Spatial distribution of air pollution in Tehran

The main air pollutant in the most polluted days of the year is the PM_{10}. Therefore, 10 daily averages (a composite of 10 days classified as a very unhealthy AQ) due to pollution (200-300 parts per million) were plotted to show the AQI spatial distribution for the 22 urban regions of Tehran during these days (Figure 8). In all the selected days that PM_{10} was responsible for air pollution, dust storm occurred (Table 3). It can be seen that PM_{10} pollutants in Tehran dominated in the Centre-East of the city with less such pollution in the North and the very South, which is shown in Figure 8 with the focus in regions number 6, 7, 9, 10, 11, 12, 14, 17 and 18 as well as parts of regions number 2, 3, 4, 5, 15, 16, 19, 21 and 22. Thus, the PM_{10} pollutants enter Tehran from the West carried by local winds due to atmospheric barotropic and inversion conditions (an effect of anticyclons) and they remain stable. In recent years, the main reasons for the decreasing trends of the AQI in the good and moderate categories and the increasing trends in the unhealthy and hazardous categories in Tehran are: i) use of substandard gasoline that does not meet international standards (main reason), which is available in fuel stations of Tehran and the rest of Iran; ii) use of vehicles, especially motorcycles, with sub-optimal environmental motor standards; and iii) road dust (with a share of 95.4% of the total outdoor PM_{10} emission in Tehran) that originate from the friction between tires and asphalt and aerosols from the interior deserts of Iran, Middle East and even Africa.

Table 3. The results of interpolation methods used.

Model	RMSE	ME
IDW	81.66	15.69
GPI	90.21	0.73
LPI	109.30	22.30
RBF	80.90	5.68
SK	89.90	4.18
OK	80.87	3.10
UK	91.50	3.22

RMSE, root mean square error; ME, mean error; IDW, inverse distance weighting; GPI, global polynomial interpolation; LPI, local polynomial interpolation; RBF, radial basis function; SK, simple Kriging; OK, ordinary Kriging; UK, universal Kriging.

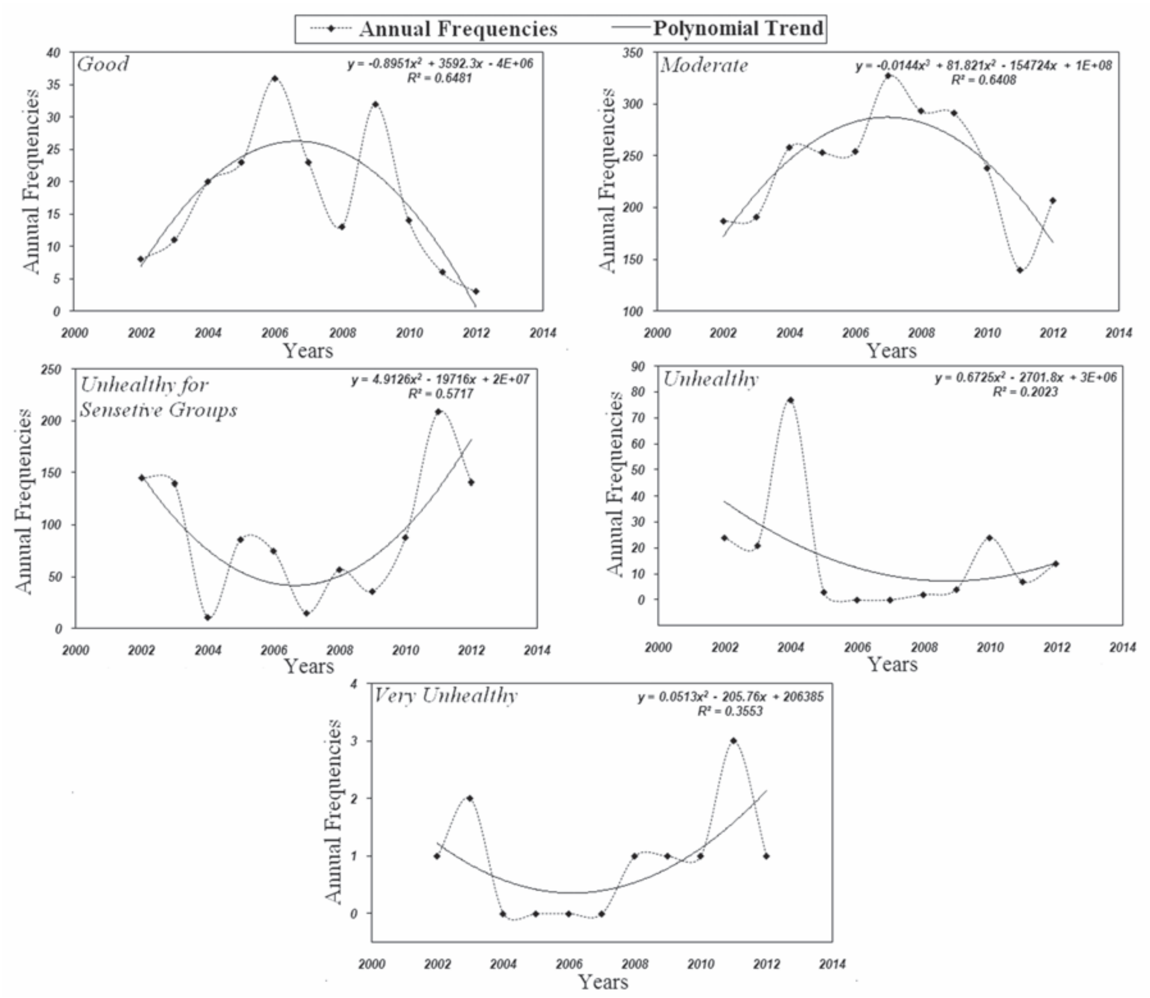

Figure 7. The temporal variation in annual frequencies of each air quality standard category in Tehran.

Calculating the relation between air quality index and pollutants

Here, the R^2 was found to be 0.985, which shows that 98.5% of variations of the dependent variable (A) can be explained by the independent variables. This coefficient is shown in Table 4. Significance of regression and linear relationship between the variables were checked by applying the analysis of variance (ANOVA) test. The obtained P values, which approve or reject the significance of regression or linear relationship between variables with a 95% confidence level, are shown in Table 5. Considering these values, it can be concluded that the regression was significant and there was a linear relationship between variables; in other words, the assumption of the significance of regression and the linear relationship between variables could be accepted at the confidence level of 95%. The main results of regression are displayed by the coefficients in Table 6. Here, the T-test statistic is shown as calculated for individual regression coefficients (Rs) including their significance levels. Given the values of significance level, the variables with significant effects can be found. The regression equation can be written based on B values in the table. Given the significant level, the equation representing the obtained regression model is as follows:

$$y=1.218 + 0.51 (CO) + 0.207 (PM_{10}) + 0.853 (PM_{2.5}) \quad \text{eq. 10}$$

Nevertheless, the beta values should be used to find the importance and role of independent variables in the regression equation, as these values are standardized. Thus, they can be applied to judge the relative importance of variables. The high amount of a variable's beta represents its relative importance and its role on A. Thus, it can be said that $PM_{2.5}$ had the highest effect on Tehran's AQ.

Discussion

There has been no serious study of the AQI trend and impacts of air pollution in Tehran. The most obvious expected effects are those related to human health. Air pollutants, mainly particulate matters, are a major cause of respiratory and cardiovascular diseases, which are highly prevalent in Tehran, particularly in the central business district. The effects of other pollutants on inner city residents are also expected to be considerable. From the geographical point of view, Tehran is wedged between two mountain ranges that trap the fumes of its bumper-to-bumper traffic. The main reason for air pollution is the low standard of gasoline used and emissions from vehicles using low quality and non-standard gasoline. However, the issue of air pollution is very complex and needs detailed further studies as it comes from various sources and as the atmosphere tends to transform it.

The fact that the pollution in Tehran enters from the West and moves in an easterly direction towards the city centre means that pollution concentrations are lower in the northern and southern parts of the city. The regression analysis showed that $PM_{2.5}$, PM_{10} and CO influenced the

Table 4. Sum of the coefficients of determination for the regression model.

R	R^2	Adjusted R^2	R^2 change SE	Change statistics R^2 change	F change
0.992	0.985	0.985	3.383	0.985	9856.006

R^2, coefficient of determination; SE, standard error; F, F statistics.

Table 5. Results of analysis of variance for fitted multiple regression.

Model	SS	DF	MS	F	P
Regression	676,665.927	6	112,777.655	9856.006	0.000
Residual	10,298.278	900	11.443		
Total	686,964.205	906			

SS, sum of squares; DF, degree of freedom; MS, mean square; F, F statistics.

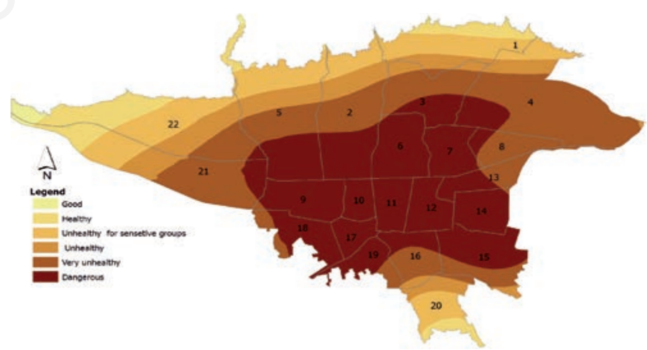

Figure 8. Map showing the average risk distribution in Tehran during ten days due to PM_{10} pollutants.

Table 6. Coefficients and model estimations for multiple regression.

Model	Non-standardised coefficients Beta	SE	Standardised coefficients Beta	T-statistics	P
Constant	1.218	0.770	-	1.582	0.114
CO	0.051	0.011	0.025	4.512	0.000
O_3	-0.013	0.009	-0.006	-1.424	0.155
NO_2	-0.012	0.010	-0.007	-1.178	0.239
SO_2	-0.008	0.026	-0.002	-0.317	0.752
PM_{10}	0.207	0.010	0.157	19.844	0.000
$PM_{2.5}$	0.853	0.009	0.855	94.921	0.000

SE, standard error.

AQ of Tehran the most, and the largest contribution of pollutants was of the $PM_{2.5}$ kind (coefficient of 0.853). It was therefore not surprising that Tehran's AQ had been reduced by approximately 11.8% between 2002 and 2012, a strongly decreasing trend that indicates that it will continue in the coming years. The frequency distribution of days with good and average quality reveals that the trend of such days declined severely during the study period. With the strong downward sloping trend of the time series, it is highly likely that the number of good (clean) days will be greatly reduced in the future.

Conclusions

According to the classification of AQ standards and the position of each study day in the classification presented in Table 1, it can be said that Tehran is not very good for life in general.

Statistical analysis of Tehran air quality index shows that Tehran air quality was not a good condition during the 11-year period from 2002 to 2012 and generally during the studied 4018 days air quality was considered unhealthy in 1190 days (29.6%). In the 2828 remaining days (70.4%), the weather has been in a state of healthy and good qualities.

The general trend of daily air quality index of Tehran in the 11-year studied period showed an upward trend which points to a 12% decrease in Tehran's air quality. The mentioned trend is meaningful and shows that in the coming years, there will probably be a decrease of 12% for Tehran AQI.

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