Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
e-ISSN: 2395-3454

Vol. 17 | No. 2 | pp. 359-366 | 2018

Original Research Paper | Open Access

Study on the Impact of Weather on Air Quality at Aqaba

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 27-07-2017
Accepted: 24-09-2017

Key Words:
Air pollution
Air quality
Meteorology
Aqaba

ABSTRACT

Seven air pollutants, SO_2, H_2S, CO, O_3 , NO_x, NH_3 and PM_{10}, in addition to basic meteorological parameters (wind speed, temperature and relative humidity) were measured in a residential area in Aqaba. Measurement took place during the time interval 31/12/2014 through 31/12/2015. Following ambient measurement, data were analysed to detect correlations between each air pollutant with meteorological parameters. Our findings showed that atmospheric concentrations of H_2S, CO, NO_x and NH_3 positively correlate with relative humidity, but PM_{10}, SO_2 and O_3 negatively correlate with it. Air temperature is found to enhance the creation of ozone. It is also found that the concentrations of PM_{10}, NH_3, NO_x and CO increase with both air temperature and wind speed. However, concentrations of SO_2 and H_2S decrease when air temperature or wind speed increases. High wind speed leads to a higher mixing rate and improved dispersion resulting in lower levels of air pollution.

INTRODUCTION

Air pollution in large cities is a growing environmental challenge, particularly in developing nations. However, Jordanian competent environmental authorities started to realize the pollution problems associated with air pollution as early as the seventies of the previous century. Environmental consequences of air pollution and its health impact influenced local authorities to take preventive measures and enforce pollution control in polluted areas. Air pollution is controlled by the strength of air pollution emissions and their dispersion in the atmosphere, which is partially governed by the meteorology (Rao & Rao 1989). This implies that meteorological conditions and atmospheric chemistry have evident impacts on air quality (Karar et al. 2006, Itlen & Selici 2007).

This paper aims to evaluate air quality at Aqaba, how it complies with corresponding National Ambient Air Quality Standards (NAAQS), and how it is impacted by prevailing weather conditions.

MATERIALS AND METHODS

Description of study area: Measurements took place in Aqaba city, which is located at the north-eastern corner of the Gulf of Aqaba along the southeastern edge of the Sinai Peninsula. Gulf of Aqaba is an inland extension of the Red Sea and has a length of 180 kilometres, a width of 14-26 kilometres, and an average depth of 800 meters (Abu-Hilal & Al-Najjar 2004). The Gulf area is characterized by mountain ridges with elevations reaching up to 1,600 meters perpendicular to the shoreline and interrupted by a series of intermittent valleys of various widths. The network of valleys acts as wind channels that are eventually responsible for the erratic behaviour of the wind direction in the vicinity of the Gulf shoreline. The coastal areas experience various changes in wind direction and temperature. This topography allows wind channelling from land through valleys to develop and in the afternoon winds with gulf breezes will also have an effect on the general circulation (Kanbour 2003).

The city has a population of about 200,000 inhabitants. Prevailing climate is the sub-Sahara climate with mild winters and hot-dry summer. The prevailing wind is mainly northerly wind, which transports dust from Araba valley. Precipitation fluctuates, but rarely exceeds 50 mm/annum. Aqaba, is very important to Jordan as it has the only sea port through which imports and exports take place. The location of Aqaba city is shown in Fig. 1 .

Data collection: Air quality data are procured using the air quality monitoring station located at Ash-sharif Shaker bin Zaid Street, which is owned and operated by Ibn Hayyan International Laboratories. The neighbourhood is classified by Aqaba Special Economic Zone Authority (ASEZA) as a residential area. Air quality and meteorology were monitored for about one year during the time interval 31/12/2014 to 31/12/2015. The monitoring was conducted continuously 24 hours a day utilizing state-of-the art equipment in all the weather conditions. The station takes continuous automatic

Table 1: descriptive statistic for the air pollutants.

Pollutant	PM_{10} (µg/m^3)	NH_3 (µg/m^3)	NOx (ppb)	O_3 (ppb)	CO (ppm)	SO_2 (ppb)	H_2S (ppb)
Minimum	0.0	11.8	2.2	102.7	0.0	0.0	0.0
Maximum	2712	335	553	197	6.9	155	60
Mean	77	9.8	20.2	33.2	0.4	3.8	2.5
S.D	141.6	16.8	25.3	14	0.4	4.2	1.7
Skewness	9.8	7.1	7.3	0.3	4.1	14	5.7
Kurtosis	126	75.8	80.8	2.7	31.2	326	84

measurements of all the parameters every 15 minutes/30 minutes/60 minutes/3 hours/6 hours/8 hours/ 12 hour/24 hour.

Statistical analysis: Acquired data were exported into Microsoft-Excel sheets and undergone vigorous statistical analysis in order to identify correlations between air pollution and meteorological parameters. JMP statistical software (2010) was used to analyse meteorological and air pollution data where several temporal techniques were tested. After creating time series plots for air pollutants, basic statistics including minimum, maximum, mean, standard deviation (SD), correlation multivariate, multiple comparisons and linear regression were calculated.

RESULTS AND DISCUSSION

Basic Statistics

Ordinary statistics including minimum, maximum, mean, standard deviation (SD), skewness and Kurtosis were carried out. Results are depicted in Table 1.

Variation of Pollutant Levels for Data Taken Daily

SO_2 trend: Concentration of atmospheric SO_2 is found to be in compliance with the Jordanian annual NAAQAS of 30 ppb. However, data demonstrated strong rises in March and June, which is partially attributed to the heavy duty vehicles that are deployed at the construction site of a mega project located to the north of the monitoring station (Fig. 2).

H_2S trend: High levels of H_2S occurred in spring and summer months. This is likely attributed to sewage overflow at the wastewater treatment station. Hydrogen sulfide is released from the wastewater treatment facilities as well as the petroleum handling at Aqaba port. Hot days enhance microbial activities in sewage handling facilities and increase evaporation from oil containers (Fig. 3).

CO trend: High CO concentration is noticed during thermal inversion events which occur in autumn (October through December). Thermal inversion suppresses vertical air motion, which restricts air mixing and leads to high levels of air pollution trapped close to earth surface (Fig. 4).

O_3 trend: Ozone is a photosynthetic gas which is formed in the troposphere when NO_2 and hydrocarbons undergo a long chain of photochemical reactions. High values of ozone are observed in hot days (March-September) (Fig. 5).

NO_X trend: NOx demonstrated low concentrations throughout the year, but it records relatively higher values in the month of February, and the reason is because of the presence of equipment maintenance team at that time, and maintenance of the NO_x device. And the reason of rise in the readings is the entry of light to the sensor, as the sensor is sensitive to light, whereas the reason of the lower values from September to December is a malfunction in the device (Fig. 6).

NH_3 trend: The main purpose of monitoring ammonia in Aqaba is to stay alert against abnormal emissions, which may reach the city from the southern industrial zone during southerly wind events. Similar to NOx, ammonia readings were higher in February. There are no significant ammonia sources within the city itself, but there are some potential minor sources such as the sewerage manholes and pumping stations. The main sources of NH_3 are the industrial and combustion processes in the industrial area southern to the city (Fig. 7).

The city may also experience high levels of ammonia during westerly wind events due to large scale cattle farming in Eilot, upwind of Aqaba.

PM_{10} trend: PM_{10} concentration is higher in November, when local and synoptic climatic phenomena result in frequent conditions of tropospheric instability, which transport dust from neighbouring states. Possible sources of PM_{10} include; wind-blown dust originating from Araba valley, traffic and the phosphate handling (Fig. 8).

Plot Series for Meteorological Parameters

Daily average of wind speed during 2015: Fig. 9 shows time series plot for wind speed during the period January 2015-December 2015. Air tranquility plays an important role in the distance which the wind may reach and in its concentration in the surrounding air as well. Pollutants are expected to be carried away and diluted during day times with high wind speeds. The lowest monthly average was

Fig. 1: Ambient air quality monitoring station.

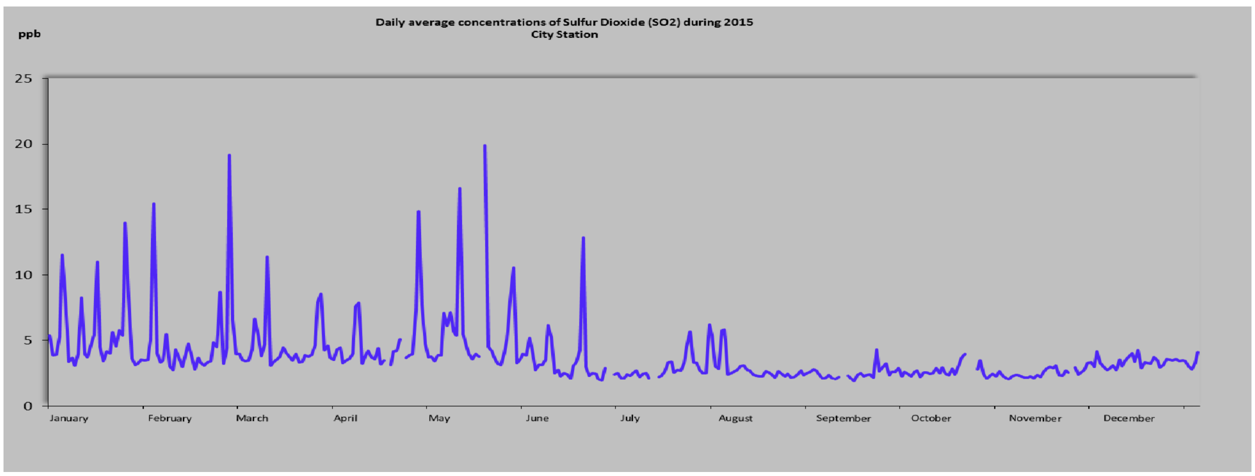

Fig. 2: Time series plot of SO_2.

recorded in July were wind blow at speed between 0-2 m/s and highest monthly average was recorded in November, wind blow at speed between 5-7 m/s .

Daily average of temperature during 2015: The lowest monthly average temperature, 8.81°C, was recorded in January and highest monthly average temperature 39°C, was recorded in August (Fig. 10).

Daily average of relative humidity during 2015: The lowest monthly average relative humidity of 4.55%, which was recorded in September, and highest monthly average relative humidity of 86.72%, which was recorded in November (Fig. 11). The more relative humidity, the lower the concentration of pollutants. The main reason for this relation is attributed to the role of relative humidity in cleaning the atmospheric pollutants and the fall of the acid rains.

Statistical Characterizations of Climatic Variables and Air Pollutants

Relationship between wind speed and air pollutants: The relatively high wind speed during day time causes higher rate of mixing and dispersion resulting in general lower levels of pollution in ambient air.

We can recognize from R Square, the strength of impact, and we can recognize from β, the orientation of impact; that means the impact of wind speed on PM_{10} and O_3 is being in a strength equal 0.0 and 0.090, respectively, where their orientation is positive and there is no relationship. Whereas, the impact of wind speed on NH_3, NOx, CO, SO_2 and H_2S is negatively correlated with wind speed. The strength equal 0.029, 0.032, 0.050, 0.042 and 0.0, respectively (Table 2).

Relationship between temperature and air pollutants: As expected, incoming solar radiation was observed to be higher during daytime than during night time. In general, the lower is the incoming solar radiation, the higher is the stability of the atmosphere, thus, the stability of the atmosphere is en-

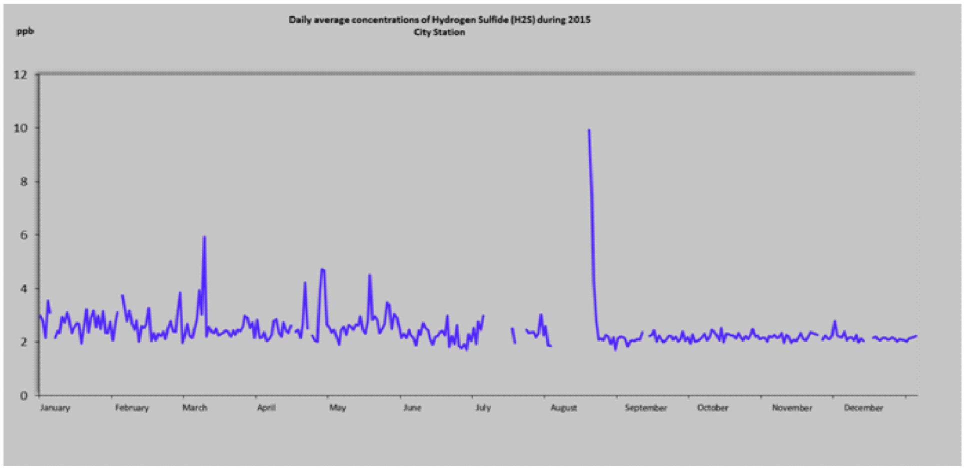

Fig. 3: Time series plot of H_2S.

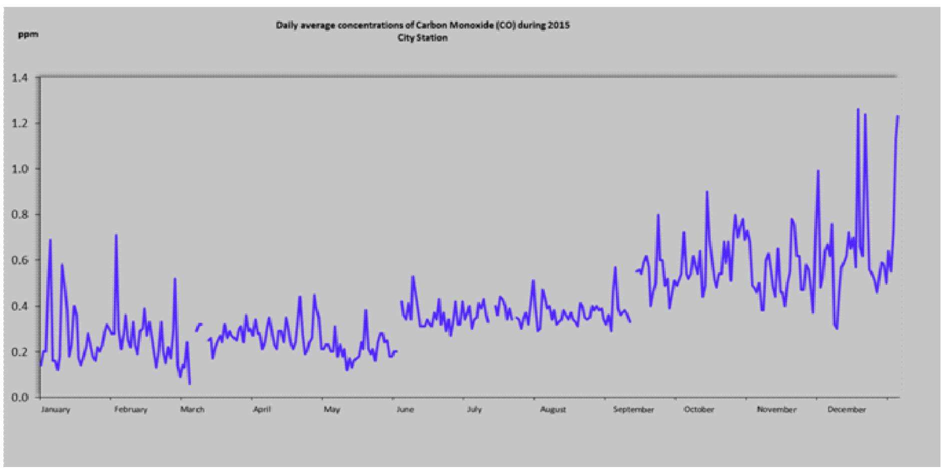

Fig. 4: Time series plot of CO.

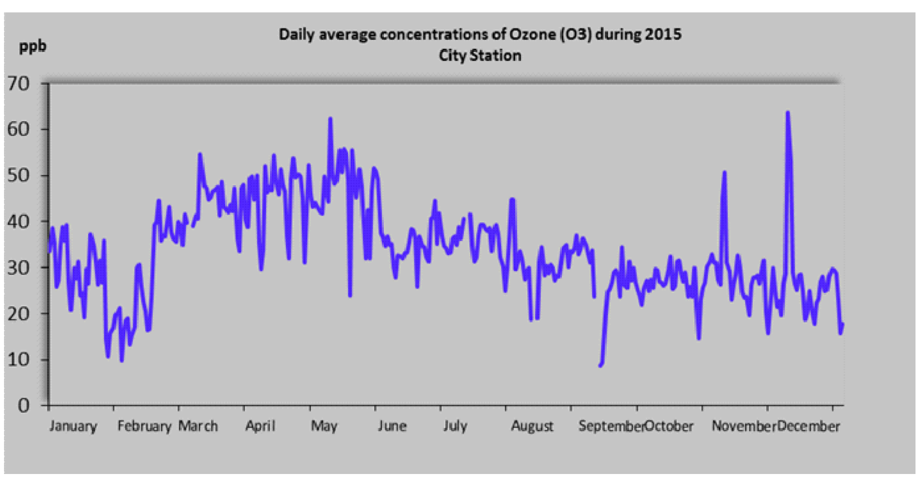

Fig. 5: Time series plot of O_3.

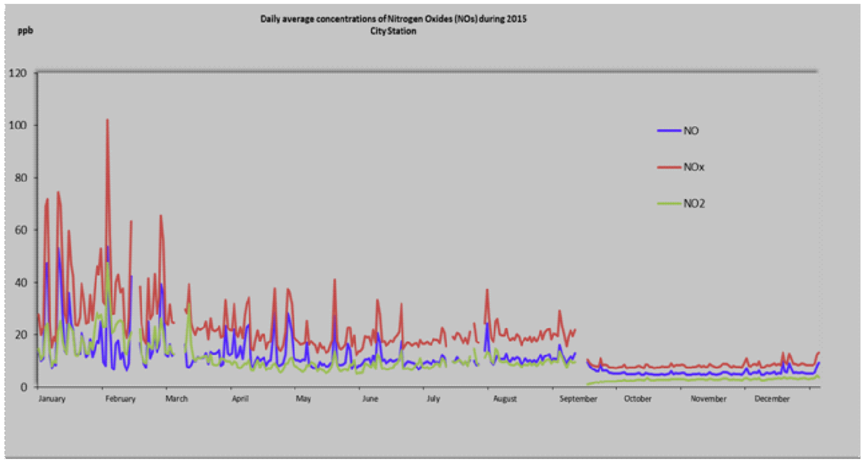

Fig. 6: Time series plot of NO_x.

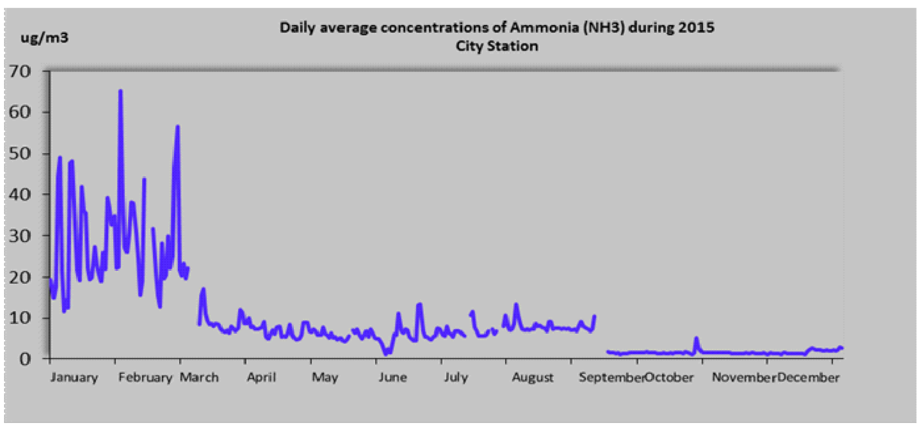

Fig. 7: Time series plot for NH_3.

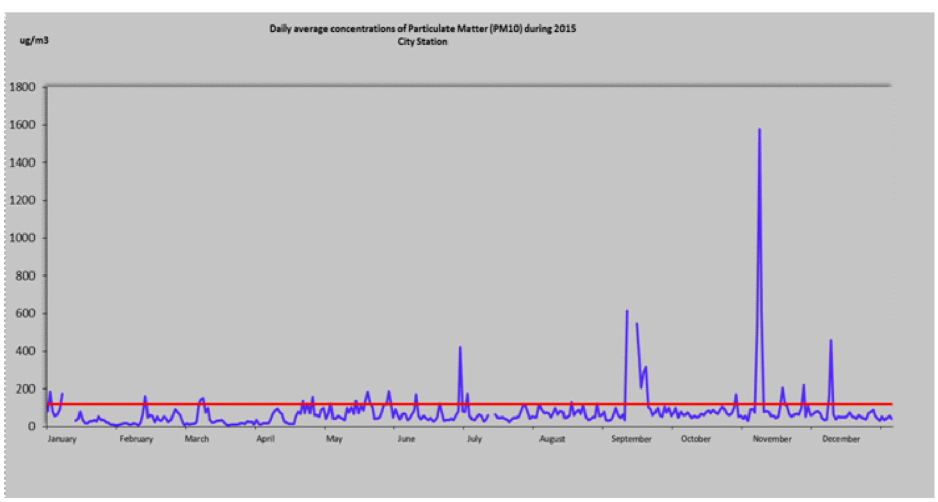

Fig. 8: Time series plot of $PM_{10.}$

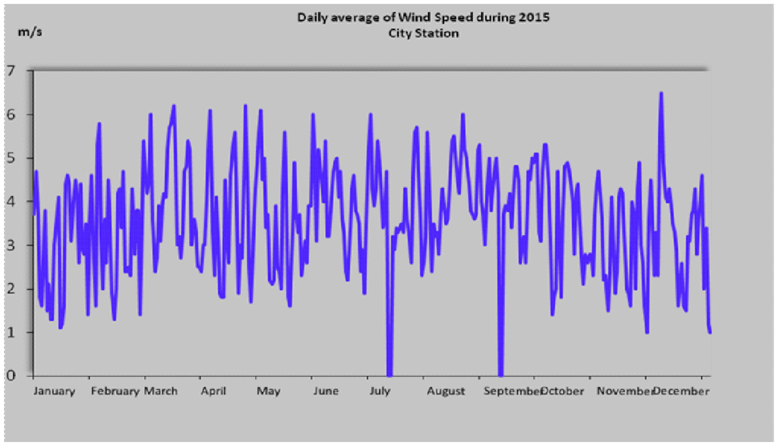

Fig. 9: Time series plot for wind speed.

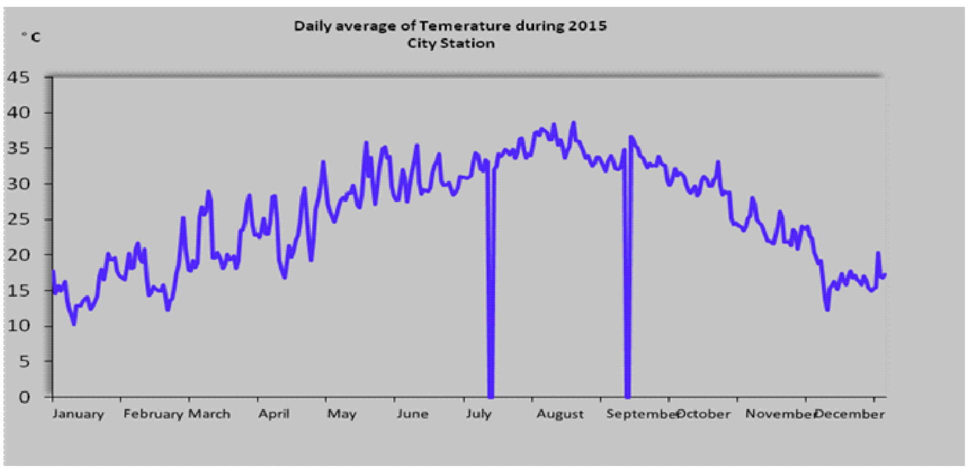

Fig. 10: Time series plot for temperature.

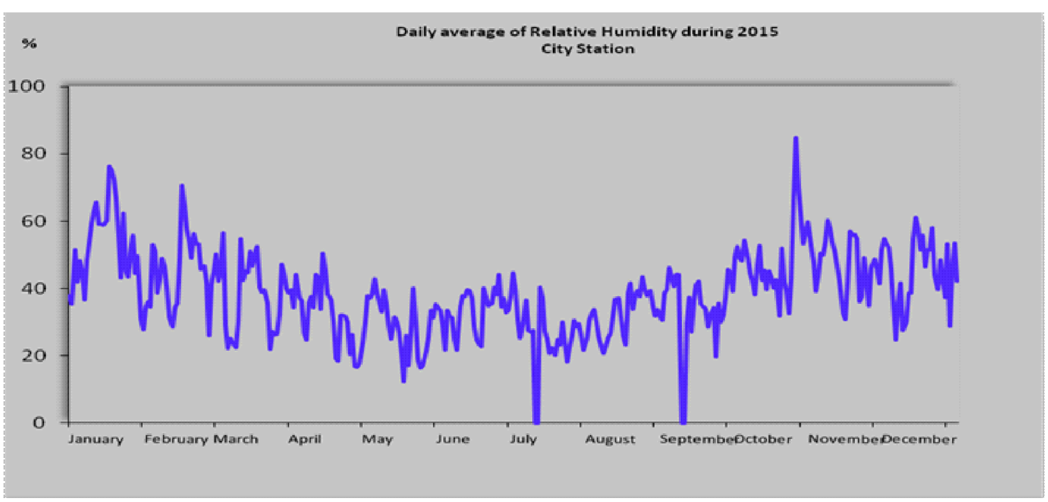

Fig. 11: Time series plot for relative humidity.

Table 2: Relationship between wind speed and air pollutants.

Pollutants	beta	Significance	f	R square	R
PM_{10}	0.005	0.918a	0.011	0.000	005a
NH_3	-0.171	0.001a	10.889	0.029	0.171a
NOx	-0.178	0.001a	11.865	0.032	0.178a
O_3	0.300	0.000a	35.990	0.090	0.300a
CO	-0.223	0.000a	18.988	0.050	0.223a
SO_2	-0.204	0.000a	15.763	0.042	0.204a

Table 3: Relationship between temperature and air pollutants.

Pollutants	beta	Significance	f	R square	R
PM_{10}	0.170	0.001a	10.761	0.029	0.170a
NH_3	-0.326	0.000a	43.090	0.106	0.326a
NOx	-0.168	0.001a	10.597	0.028	0.168a
O_3	0.162	0.002a	9.824	0.026	0.0162a
CO	0.091	0.084a	3.006	0.008	0.091a
SO_2	-0.064	0.224a	1.487	0.004	0.064a
H_2S	-0.052	0.320a	0.992	0.003	0.052a

Table 4: Relationship between relative humidity and air pollutants.

Pollutants	beta	Significance	f	R square	R
PM_{10}	-0.042	0.429a	0.628	0.002	0.042a
NH_3	0.216	0.000a	17.830	0.047	0.216a
NOx	0.065	0.213a	1.558	0.004	0.065a
O_3	-0.0161	0.002a	9.662	0.026	0.161a
CO	0.292	0.000a	33.712	0.085	0.292a
SO_2	-0.071	0.174a	1.856	0.005	0.071a
H_2S	0.119	0.023a	5.243	0.014	0.119a

hanced during night time causing lower rates of mixing and dispersion resulting in relatively higher pollutant levels in ambient air.

We can recognize from Table 3, that the impact of temperature on PM_{10}, O_3 and CO is being in a strength equal 0.029, 0.026 and 0.008, respectively, where their orientation is positive. Whereas, the impact of temperature on NH_3, NOx, SO_2 and H_2S is negatively correlated with temperature. The strength equal 0.106, 0, 0.004 and 0.003, respectively.

Relationship between relative humidity and air pollutants: When studying moisture, we consider that other factors associated with it may influence the concentrations, such as wind direction and the movement of cars and the time of year, whether summer or winter.

Table 4 shows the impact of relative humidity on pollutant concentration, and we can recognize from R Square and β, that mean the impact of relative humidity on NH_3, NOx, CO and H_2S is positively correlated. It being in a strength equal to 0.047, 0.004, 0.085 and 0.014, respectively. Whereas, the impact of relative humidity on PM_{10}, O_3 and SO_2 is negatively correlated. The strength equal to 0.002, 0.026 and 0.005, respectively.

CONCLUSION

This study was taken in order to know the effect of weather and climatic change on the air pollutants by using a linear regression model. The study has shown that the temperature and wind speed was positively correlated with the concentration of PM_{10}, NH_3, NO_x, O_3 and CO, whereas it was negatively correlated with both SO_2 and H_2S concentration. It was also found that relative humidity was positively correlated with H_2S, CO, NO_X and NH_3, whereas it was negatively correlated with PM_{10}, SO_2 and O_3. Other factors associated with relative humidity may influence the concentrations, such as wind direction and the movement of cars and the time of year, whether summer or winter. The relatively high wind speed during day time causes higher rate of mixing and dispersion, resulting in general lower levels of pollution in ambient air.

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