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Nitrogen dioxide hourly distribution and health risk assessment for winter season in low town of Mohammedia city, Morocco

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Abstract

Purpose – Air quality and its assessment in urban areas has become a necessity. This is attributed to the increasing air pollution in urban landscape from anthropogenic activities necessary for economic growth and development. This study investigates air quality and potential health risk posed from nitrogen dioxide (NO_2) to the residents of low town of Mohammedia city, Morocco.

Design/methodology/approach – The NO_2 concentration was measured on an hourly basis for the winter season of the year 2014, 2015 and 2016. The air quality was assessed in terms of Air Quality Index (AQI). Noncarcinogenic risk assessment was done to evaluate possible health risk to the inhabitant of low town from NO_2 exposure.

Findings – The maximum concentration reached 85–96 $\mu g/m^3$ (at 6 p.m., 2014), 96–104 $\mu g/m^3$ (7–9 p.m., 2015) and 102–117 (8–11 p.m., 2016). The AQI during maximum NO_2 levels (peak hours) ranged between 0–50 $\mu g/m^3$ (good) to 51–100 $\mu g/m^3$ (unhealthy for sensitive group). The risk quotient (RQ) was calculated for average daily intake and average hourly intake of NO_2. RQ was found to be less than 1 (no potential health risk, lifetime and hourly) for all three years. However, increase in RQ value from 0.84 (2014) to 0.98 (2016) indicates increase in potential health risk. Hence, policy and measures should be adopted to reduce the potential health risk.

Originality/value – This study is very first of its kind for the area and hence can serve as reference study for future works. Further studies are required to assess air pollution in other seasons (summer, spring, autumn), impact of climatic condition and parameters on air quality. Also, for direct impact assessment number of cases attributed to air pollution needs to be investigated.

Keywords Average daily inhalation, Average hourly inhalation, Air Quality Index, Nitrogen dioxide, Risk quotient

Paper type Research paper

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Introduction

Adverse health impact in urban landscapes is attributed to urban air pollution (Shi *et al.*, 2020). In 2016, alone 4.2 million deaths were attributed to air pollution. Economy growth and advancement contributes to increase in air pollution (Bao *et al.*, 2021). This puts air pollution among one of the greatest risks to human health (Huang *et al.*, 2021). The short- and long-term effect of air pollution has been established by various epidemiology studies (Fenech and Aquilina, 2020). Nitrogen dioxide (NO_2) is among the primary pollutants contributing to urban air pollution (Cisneros *et al.*, 2021). The source of NO_2 in urban air primarily comes from combustion processes in automobiles and industries (Cisneros *et al.*, 2021).

This had led to a number of research works for assessing NO_2 concentration worldwide. Cisneros *et al.* (2021) assessed NO_2 concentration during cold season in California, USA, for the 2005–2015 duration. Burns *et al.* (2021) assessed NO_2 concentration during coronavirus disease 2019 (COVID-19) to determine its reduction in urban environment of Munich, Germany. In Malaga (Spain), air quality network was designed in order to minimize adverse environment and health impact attributed to NO_2 (Lozano *et al.*, 2009). In Seoul, Korea; an NO_2 levels assessment was conducted to determine exceedance air quality pattern for a period of 1990–2000 (Kim *et al.*, 2005). Paraschiv and Paraschiv (2019) conducted studies in two urban areas of Romania and determine the contribution of industries and traffic to NO_2 levels in urban environment. Also, NO_2 concentration was assessed in Middle Eastern and Asian countries (Amini *et al.*, 2019; Duan *et al.*, 2019; Ghozikali *et al.*, 2016; Ji *et al.*, 2019). Nevertheless, the literature work on North African countries especially Morocco in context to NO_2 concentration and urban air quality is still lacking.

This not only necessitates NO_2 levels assessment but also evaluation of health risks posed by it in urban environment of Morocco. Also, NO_2 has been reported to vary seasonally (Duan *et al.*, 2019). NO_2 concentration is highly affected by local traffic condition in urban environment. Also, the hourly distribution varies significantly during peak traffic hours. Hence, this study assesses the hourly concentration of NO_2 in low town area of Mohammedia city to identify peak hours. This further lead to assess air quality in terms of Air Quality Index (AQI) and evaluate health risk posed by NO_2 on the urban population exposed to these concentrations.

Methodology

Study area decsription

This study was conducted in the lower town area of Mohammedia city shown in Figure 1. The study area is located in west side of Mohammedia city, between “Samir refinery” and “Sablet beach”, close to the industrial areas well as the city center (epicenter of road traffic pollution), caused by 404,648 of residents (Monographie de Mohammadia, 2015). The climate of the city is influenced by Atlantic Ocean and experiences subhumid to semi-arid climatic conditions (Kanbouchi *et al.*, 2014). The average temperature of 13 °C in winter and 31 °C are experienced during winters and summers, respectively (NOVEC, 2014).

Data collection

This work is carried out within the framework of the partnership FLSHM and DGM “Direction de la météorologie nationale” Morocco. The data were obtained from meteorological station of low town of Mohammedia city. The NO_2 concentration was measured on an hourly basis in this study. The study duration was for three consecutive winter season of the year 2014, 2015 and 2016 (see Table 1). The NO_2 levels were assessed based on the hourly concentration, daywise hourly concentration and weekly hourly concentration. The hourly concentration was chosen as in urban environment traffic volumes

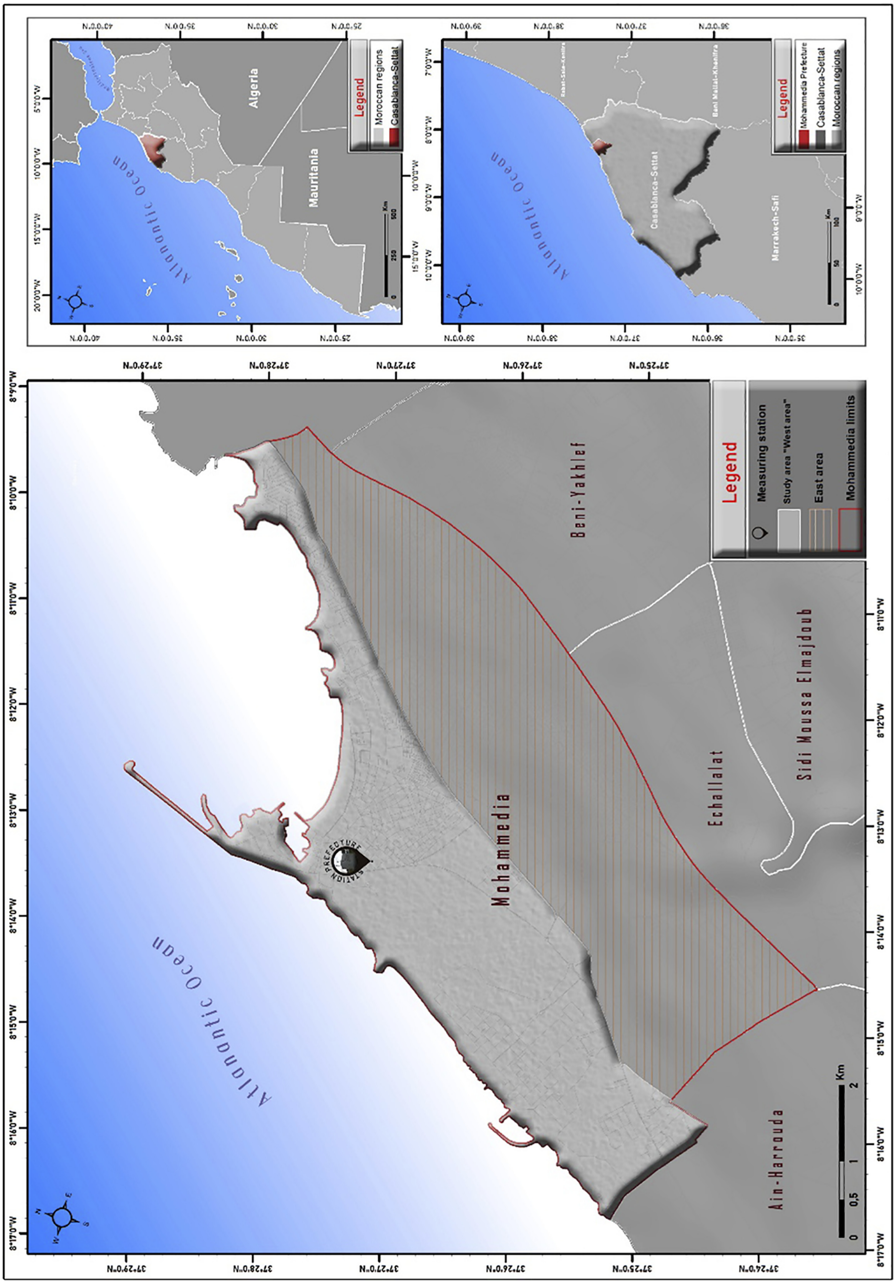

Figure 1.
Study area within Mohammedia prefecture

Time	2014 Mean	2014 Median	2014 Std. deviation	2015 Mean	2015 Median	2015 Std. deviation	2016 Mean	2016 Median	2016 Std. deviation
1 a.m.	20	92	26	37	105	34	27	112	39
2 a.m.	13	69	17	28	100	31	19	107	32
3 a.m.	9	67	13	21	90	27	14	101	26
4 a.m.	10	82	16	19	67	23	12	101	24
5 a.m.	10	63	13	15	69	20	9	82	20
6 a.m.	15	76	19	14	71	19	12	78	22
7 a.m.	33	94	30	21	78	23	17	101	30
8 a.m.	25	100	28	40	90	30	21	101	34
9 a.m.	19	80	22	43	98	32	21	104	32
10 a.m.	17	67	21	35	104	31	30	102	35
11 a.m.	19	104	26	36	98	31	29	104	37
12 a.m.	16	106	24	32	110	36	28	102	35
1 p.m.	14	98	23	30	116	37	25	100	32
2 p.m.	13	86	21	23	110	32	15	103	26
3 p.m.	12	108	23	18	101	28	12	106	24
4 p.m.	16	106	27	17	100	28	12	112	25
5 p.m.	34	104	38	17	112	30	17	112	32
6 p.m.	50	112	43	25	110	36	21	117	39
7 p.m.	52	112	44	48	111	46	22	116	39
8 p.m.	54	111	43	59	116	48	24	114	39
9 p.m.	49	105	43	68	111	45	32	116	44
10 p.m.	44	103	39	73	106	39	38	115	47
11 p.m.	38	103	35	66	105	37	35	117	46
12 p.m.	26	96	30	51	108	35	35	111	43

Table 1. Statistics of AQI for winters of the year 2014–2016

and industrial activities are much affected by time and can vary by a big margin in just few minutes. Hence, the hourly concentration can represent more closely real-time air quality as compared to average readings of 24 h, weekly or monthly. The NO_2 concentration during three winter years of 2014, 2015 and 2016 is presented in Figure 2.

Air Quality Index

Indexing approach is one of the simplest methods to present air quality. The AQI approach employed in this study is in conformance to United States Environmental Protection Agency (US EPA) standards (US EPA, 2009). This method allows to calculate AQI for each pollutant in consideration, i.e. AQI_i. This study has calculated AQI based on the hourly concentration of NO_2 and SO_2. The range of values adopted for AQI varies between 0 and 500. AQI for the pollutant was calculated as shown in Eq. (1).

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{HI} - BO_{Lo}}(C_p - BP_{Lo}) + I_{Lo} \tag{1}$$

Where, I_p is index for pollutant (p), C_p is pollutant concentration, BP_{Hi} is concentration breakpoint $\geq C_p$; BP_{Lo} is breakpoint concentration $\leq C_p$; I_{Hi} is AQI value for BP_{Hi}; and I_{Lo} is AQI for BP_{Lo}.

Health risk assessment

Health risk assessment was performed in accordance with standards (United States Environmental Protection Agency, 2013; WHO Regional Office for Europe, 2016). These methods have been adopted in several studies (Bo *et al.*, 2020; Luo *et al.*, 2020; Odekanle *et al.*, 2020; Suman, 2020). Health risk assessment was carried out based on average hourly intake (AHI) and average daily intake (ADI). AHI was calculated using Eq. (2).

$$\mathrm{AHI} = \frac{C \times \mathrm{IR}}{\mathrm{BW}} \tag{2}$$

Where, C is concentration of pollutant (μg/m^3), inhalation rate (m^3/hr) and BW (body weight) in kg.

For chronic exposure average daily inhalation was calculated using Eq. (3)

$$\mathrm{ADI} = \frac{(C \times \mathrm{IR} \times \mathrm{EF} \times \mathrm{ED})}{(\mathrm{BW} \times \mathrm{AT})} \tag{3}$$

Where, exposure frequency (EF) days/year; exposure duration (ED) years; exposure time (ET) hours/day and average time (AT) in days (period over which exposure is averaged)

Risk quotient for acute exposure risk from the hourly concentration was estimated using Eq. (4)

$$\mathrm{RQ} = \frac{\mathrm{AHD}}{\mathrm{Rfc}} \tag{4}$$

Risk quotient for chronic exposure was calculated using Eq. (5)

$$\mathrm{RQ} = \frac{\mathrm{ADD}}{\mathrm{Rfc}} \tag{5}$$

Where, reference concentration (RfC) value was 0.02 mg/kg/day for NO_2 obtained from EPA/NAAQA 1990 and IRIS (US-EPA) (Gusti, 2019).

Result and discussion

NO_2 concentration in study area

NO_2 has been identified as a pollutant which can adversely affect human health (Guo *et al.*, 2021). Long-term NO_2 exposure has been linked to lung infection and mortality (Hou *et al.*, 2020; Huang *et al.*, 2021). Short-term NO_2 exposure has been investigated for conjunctivitis and mortality (Amini *et al.*, 2019; Samoli *et al.*, 2006). Additionally NO_2 has been positively linked to

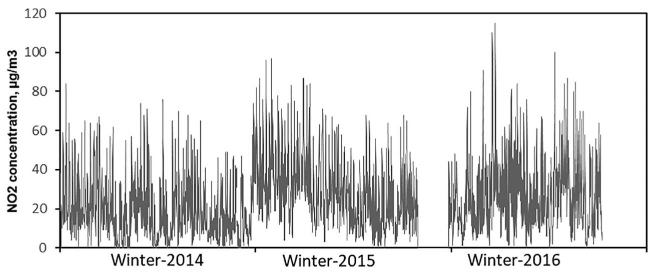

Figure 2.
Hourly concentration of NO_2 in winters for the year 2014, 2015 and 2016

prebirth, conjunctivitis, skin disease, increase of asthma patients and cardiovascular mortality (Cisneros *et al.*, 2021; Duan *et al.*, 2019; Ji *et al.*, 2019; Li *et al.*, 2020; Nitschke *et al.*, 1999).

The NO_2 concentration in the environment of low town in Mohammedia city was measured at an hourly interval. Figures 3–5 represent the concentration of NO_2 for the winters of the year 2014–2016. In the year 2014, NO_2 was maximum at 6 p.m. In the year 2015, NO_2 levels in urban were found to be at peak at 1 p.m. and 8–10 p.m. indicating which can be attributed to shift in traffic hours in the city. However, in winters of 2016, the NO_2 level peaks lasted from 6 p.m. to 11 p.m. The shift in peak and increase in peak hours indicates the deterioration of air quality and increase in air pollution in the city (Cisneros *et al.*, 2021; Kim *et al.*, 2005). These results indicate that NO_2 concentration in low town city of Mohammedia is primarily attributed to traffic conditions. As industrial pollution prevails for much longer period of time (Morakinyo *et al.*, 2017). This is primarily due to the reason that work shifts in industries lasts for 6–8 h. Hence, concentration of NO_2 will remain relevantly constant. However, the increase in NO_2 is not constant and only shows spikes attributed to increase in traffic volume at given hours in the city.

Air Quality Index

The AQI was developed to represent air quality. US EPA, has defined AQI into six categories, namely, good (0–50), moderate (51–100), unhealthy to sensitive groups (101–150), unhealthy (151–200), very unhealthy 201–300 and hazardous (301–500) (United States Environmental Protection Agency, 2013). However, for NO_2 this range is 0–53, 54–100, 101–360, 361–649, 650–1,249, 1,250–1,649 and 1,650–2,049 ppb for the categories of good – hazardous,

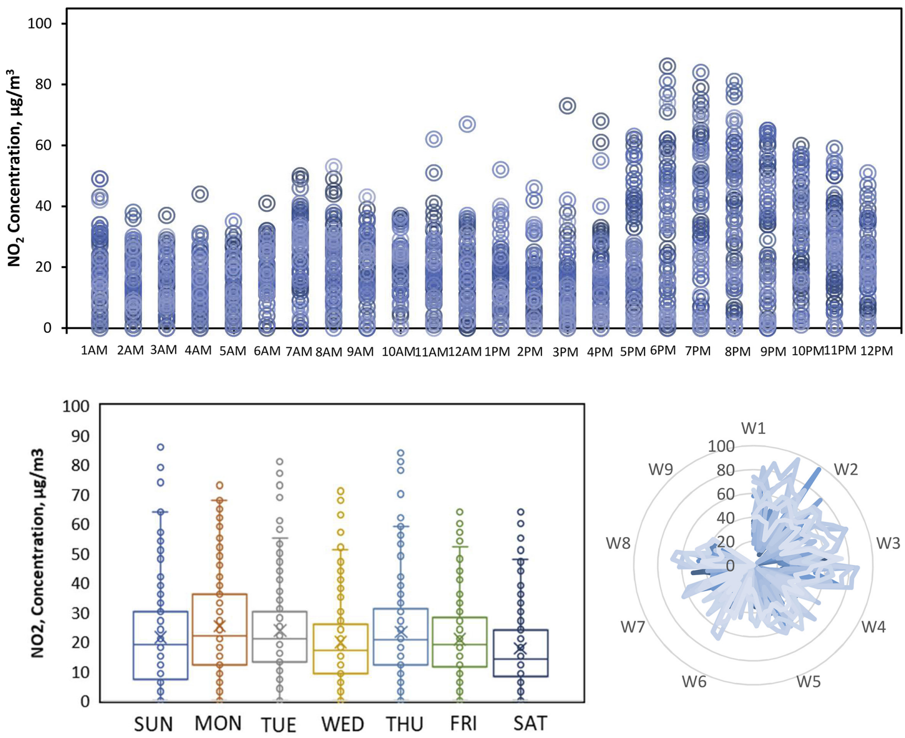

Figure 3.
NO_2 hourly, daywise and weekly concentration during winters of the year 2014

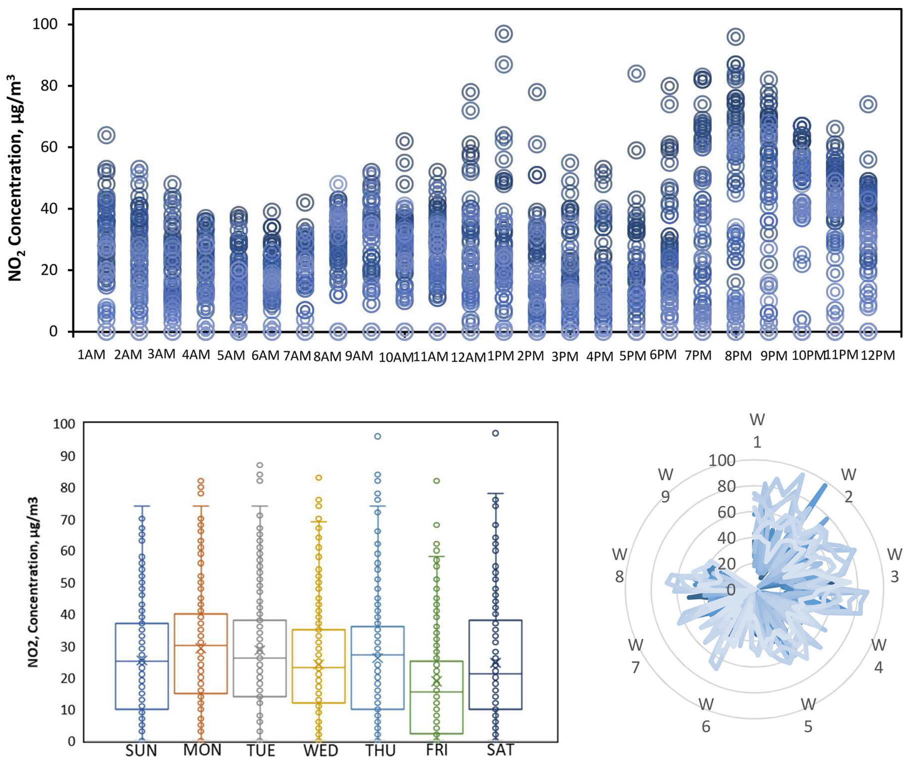

Figure 4.
NO_2 hourly, daywise and weekly concentration during winters of the year 2015

respectively (United States Environmental Protection Agency, 2013). AQI was estimated for the hourly NO_2 concentration for each year. During winters of the year 2014–2016, AQI ranged between good – unhealthy to sensitive group conditions. In the year 2014, at peak hour of 8 p.m., 27% of the observations were found to moderate, 26% unhealthy to sensitive group and 47% good. For the year 2015, the peak hours of 1 p.m. and 8–10 p.m.; the 1 p.m. only showed few spikes in NO_2 levels, while 30% of AQI were unhealthy to sensitive group and 4% AQI were moderate and 64% were good. Nevertheless, in the year 2016, AQI was 70% in good category, while 12% moderate and 16% unhealthy to sensitive group. The AQI infers that even though there were spikes and increase in peak hour concentration in three consecutive winter seasons but the overall air quality was improving for these particular hours and can be attributed to local traffic and parameters (Zhou *et al.*, 2020).

Noncarcinogenic risk

Noncarcinogenic risk assessment represents all the possible adverse health impact that may occur to the person on exposure to the pollutant (Brauer *et al.*, 2002; Ghozikali *et al.*, 2016). This study conduct health risk assessment based on life time exposure and hourly exposure. This was done to investigate whether the hourly spikes in NO_2 concentration can pose any risk to human health or not. The risk quotient represents noncarcinogenic risks (Fenech and Aquilina, 2020; Paraschiv and Paraschiv, 2019). RQ < 1 refers to no possible adverse health effect to the population exposed to pollutant (Brunt and Jones, 2019; Odekanle *et al.*, 2020). The RQ value for ADI and AHI was found to be less than 1. The RQ based on AHI ranged in

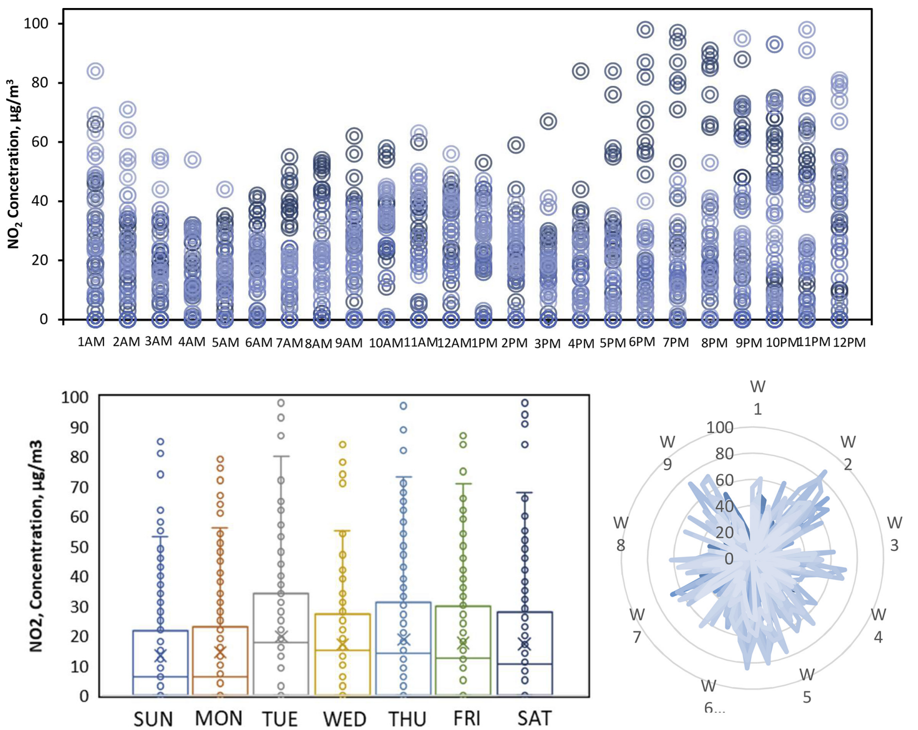

Figure 5.
NO_2 hourly, daywise and weekly concentration during winters of the year 2016

between 0.1 and 0.2 for all three winters season of 2014–2016. Nonetheless, RQ ranged between 0 and 0.84 (6 p.m.) in the year 2014, 0 to 0.96 in 2015, and in 2016 it increased 0–0.98. Even though RQ < 1 for each year but the increasing trend suggests that mitigation measures need to be adopted to overcome the yearly increasing risk.

Conclusion

This study was conducted to investigate the hourly concentration of NO_2 at low town in Mohammedia city, Morocco. The hourly concentration peaks were identified and were investigated for AQI, and possible health risk. The peak hours suggest increase in NO_2 concentration during winters of the year 2014–2016, also the peak hours increase from 6 p.m. in 2014 to 8–11 p.m. during 2016 winters. But other than peak hours the concentration was within ambient air limits.

Even though the number of spikes in winter season have increased for every year. But AQI suggests that overall air quality has improved from 47% of the peak hour observation were found to be in good category in 2014 which increased to 70% in winters of 2016. Despite the spikes during peak hours of NO_2 concentration the RQ < 1 at every hour. However, the increasing trend of RQ values yearwise indicates that there is an increase in possible risk to city residents. The correlation between AQI and RQ was found to be strong. The correlation between AQI and RQ was 0.95 (ADI) and 0.94 (AHI). The strong correlation value further validates results of the study, i.e. AQI is directly related to health risk.

The hourly concentration helps in identifying the time duration of air pollution which may pose potential risk to human health. Thereby it also provides an option to adopt policy and measures to mitigate adverse effect of pollutant. As, this may aid in adopting measures strictly for specified time duration, thus saving efforts and resources which may be used for full 24-h duration. Future studies are required to determine impact of climatic parameters (temperature, precipitation, humidity, wind direction), on NO_2 concentration.

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