04	41.38 ± 2.82	43.72 ± 2.89	46.48 ± 2.97
4–5 pm	26.63 ± 0.84	41.78 ± 1.32	48.19 ± 1.47	55.05 ± 1.65
5–6 pm	30.22 ± 1.46	49.23 ± 2.26	57.23 ± 2.43	65.81 ± 2.60
6–7 pm	39.02 ± 2.02	64.12 ± 2.90	68.97 ± 2.97	77.67 ± 2.08
7–8 pm	36.26 ± 2.08	57.43 ± 3.41	65.68 ± 3.63	74.43 ± 3.86

(c)	Particulate Matter (μg.m⁻³)			
Time (hour)	$PM_{1.0}$	$PM_{2.5}$	PM_5	PM_{10}
6–7 am	33.34 ± 2.09	49.52 ± 3.02	54.20 ± 3.10	59.33 ± 319
7–8 am	49.47 ± 2.37	74.18 ± 3.37	81.48 ± 3.47	89.28 ± 3.61
8–9 am	37.50 ± 2.41	60.72 ± 3.97	69.38 ± 4.30	78.54 ± 4.68
9–10 am	36.87 ± 2.39	60.83 ± 4.13	70.70 ± 4.59	81.05 ± 5.09
4–5 pm	39.45 ± 2.14	70.87 ± 4.20	85.41 ± 4.80	100.68 ± 5.46
5–6 pm	37.83 ± 1.74	67.72 ± 3.19	83.00 ± 3.82	98.64 ± 4.47
6–7 pm	47.29 ± 2.54	83.75 ± 4.79	98.67 ± 5.30	114.11 ± 5.83
7–8 pm	50.14 ± 2.42	86.65 ± 3.96	100.56 ± 4.20	114.59 ± 4.60

(d)	Particulate Matter ($\mu g.m^{-3}$)			
Time (hour)	$PM_{1.0}$	$PM_{2.5}$	PM_5	PM_{10}
6–7 am	41.40 ± 3.07	62.18 ± 5.06	66.95 ± 5.13	72.28 ± 5.91
7–8 am	50.79 ± 2.61	78.72 ± 5.34	84.00 ± 5.61	89.93 ± 5.91
8–9 am	44.89 ± 2.34	65.83 ± 3.92	70.24 ± 3.98	75.04 ± 4.04
9–10 am	41.52 ± 2.25	65.15 ± 4.94	70.26 ± 5.23	76.05 ± 5.60
4–5 pm	29.82 ± 0.90	48.43 ± 1.40	56.87 ± 1.62	65.78 ± 1.87
5–6 pm	29.48 ± 1.36	48.81 ± 2.31	57.26 ± 2.64	66.15 ± 3.03
6–7 pm	33.32 ± 2.09	54.37 ± 3.21	63.66 ± 3.42	73.47 ± 3.66
7–8 pm	39.45 ± 1.68	65.01 ± 3.22	75.36 ± 3.67	86.22 ± 4.18

(e)	Particulate Matter ($\mu g.m^{-3}$)			
Time (hour)	$PM_{1.0}$	$PM_{2.5}$	PM_5	PM_{10}
6–7 am	37.86 ± 2.27	59.35 ± 3.76	66.49 ± 3.86	74.01 ± 3.97
7–8 am	32.98 ± 1.65	49.29 ± 2.41	54.19 ± 2.55	59.59 ± 2.70
8–9 am	44.07 ± 2.41	68.60 ± 3.82	76.35 ± 3.94	84.57 ± 4.09
9–10 am	34.43 ± 1.45	57.27 ± 2.24	68.01 ± 2.45	79.24 ± 2.74
4–5 pm	35.29 ± 1.89	61.39 ± 3.71	72.68 ± 4.25	84.42 ± 4.84
5–6 pm	35.77 ± 1.62	60.98 ± 2.97	71.81 ± 3.49	83.18 ± 4.07
6–7 pm	37.09 ± 1.73	61.42 ± 2.74	72.16 ± 2.93	83.43 ± 3.18
7–8 pm	36.45 ± 1.61	58.83 ± 2.76	67.50 ± 2.91	76.70 ± 3.07

(f)	Particulate Matter ($\mu g.m^{-3}$)			
Time (hour)	**$PM_{1.0}$**	**$PM_{2.5}$**	**PM_5**	**PM_{10}**
6–7 am	30.14 ± 0.93	47.35 ± 1.65	54.57 ± 1.88	62.29 ± 2.14
7–8 am	48.52 ± 2.43	79.87 ± 4.24	91.78 ± 4.55	104.13 ± 4.86
8–9 am	31.11 ± 1.30	50.45 ± 2.32	58.90 ± 2.82	67.82 ± 3.35
9–10 am	32.73 ± 2.32	58.93 ± 5.85	70.37 ± 7.01	82.02 ± 8.16
4–5 pm	37.36 ± 1.34	64.48 ± 2.32	76.92 ± 2.75	89.82 ± 3.24
5–6 pm	38.71 ± 1.86	67.00 ± 3.40	79.86 ± 4.04	93.38 ± 4.79
6–7 pm	34.96 ± 1.39	58.93 ± 2.31	69.70 ± 2.62	80.87 ± 2.97
7–8 pm	36.97 ± 1.84	62.31 ± 4.55	71.89 ± 4.88	81.96 ± 5.23

(g)	Particulate Matter ($\mu g.m^{-3}$)			
Time (hour)	**$PM_{1.0}$**	**$PM_{2.5}$**	**PM_5**	**PM_{10}**
6–7 am	27.33 ± 1.20	43.70 ± 1.93	50.92 ± 2.19	58.63 ± 2.44
7–8 am	37.67 ± 2.43	62.93 ± 4.13	73.32 ± 4.33	84.19 ± 4.65
8–9 am	37.09 ± 2.12	60.68 ± 3.69	70.02 ± 4.13	79.75 ± 4.57
9–10 am	44.79 ± 2.42	64.97 ± 3.61	69.59 ± 3.64	74.64 ± 3.66
4–5 pm	38.04 ± 2.11	56.17 ± 3.40	60.64 ± 3.47	65.75 ± 3.55
5–6 pm	31.86 ± 1.99	45.00 ± 2.98	47.68 ± 3.10	50.86 ± 3.21
6–7 pm	29.95 ± 1.18	42.88 ± 1.74	46.06 ± 1.79	49.83 ± 1.85
7–8 pm	35.87 ± 2.31	52.17 ± 3.54	55.74 ± 3.62	59.74 3.72

The various PM concentration patterns throughout the measurement campaign are shown in Fig. 3. The concentrations of the particulate matter during the measurement days were then statistically analyzed. The mean, the categorization of pollutants (minimum and maximum), the standard deviation (SD), the standard error (SE), and the coefficient of asymmetric distribution are the statistical components considered in this work.

3.2. Parameters influencing variations in fine particle concentrations

The various variances seen in Fig. 3 result from various differences in daily traffic patterns or weather conditions. According to several research (Amgalan et al., 2016; Cataldo and González, 2018; Das et al., 2021; Houngbégnon et al., 2019; Sahu et al., 2020), meteorological factors can affect changes in the mass concentrations of PMs in ambient air. Some authors (Hashim et al., 2021; Houngbégnon et al., 2019; Mezoue et al., 2017; Onyeka et al., 2020) have demonstrated that the change in mass concentrations of concentrations can also rely on the density of road traffic during measurement hours. The specific cause of the numerous variations in the mass concentrations of tiny particles in the context of our inquiry is not known. The three meteorological factors considered in this study are temperature, relative humidity, and wind speed. It is significant to note that the measuring campaign was conducted during the wet season, which is supported by the relative humidity reading, which ranges from 87–94.6%. (Fig. 3). It's observed that, the climatic characteristics in Fig. 4 are consistent throughout all measurement campaign days. The fact that humidity has a direct influence on temperature and wind speed and that the more humid an area is, the less variable the meteorological parameters are. Regarding how humidity affects wind speed, Houngbégnon et al., (2019) demonstrates that $PM_{2.5}$ concentrations are greater during wet seasons than they are during dry ones. The explanations that follow from these findings are that during the rainy season, the amount of particles dispersed is lower owing to the quiet or moderate wind speed, and that the threshold of concentrations at the location of measurement rises the less a particle disperses. There is no association between the hourly fluctuations of fine particles and climatic factors, as shown in Fig. 4. This variance, in our opinion, results from traffic.

3.3. Analysis of the causes of small particles using linear regression

The campaign is conducted in an open area where there may be a variety of possible sources of fine particles (the pavement, restaurants, bakeries, carpentry, printing, welding workshops, etc ...). In this work, an interest in determining which sources would originate from the particles is considered similarly as Hashim et al.,(2021) which assessed the mass concentrations of four pollutants during the COVID-19 pandemic lockdown in IRAQ: PM10, PM2.5, NO2, and O3 to determine if the pollutants all originated from the same source. So, research on the correlations between the different contaminants has been conducted.

All the pairings of particles for each measurement day exhibit substantial correlations with one another, as shown in Table 4 below, which summarizes the various correlations recorded for each measurement day. The idea that fine particles mostly originate from a single source may next be examined.

Table 4
Study on the origin of fine particle by the linear regression method

Campaigns days	pairs of particles	R^2 (correlation coefficients)	regression equations
Day 1	PM_{10}; PM_1	0.8707	$y = 1.6797x + 11.206$
	PM_1; PM_5	0.9196	$y = 0.5652x + 0.2055$
	$PM_{2.5}$; PM_5	09876	$y = 0.9435x - 3.7482$
	PM_{10}; PM_5	0.9906	$y = 1.056x + 4.2653$
	$PM_{2.5}$; PM_{10}	0.9581	$y = 0.8757x - 6.2033$
	$PM_{2.5}$; PM_1	0.956	$y = 1.5747x - 0.4192$
Day 2	PM_{10}; PM_1	0.9208	$y = 1.6516x + 6.4707$
	PM_1; PM_5	0.951	$y = 0.6015x - 0.2899$
	$PM_{2.5}$; PM_5	0.9928	$y = 0.9421x - 2.0927$
	PM_{10}; PM_5	0.9942	$y = 1.0586x + 2.5648$
	$PM_{2.5}$; PM_{10}	0.9746	$y = 0.8792x - 3.7499$
	$PM_{2.5}$; PM_1	0.9513	$y = 1.4084x - 0.2156$
Day 3	PM_{10} ; PM_1	0.8432	$y = 1.9443x + 11.436$
	PM_1 ; PM_5	0.9025	$y = 0.4992x + 1.3376$
	$PM_{2.5}$; PM_5	0.9853	$y = 0.8928x - 2.5214$

Campaigns days	pairs of particles	R^2 (correlation coefficients)	regression equations
	PM_{10} ; PM_5	0.9903	$y = 1.1075x + 3.0054$
	$PM_{2.5}$; PM_{10}	0.9527	$y = 0.7888x - 3.3506$
	$PM_{2.5}$; PM_1	0.9534	$y = 1.6712x - 0.0532$
Day 4	PM_{10} ; PM_1	0.8142	$y = 1.7943x + 5.9869$
	PM_1 ; PM_5	0.8638	$y = 0.4953x + 5.1071$
	$PM_{2.5}$; PM_5	0.9905	$y = 0.9487x - 3.5391$
	PM_{10} ; PM_5	0.9923	$y = 1.0554x + 3.7833$
	$PM_{2.5}$; PM_{10}	0.967	$y = 0.8848x - 5.8693$
	$PM_{2.5}$; PM_1	0.9021	$y = 1.6993x - 4.9125$
Day 5	PM_{10} ; PM_1	0.8172	$y = 1.7946x + 12.22$
	PM_1 ; PM_5	0.8891	$y = 0.519x + 1.1052$
	$PM_{2.5}$; PM_5	0.982	$y = 0.9132x - 3.0547$
	PM_{10} ; PM_5	0.9869	$y = 1.0856x + 3.6251$
	$PM_{2.5}$; PM_{10}	0.9396	$y = 0.8175x - 4.2506$
	$PM_{2.5}$; PM_1	0.947	$y = 1.6292x - 0.2163$
Day 6	PM_{10} ; PM_1	0.8389	$y = 2.4254x - 5.2555$

Campaigns days	pairs of particles	R^2 (correlation coefficients)	regression equations
	PM_1 ; PM_5	0.8802	$y = 0.4032x + 7.3822$
	$PM_{2.5}$; PM_5	0.9888	$y = 0.8661x - 0.9726$
	PM_{10} ; PM_5	0.9929	$y = 1.1335x + 1.4534$
	$PM_{2.5}$; PM_{10}	0.965	$y = 0.7521x - 1.0952$
	$PM_{2.5}$; PM_1	0.9187	$y = 1.9425x - 9.3695$
Day 7	PM_{10} ; PM_1	0.8789	$y = 1.6786x + 6.1171$
	PM_1 ; PM_5	0.9291	$y = 0.5716x + 1.4682$
	$PM_{2.5}$; PM_5	0.988	$y = 0.9403x - 2.1424$
	PM_{10} ; PM_5	0.9909	$y = 1.0569x + 2.8096$
	$PM_{2.5}$; PM_{10}	0.9589	$y = 0.7825x - 3.5183$
	$PM_{2.5}$; PM_1	0.9676	$y = 1.5693x - 1.8785$

The measurement campaign is being conducted in August, a month when most academic institutions are on break. Holidays have the immediate effect of forcing some activity on university and neighbourhood property to cease. Therefore, during this monitoring campaign, the main source of fine particulate matter in the vicinity of the research area is road traffic. This justifies the cause of the changes in concentrations in Fig. 4 once again. The particle pairs, correlation coefficients (R^2), and regression equations are shown in Table 4. In the days leading up to campaigns, a significant link between the pairs of PMs is demonstrated (Table 4 and Fig. 5, 6, 7, 8, 9, 10, 11).

3.4. Air quality index

Assessment of the air quality index is made using Eq. 1, data gathered during the measurement campaign, and Table 2, which contained the WHO guideline values. The air quality index (AQI) over the Northeast of the city of Douala between August 2 and August 8, 2021, is depicted in Fig. 12. Out of the four detected particles, an estimate of the AQI for two fine particles is made. The AQI ranges from 115.66 to 184.14 for PM10 and from 191.11 to 244.64 for PM2.5 (see Fig. 12). All of the one-week data's AQI levels range from poor to extremely poor.

The AQI research also enables us to comprehend the population's degree of exposure in this area. According to the research of Houngbégnon et al. 2019, humidity does not encourage the dispersion of pollutants; hence the fact that the quality index is low may also be explained by the fact that it is rainy season. In fact, Fig. 11 demonstrates that $PM_{2.5}$ has an AQI that is consistently greater than PM_{10}. With the use of this new knowledge, a particle's health hazard increases with particle size is confirmed. According to our theory, fine particles can more readily pass through the body's finest blood arteries, leading to major health issues.

4. Conclusion

Based on the daily average concentration values that are over WHO guidelines (see Fig. 2) and the bad to very poor air quality index (see Fig. 12 and Table 5), which were acquired during air quality monitoring campaigns, this help to conclude that, the air that locals breathe is not always of high quality in the study region. Fine particles in air is causing severe health issues on the population, such as malignancies, asthma, eye discomfort, and respiratory and cancers. Particulate matter is produced by biomass fires, industry, and road transportation. Due to the lack of bituminous roads, which are the sources of PMs in metropolitan areas, the threshold of particle matter frequently rises there. The relevance of conducting an air quality monitoring campaign can be realized or made known thanks to this study. Additionally, it enables the authorities to take strong action to prevent circumstances in which the WHO guidance levels in metropolitan areas are exceeded. This entails resurfacing municipal streets with asphalt, monitoring the quality of the lubricants and fuels used by cars, replacing the fleet of vehicles on a regular basis, and applying imposed Euro standards on automobiles. Cameroon will be able to adopt its own standard value for the concentration of small particles in the air thanks to several campaigns like this one on air quality. Effective management is needed over the traffic fleet, the growth of the GDF and people, excellent roads, and a host of other factors before we can set our own limit levels.

Table 5
Air Quality Index (AQI) and Air Quality Index category for different day of the measurement Campaign

Day of the measurement Campaign	Air Quality Index (AQI)	Air Quality Index category
$PM_{2.5}$		
Day_1	242.80	Very Bad
Day_2	191.16	Bad
Day_3	227.12	Very Bad
Day_4	244.24	Very Bad
Day_5	238.56	Very Bad
Day_6	244.64	Very Bad
Day_7	214.24	Very Bad
PM_{10}		
Day_1	125.00	Bad
Day_2	115.66	Bad
Day_3	184.14	Bad
Day_4	151.22	Bad
Day_5	156.28	Bad
Day_6	165.28	Bad
Day_7	130.84	Bad

Declarations

Authors' Contributions:

Cyrille Adiang Mezoue and Yannick Cedric Ngangmo: Conceptualization, Methodology, Formal analysis, Writing : original draft, Writing : review & editing.

Arti Choudhary: Data curation - Prepared figures – review & editing

Severin Nguiya: review & editing.

Andre Lenouo and David Monkam: review & editing, Supervision, and Project administration.

Data availability: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Statements and Declarations

Ethics approval: Not applicable.

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Competing interests: The authors declare no competing interests.

References

1. Abu-Allaban, M., Gillies, J.A., Gertler, A.W., Clayton, R., Proffitt, D., 2003. Tailpipe, resuspended road dust, and brake-wear emission factors from on-road vehicles. Atmos. Environ. 37, 5283–5293.
2. Amgalan, N., Narantsetseg, T., Shagjjamva, D., 2016. Valuations of elemental concentrations of particle matter in Ulaanbaatar, Mongolia. Open J. Air Pollut. 5, 160.
3. Antonel, J., Chowdhury, Z., 2014. Measuring ambient particulate matter in three cities in Cameroon, Africa. Atmos. Environ. 95, 344–354. https://doi.org/10.1016/j.atmosenv.2014.06.053
4. Berico, M., Luciani, A., Formignani, M., 1997. Atmospheric aerosol in an urban area—measurements of TSP and PM10 standards and pulmonary deposition assessments. Atmos. Environ. 31, 3659–3665.
5. Cao, G., Orrù, R., 2014. Current environmental issues and challenges. Springer.
6. Cataldo, J., González, A.E., 2018. Analysis of the Relation between Particle Matter Concentration and Meteorological Parameter at Montevideo City. Open J. Air Pollut. 7, 120.
7. Das, M., Das, A., Sarkar, R., Mandal, P., Saha, S., Ghosh, S., 2021. Exploring short term spatio-temporal pattern of PM2. 5 and PM10 and their relationship with meteorological parameters during COVID-19 in Delhi. Urban Clim. 39, 100944.
8. Dockery, D.W., Pope, C.A., Xu, X., Spengler, J.D., Ware, J.H., Fay, M.E., Ferris, B.G., Speizer, F.E., 1993. An association between air pollution and mortality in six US citites. N Engl J Med 329, 1753–1759. https://doi.org/10.1056/nejm199312093292401
9. El Raey, M., 2006. Air quality and atmospheric pollution in the Arab region. ESCWA/League Arab States, United Nations Environ. Program. Reg. Off. West Asia.
10. Graff, D.W., Cascio, W.E., Rappold, A., Zhou, H., Huang, Y.-C.T., Devlin, R.B., 2009. Exposure to concentrated coarse air pollution particles causes mild cardiopulmonary effects in healthy young adults. Environ. Health Perspect. 117, 1089–1094.
11. Hashim, B.M., Al-Naseri, S.K., Al-Maliki, A., Al-Ansari, N., 2021. Impact of COVID-19 lockdown on NO2, O3, PM2. 5 and PM10 concentrations and assessing air quality changes in Baghdad, Iraq. Sci. Total Environ. 754, 141978.
12. Houngbégnon, Parfait, Ayivi-Vinz, G., Lawin, H., Houessionon, K., Tanimomon, F., Kêdoté, M., Fayomi, B., Dossou-Gbété, S., Agueh, V., Houngbégnon, P, 2019. Exposure to PM 2.5 Related to Road Traffic:

Comparison between Crossroads and Outside of Crossroads at Cotonou, Benin. Open J. Air Pollut. 8, 108–117. https://doi.org/10.4236/OJAP.2019.84006

13. Kumar, A., Dikshit, A.K., Fatima, S., Patil, R.S., 2015. Application of WRF model for vehicular pollution modelling using AERMOD. Atmos. Clim. Sci. 5, 57.
14. Leem, J.H., Kim, S.T., Kim, H.C., 2015. Public-health impact of outdoor air pollution for 2nd air pollution management policy in Seoul metropolitan area, Korea. Ann. Occup. Environ. Med. 27. https://doi.org/10.1186/S40557-015-0058-Z
15. Lenouo, A., Monkam, D., Vondou, D. a., Tanessong, R. s., Mkankam Kamga, F., 2009. Analyse des conditions météorologiques pour la sécurité aérienne à Douala. La Météorologie 8, 46. https://doi.org/10.4267/2042/27951
16. McKenzie, J., Pinger, R., Kotecki, J., 2011. An introduction to community health. Jones & Bartlett Publishers.
17. Mezoue A., C., Monkam, D., Njeugna, E., Gokhale, S., 2017. Projecting impacts of two-wheelers on urban air quality of Douala, Cameroon. Transp. Res. Part D Transp. Environ. 52, 49–63. https://doi.org/10.1016/j.trd.2017.02.010
18. Mezoue, A.C., Monkam, D., Lenouo, A., Njeugna, E., Gokhale, S., 2017. Evaluating impacts of two-wheeler emissions on roadside air quality in the vicinity of a busy traffic intersection in Douala, Cameroon. Air Qual. Atmos. Heal. 10, 521–532. https://doi.org/10.1007/s11869-016-0445-9
19. Ndarwe, D., Bongue, D., Monkam, D., Moudi, P., Philippon, N., KenfacK, C.A., 2019. Analysis of the diurnal to seasonal variability of solar radiation in Douala, Cameroon. Theor. Appl. Climatol. 138, 249–261.
20. Nducol, N., Tchuente Siaka, Y.F., Younui Yakum-Ntaw, S., Saidou, Dika Manga, J., Vardamides, J.C., Hamadou, Y.A., Simo, A., 2020. Ambient air particle mass concentrations in the urban area of the capital city of Yaoundé (Cameroon, Central Africa): monthly and seasonal behaviour. https://doi.org/10.1080/03067319.2020.1715378 101, 2909–2925. https://doi.org/10.1080/03067319.2020.1715378
21. Oceanus, 2016. Handheld Laser particle counter with optical sensor [WWW Document]. URL https://www.ocgasdetector.com/en/product/Handheld-Laser-particle-counter-with-optical-sensor.html (accessed 11.27.21).
22. OECD, 2012. OECD Environmental Outlook to 2050: The Consequences of Inaction - OECD.
23. OGIMET, 2022. Ogimet home page [WWW Document]. URL https://www.ogimet.com/index.phtml.en (accessed 9.21.22).
24. Onyeka, O., Ifeyinwa, O.C., Ernest, E., Adunola, I.B., Onyinye, N.J., 2020. Out-Door Air Pollution Levels in Vehicular-Traffic Junctions in Nsukka Metropolis, Enugu Metropolis and Awgu Semi-Urban Area in Enugu State, Nigeria. Open J. Air Pollut. 9, 105–115.
25. Sahu, S.K., Sharma, S., Zhang, H., Chejarla, V., Guo, H., Hu, J., Ying, Q., Xing, J., Kota, S.H., 2020. Estimating ground level PM2.5 concentrations and associated health risk in India using satellite

based AOD and WRF predicted meteorological parameters. Chemosphere 255, 126969. https://doi.org/10.1016/J.CHEMOSPHERE.2020.126969

26. Schleicher, N.J., 2012. Chemical, Physical and Mineralogical Properties of Atmospheric Particulate Matter in the Megacity Beijing. KIT Scientific Publishing.
27. Sharma, S., Zhang, M., Gao, J., Zhang, H., Kota, S.H., 2020. Effect of restricted emissions during COVID-19 on air quality in India. Sci. Total Environ. 728, 138878.
28. Sighomnov, D., Nkamdjou, S., Tanyileke, G., 1993. Les fortes pluies de la région du mont Cameroun: le cas d'Idenau. La Météorologie.
29. Sow, B., Tchanche, B., Fall, I., Souaré, S., Mbow-Diokhané, A., 2021. Monitoring of Atmospheric Pollutant Concentrations in the City of Dakar, Senegal. Open J. Air Pollut. 10, 18.
30. Tanessong, R.S., Vondou, D.A., Djomou, Z.Y., Igri, P.M., 2017. WRF high resolution simulation of an extreme rainfall event over Douala (Cameroon): a case study. Model. Earth Syst. Environ. 3, 927–942.
31. Tang, D., Wang, C., Nie, J., Chen, R., Niu, Q., Kan, H., Chen, B., Perera, F., 2014. Health benefits of improving air quality in Taiyuan, China. Environ. Int. 73, 235–242. https://doi.org/10.1016/J.ENVINT.2014.07.016
32. Vallero, D., 2014. Fundamentals of air pollution. Academic press.
33. WHO, 2014. 7 million premature deaths annually linked to air pollution.
34. WHO, W.H.O., 2006. Lignes directrices OMS relatives à la qualité de l'air: particules, ozone, dioxyde d'azote et dioxyde de soufre: mise à jour mondiale 2005: synthèse de l'évaluation des risques. Genève: Organisation mondiale de la Santé.

Figures

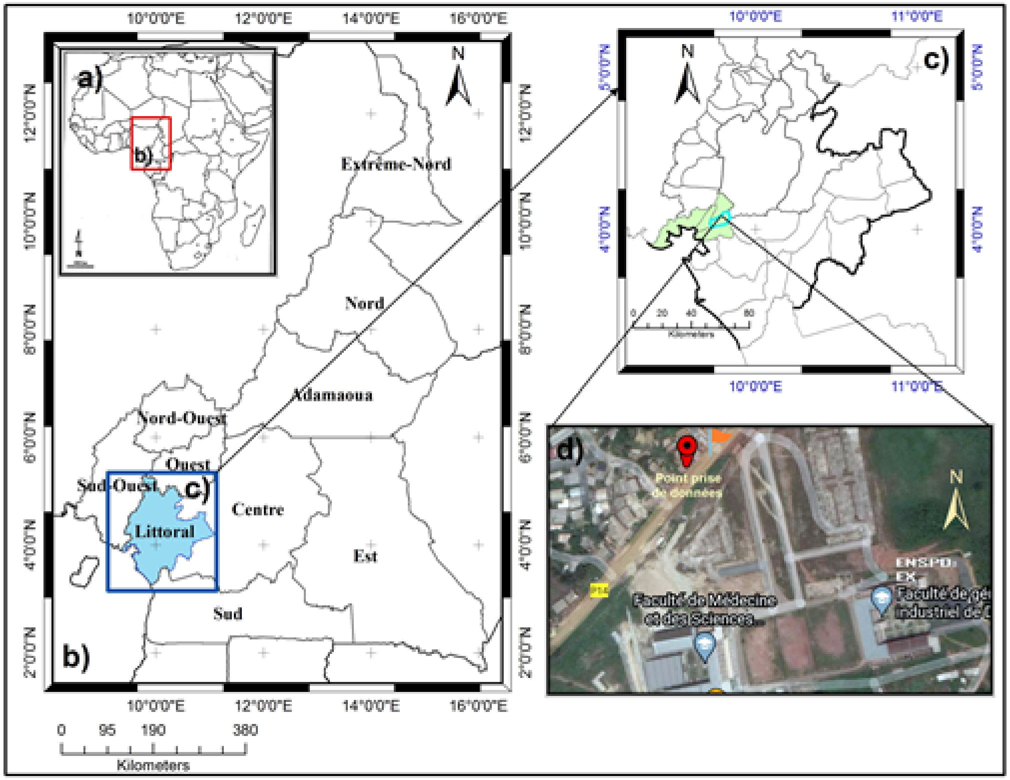

Figure 1

Location of study area : (a) Africa; (b) Cameroon; (c) Douala city; (d) Measurement point.

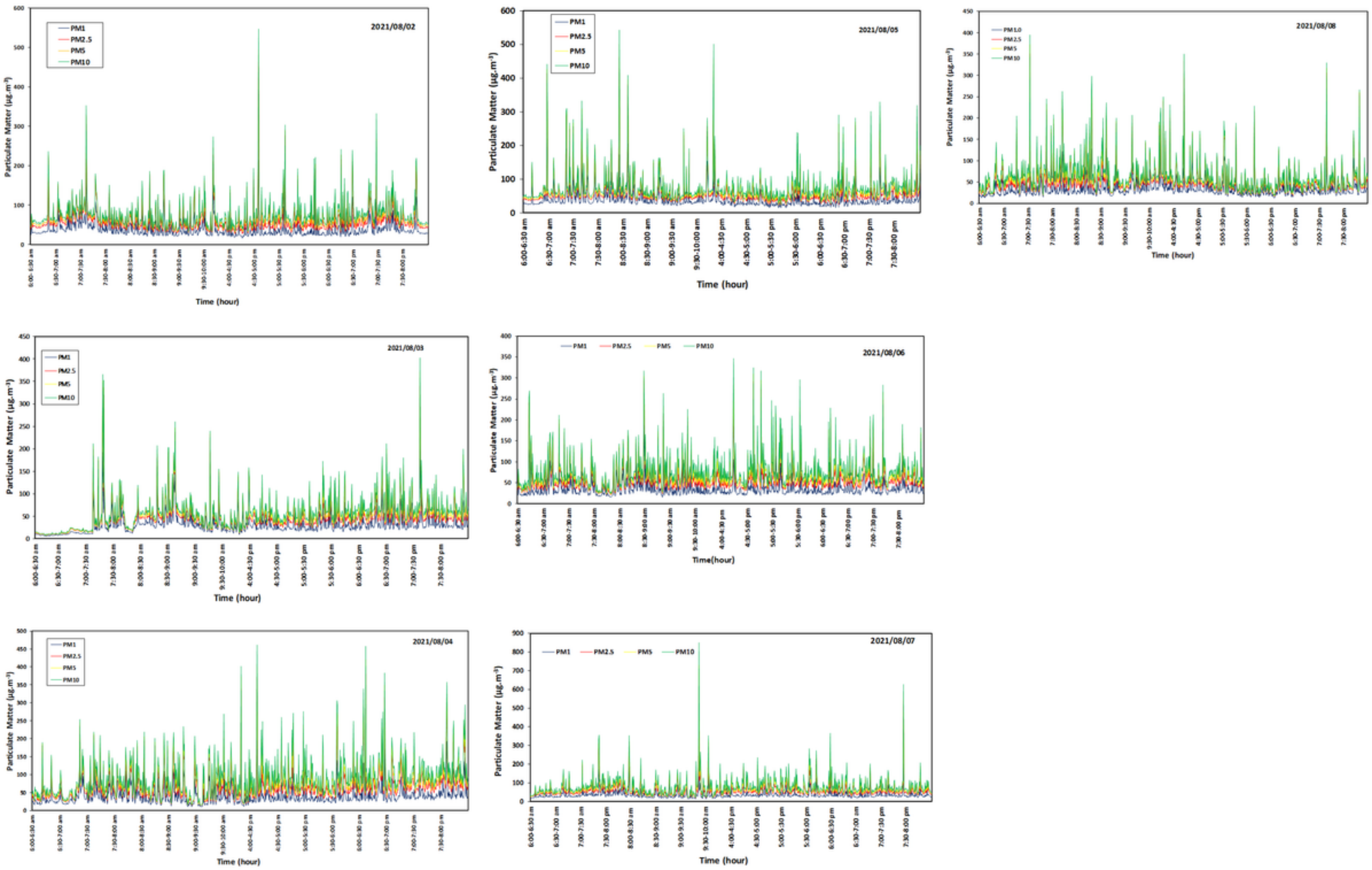

Figure 2

Time evolution of daily PM concentrations from Day 1 to Day 7 of the air quality monitoring campaign (a) Day 1; (a) Day 1; (b) Day 2; (c) Day 3; (d) Day 4; (e) Day 5; (f) Day 6; (g) Day 7.

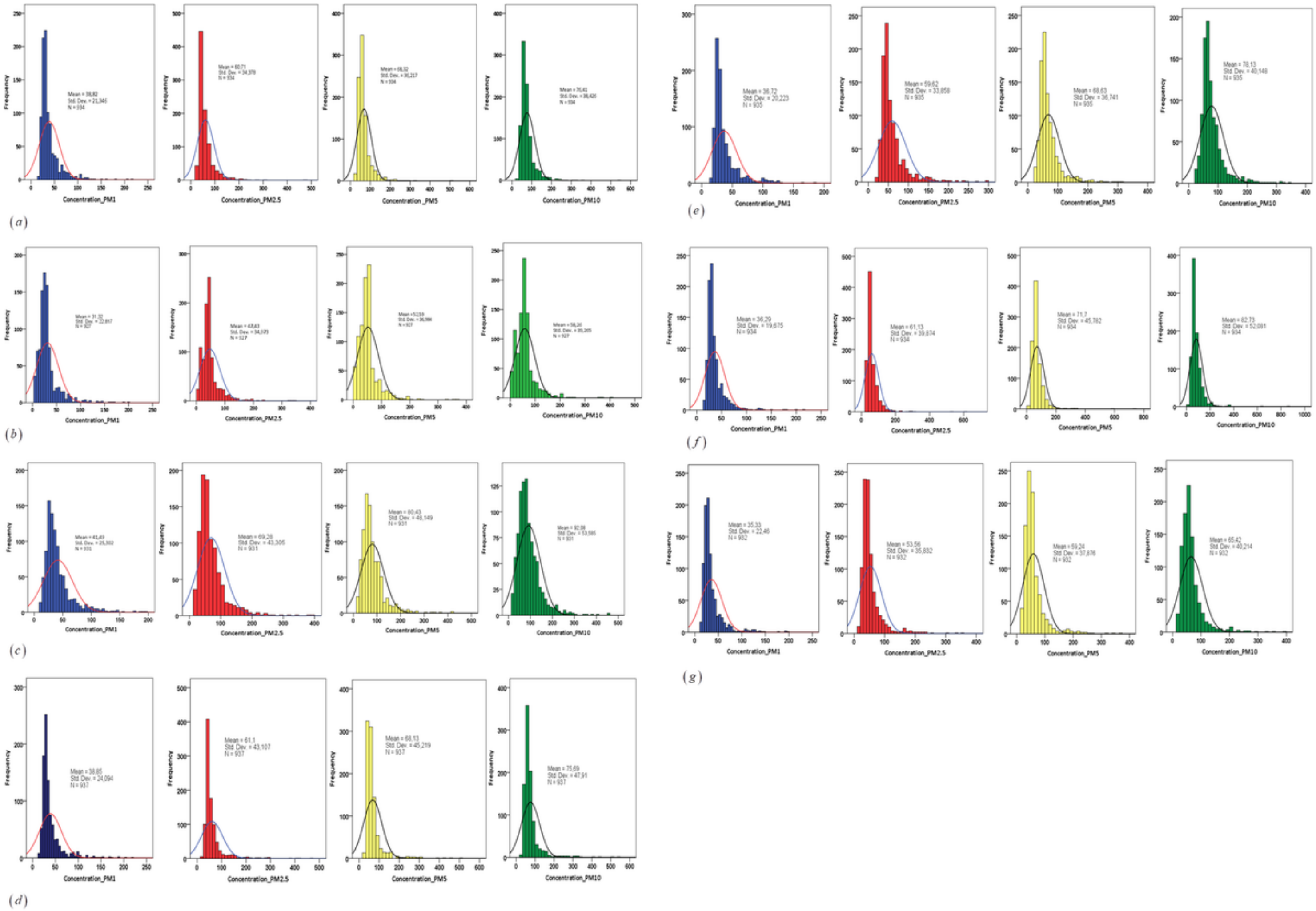

Figure 3

Profile of particle matter concentration (PM_1, $PM_{2.5}$, PM_5, PM_{10}). First measurement day (a), second measurement day (b), third measurement day (c), fourth measurement day (d), fifth measurement day (e), sixth measurement day (f), and seventh measurement day (g).

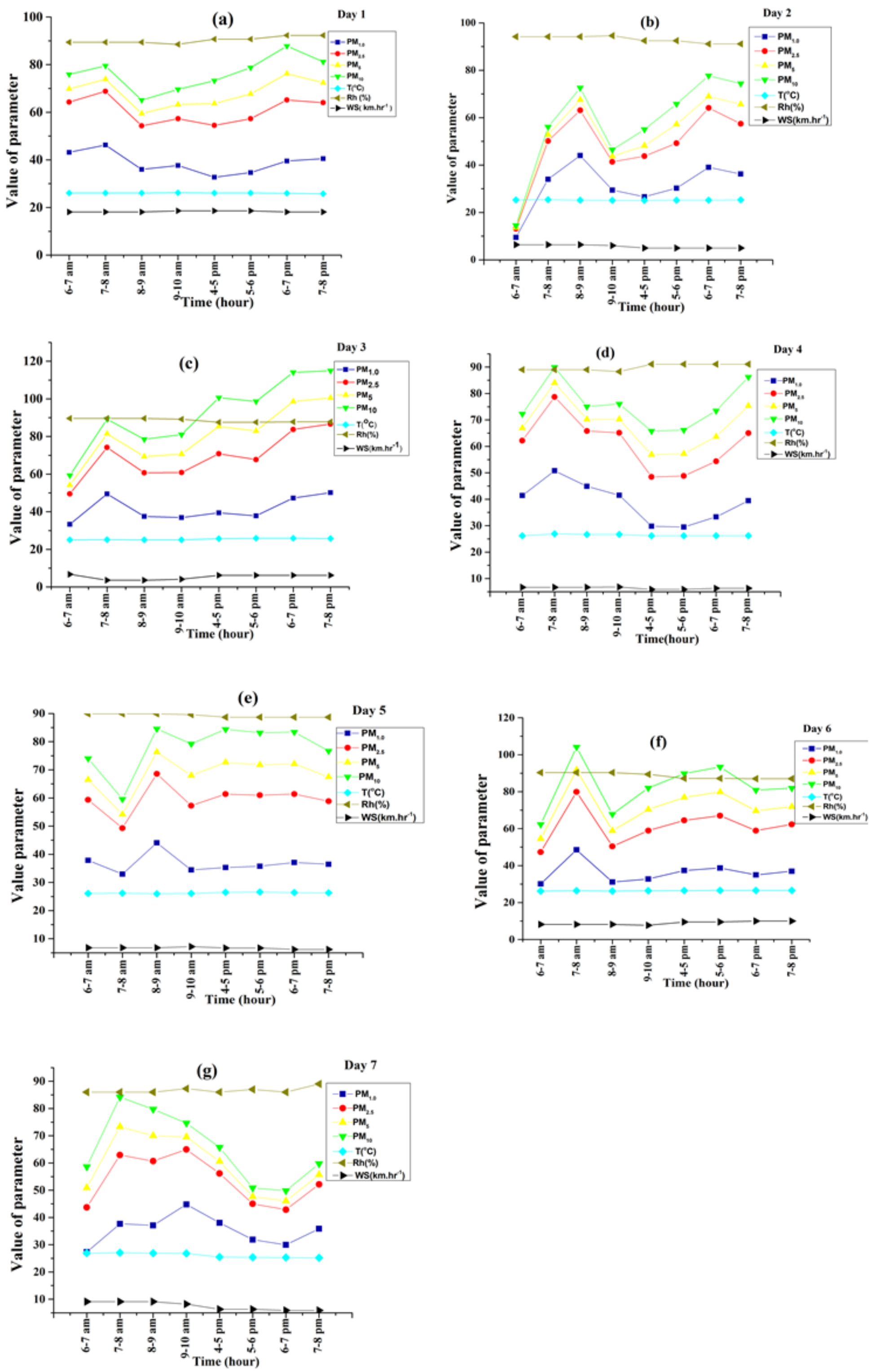

Figure 4

Time evolution of daily mean concentrations of PMs for the seven days of the air quality monitoring campaign: (a) First day, (b) Second day, (c) Third day, (d) Fourth day, (e) Fifth day, (f) Sixth day, (g) Seventh day

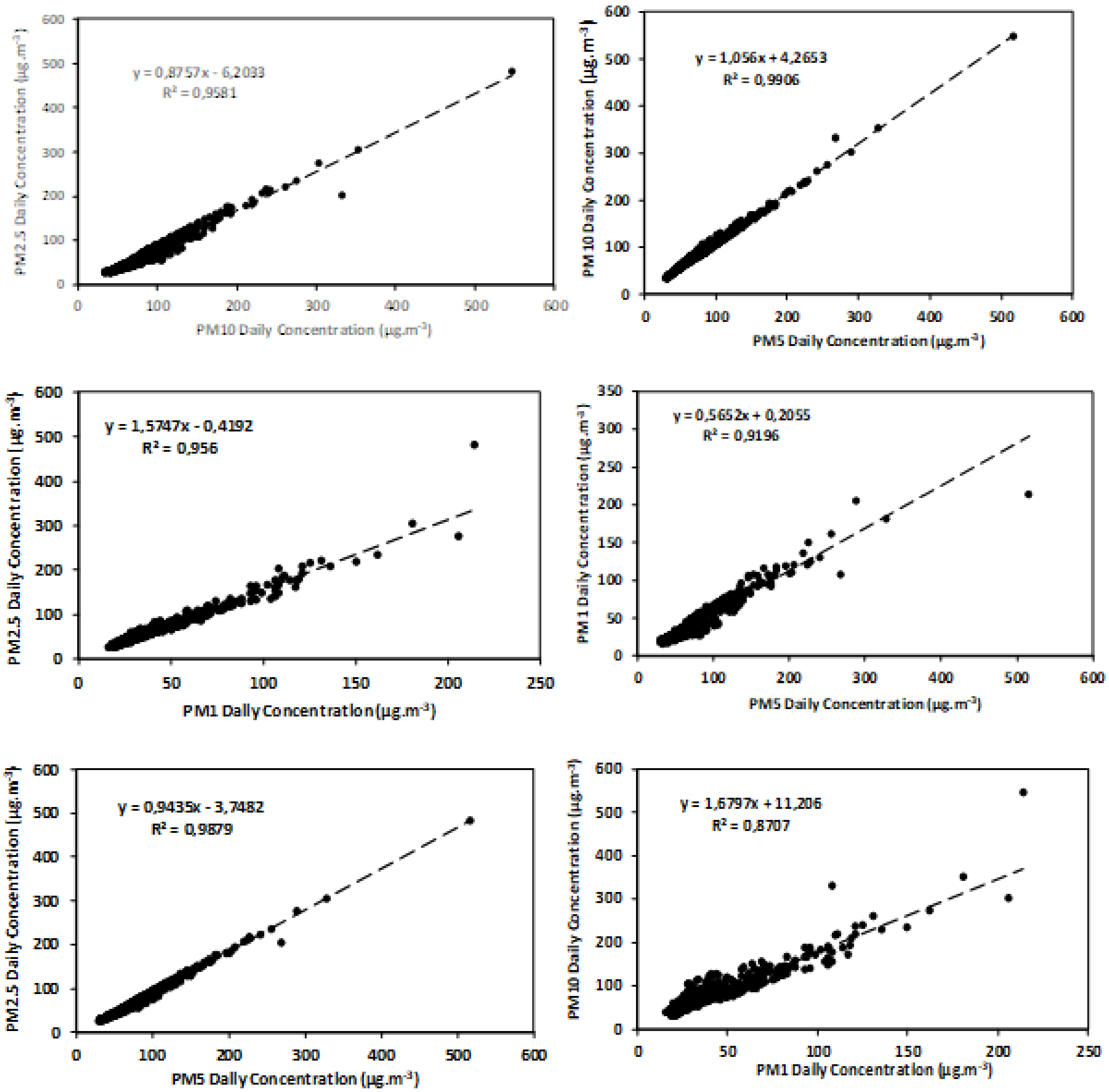

Figure 5

The correlation coefficients between air pollutants (PM_{10}, PM_5, $PM_{2.5}$ and $PM_{1.0}$) on the first day of the measurement campaign.

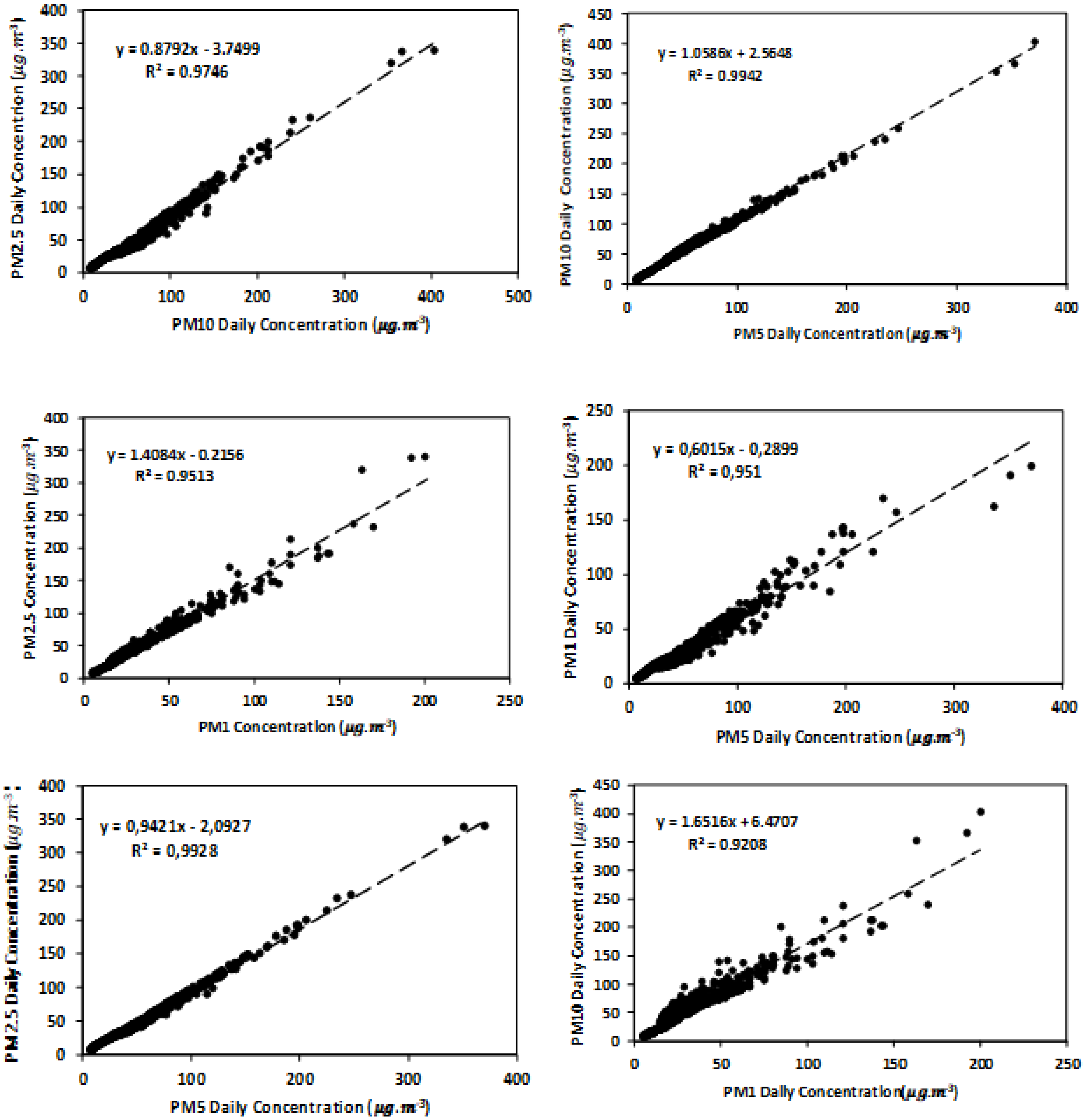

Figure 6

The correlation coefficients between air pollutants (PM_{10}, PM_5, $PM_{2.5}$ and $PM_{1.0}$) on the second day of the measurement campaign.

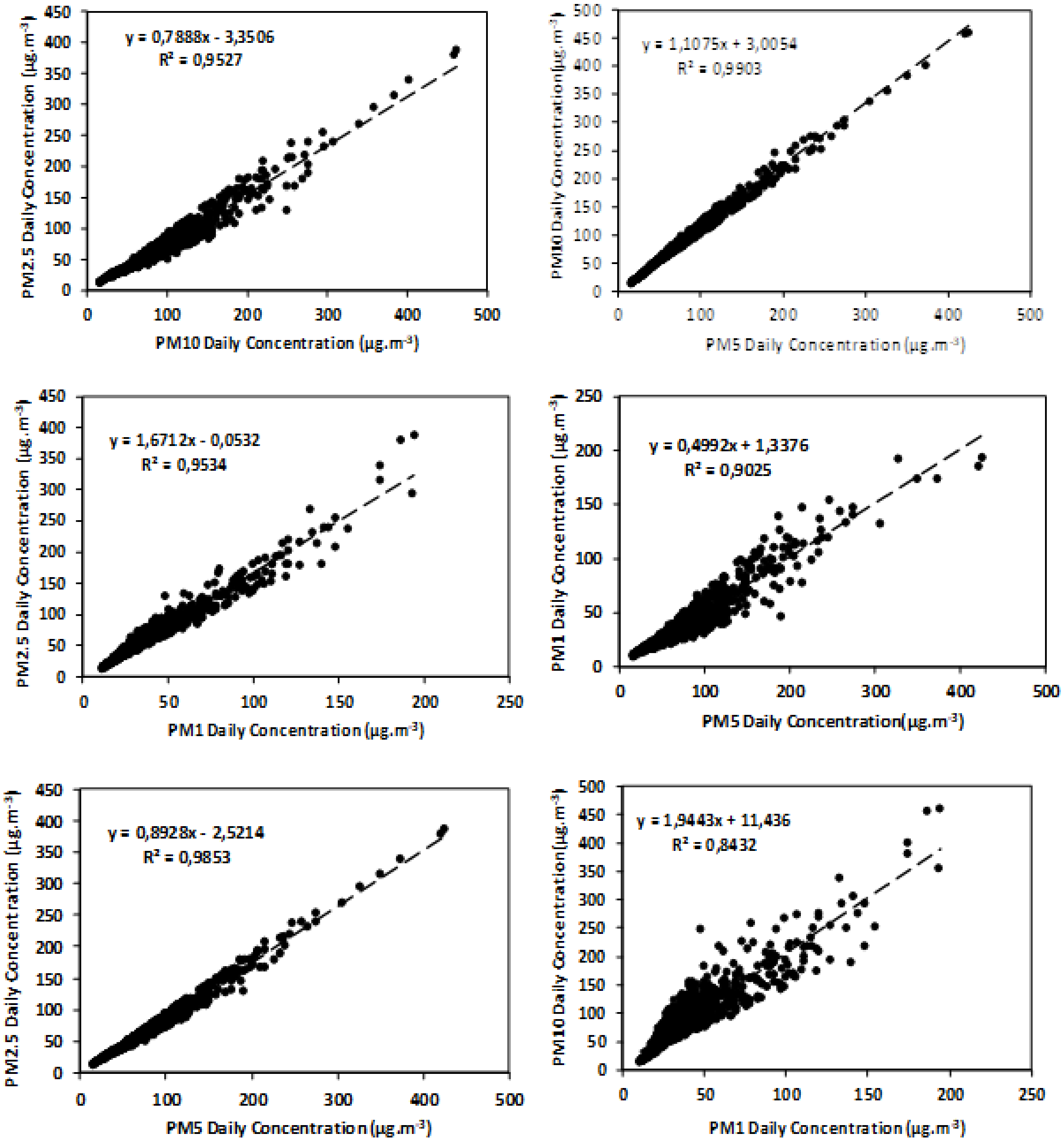

Figure 7

The correlation coefficients between air pollutants (PM_{10}, PM_5, $PM_{2.5}$ and $PM_{1.0}$) on the third day of the measurement campaign.

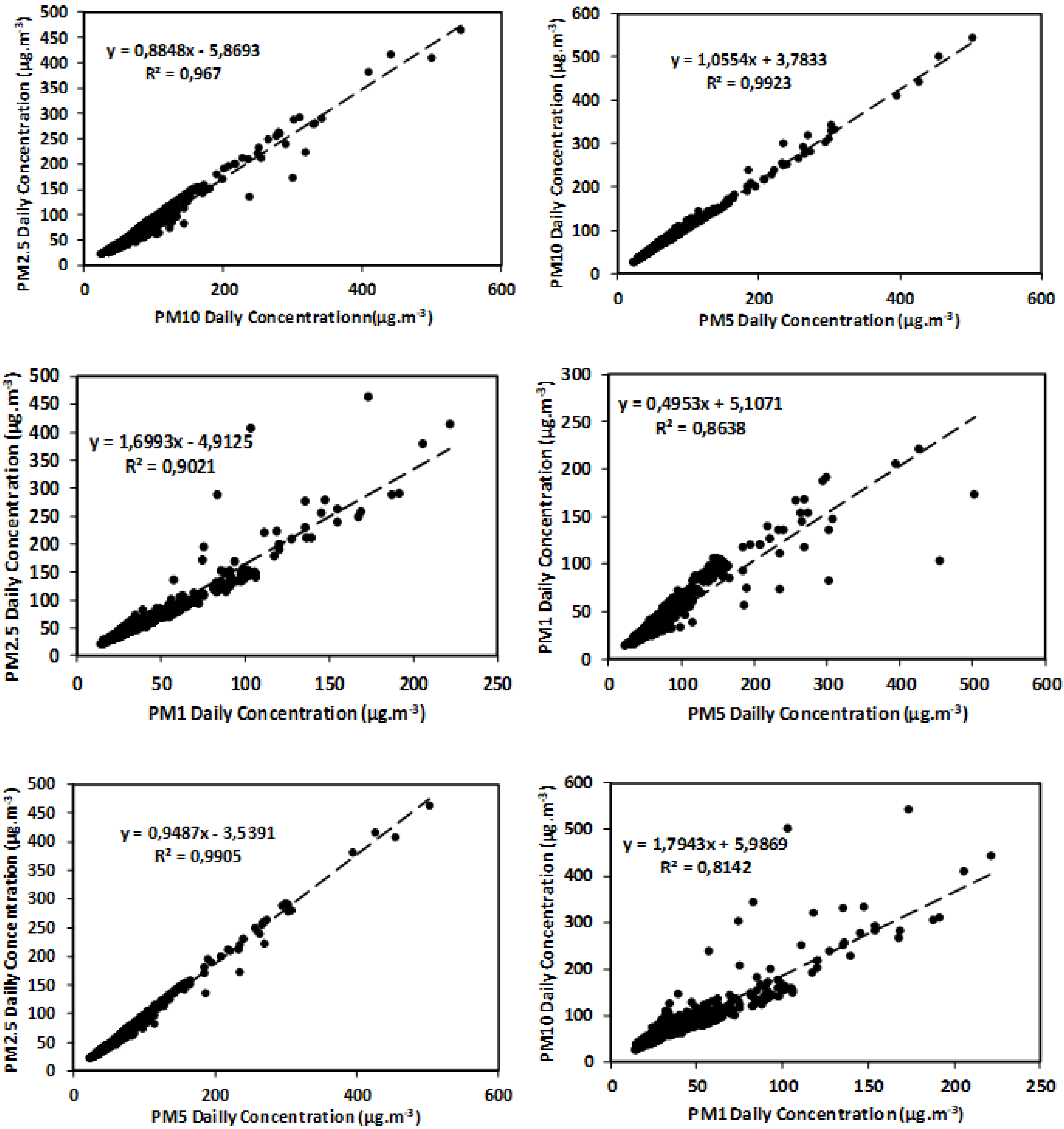

Figure 8

The correlation coefficients between air pollutants (PM_{10}, PM_5, $PM_{2.5}$ and $PM_{1.0}$) on the fourth day of the measurement campaign

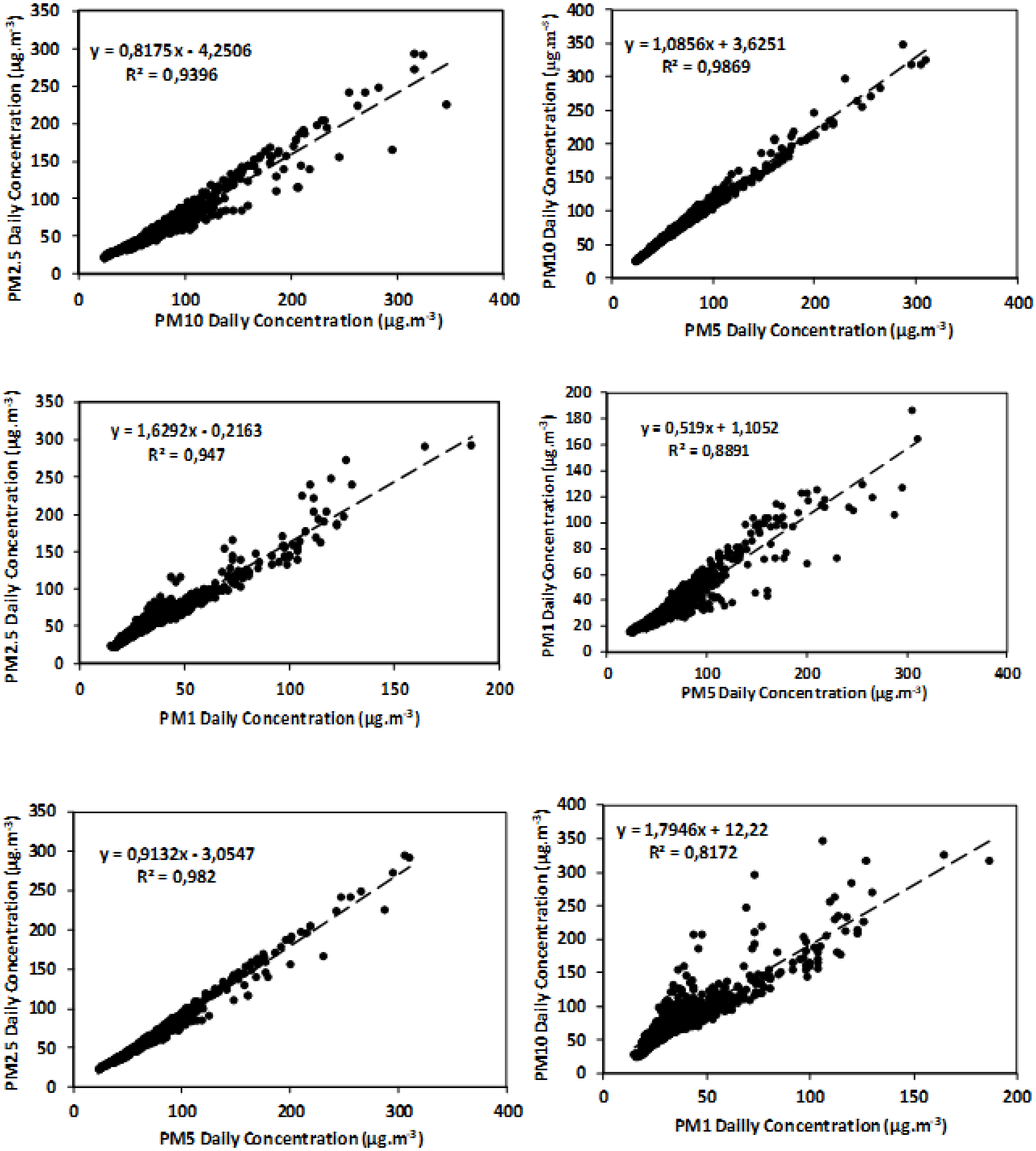

Figure 9

The correlation coefficients between air pollutants (PM_{10}, PM_5, $PM_{2.5}$ and $PM_{1.0}$) on the fifth day of the measurement campaign.

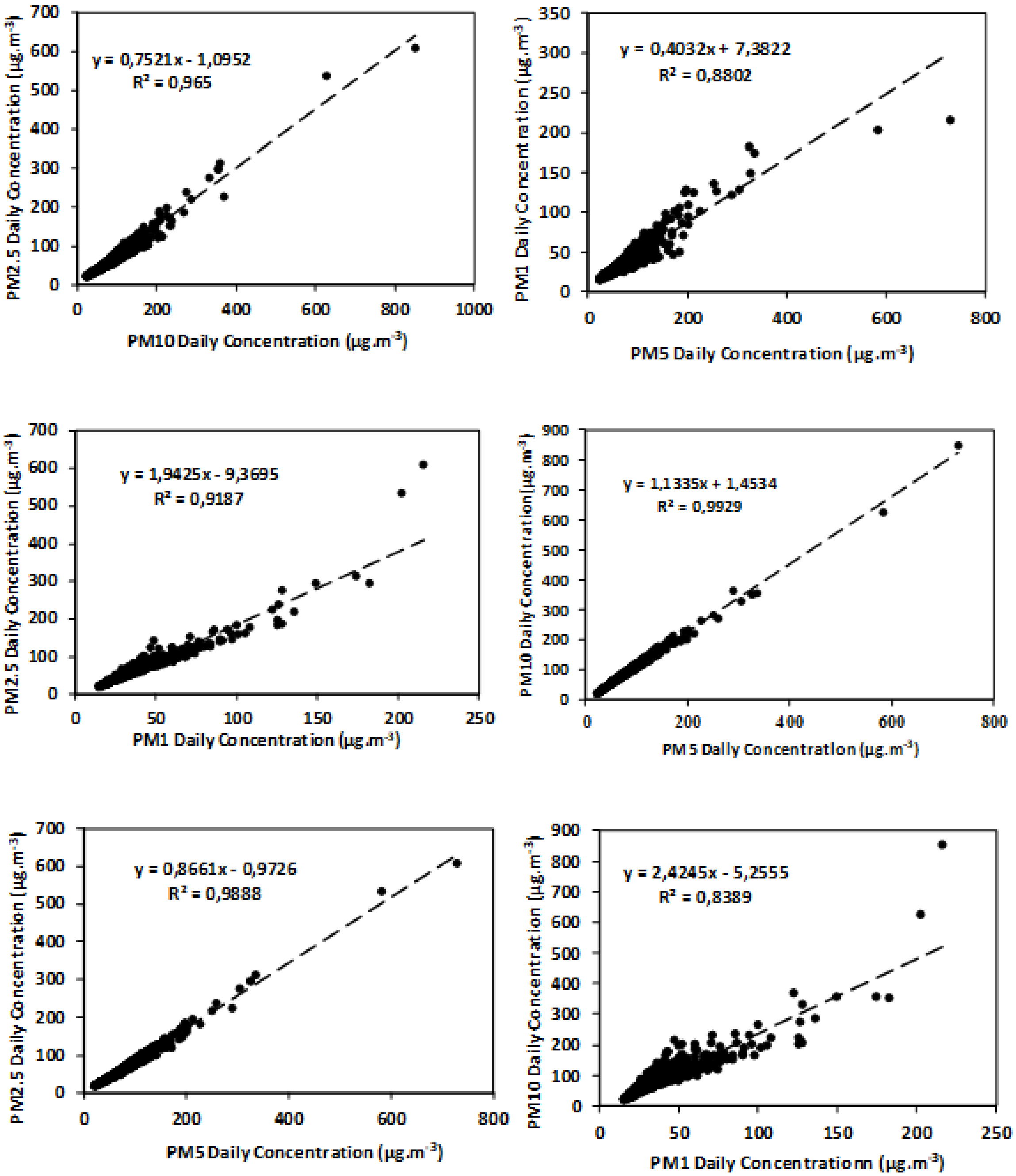

Figure 10

The correlation coefficients between air pollutants (PM_{10}, PM_5, $PM_{2.5}$ and $PM_{1.0}$) on the sixth day of the measurement campaign

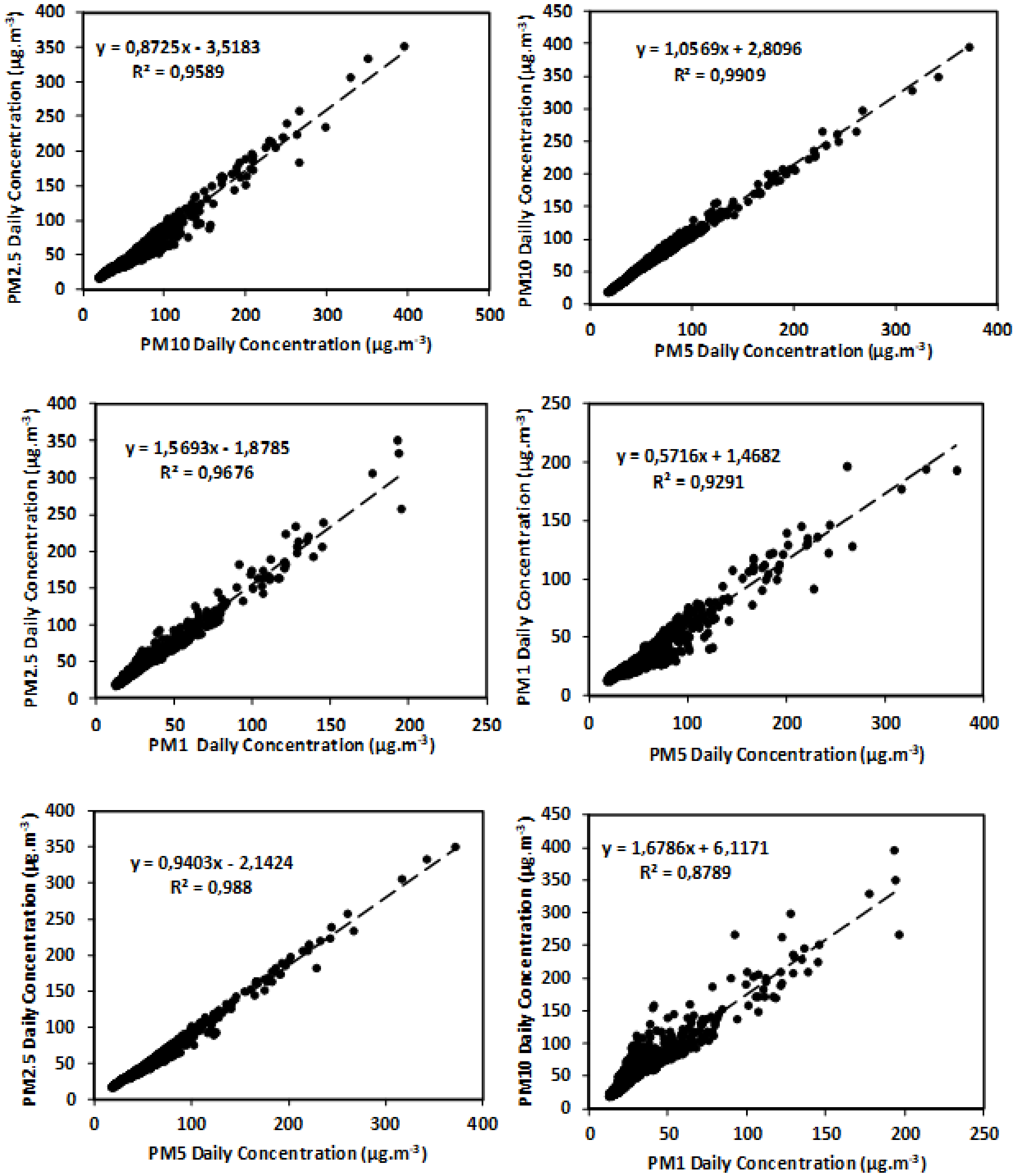

Figure 11

The correlation coefficients between air pollutants (PM_{10}, PM_5, $PM_{2.5}$ and $PM_{1.0}$) on the seventh day of the measurement campaign.

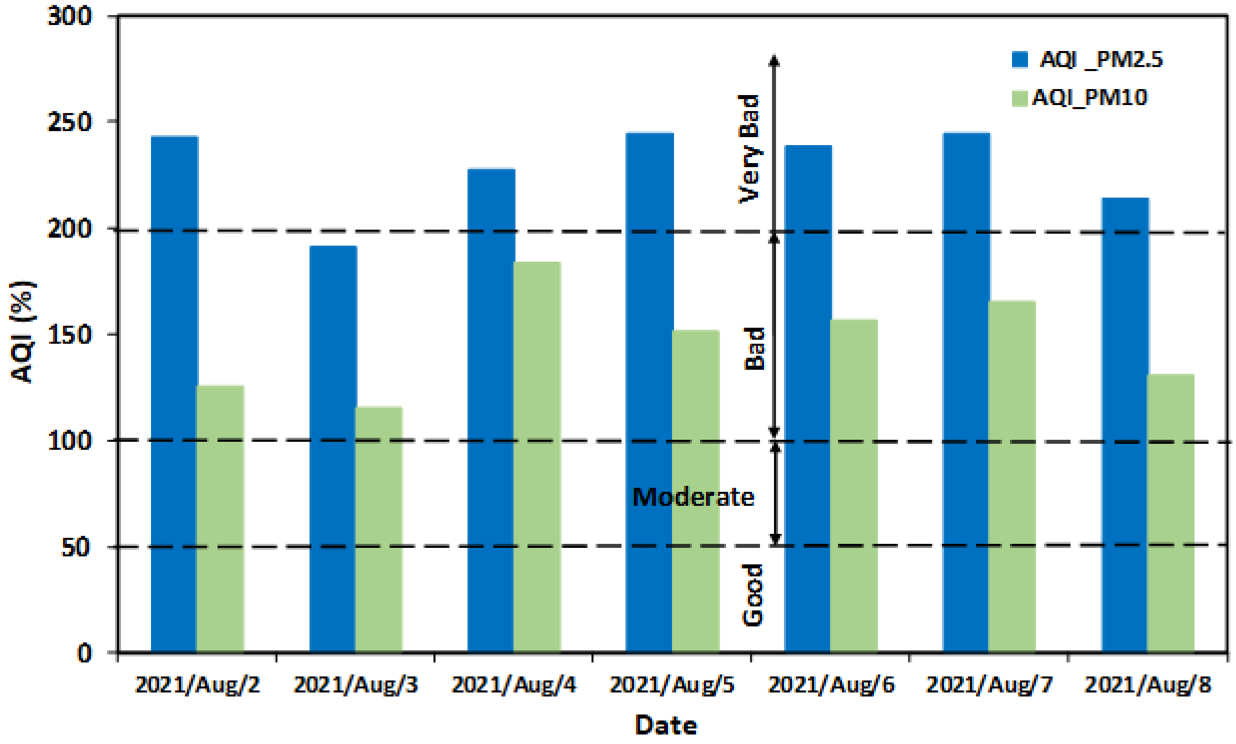

Figure 12

Daily change in the air quality index