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ORIGINAL PAPER

Analyzing the effects of air pollution on life expectancy in Tehran, Iran

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Abstract

The present paper aims to analyze twenty-one-year long-term data of life expectancy and levels of PM_{10}, $PM_{2.5}$, CO, O_3, SO_2, and NO_2 pollutants in Tehran, Iran, to investigate the correlation between air pollution and life expectancy. Data are analyzed using the Pearson correlation coefficient and regression model. The regression analysis of the data used is performed to understand how the level of life expectancy alters by changing any of the above-mentioned pollutants and keeping constant the other independent variables. Enter Method is used for regression analysis. The level of life expectancy in Tehran was 70.18 years in 2000 and increased to 77.53 in 2020. Calculation of 21-year long-term data on air pollution index indicates no uniform and linear trend, but the trend of life expectancy is increasing. According to the adjusted R-squared calculation, it is concluded that 89.1% of the changes in the dependent variable (life expectancy) are explained by independent variables (air pollutants), which is a large value and is considered a fit model. The result of regression analysis of variance for statistical hypotheses also reveals that the Sig value is less than 0.05, thereby confirming the hypothesis of linear correlation between the two variables. However, the correlation coefficient is not a simple linear function, and the increase in life expectancy should be sought in the growth of other control variables such as improved health, treatment, nutrition, and quality of life.

Keywords Air pollution risk · Air pollutants · Life expectancy · Air quality index

Introduction

Urban pollution is one of the major challenges of urbanization, which has threatened the urban environment. Urban pollution is mainly characterized by local air pollution, greenhouse gas emissions (Zheng and Kahn 2013), groundwater pollution, and soil pollution (Ma and Xu 2018). Urban pollutants can inhibit the ecological functions and processes of cities, and endanger people's lives, especially processes that provide vital benefits and services to humans (Wade 2018).

Every person is exposed to ambient air pollution on a daily basis, some to a greater extent and some to a lesser extent. Several severe pollution events, such as the Meuse Valley fog of 1930 (Firket 1936) and the infamous London fog episode of 1952 that killed thousands, have helped draw public attention (Logan 1953; Ministry of Health 1954). Although particulate and gaseous pollutants coexist and may have both health side effects (such as ozone) (Bell et al. 2004), the most convincing evidence suggests Airborne particulate matter (PM) as a major cause of the human disease (Pope and Dockery 2006; Brook et al. 2004; US EPA 2004). The PM itself is a heterogeneous amalgam of compounds that vary in concentration, size, chemical composition, surface area, and sources of origin. Although it may seem intuitive that PM poses a significant risk to lung health, general evidence suggests that most of the side effects of PM are on the cardiovascular system (Pope and Dockery 2006; Brook et al. 2004; US EPA 2004).

Among urban pollutants, air pollution as one of the important environmental stimuli has caused more concerns about public health, especially in crowded and large cities (de Hartog et al. 2009; Prieto-Parra et al. 2017; Talbott et al. 2014; Weber et al. 2016; Zanobetti et al. 2014). Air pollution occurs as a result of a complex combination of compounds in gases [O_3, CO and NOx (nitrogen oxides)] and particulate matter (Pope and Dockery 2006; Brook et al. 2004; US EPA 2004; Environmental Protection Agency 2006).

As evidence of the negative health impacts of air pollution has been collected, the quantity of the effects of air

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pollution on public health and the consequent cost–benefit analysis has become increasingly important in policy discussions. In fact, several studies have estimated the health impacts of air pollution both physically (Kunzli et al. 2000) and financially (Zaim 1997; El-Fadel and Massoud 2000), all of which emphasized the impact of air pollution on public health.

Sociological factors, as measured by population growth and urbanization, also have a negative impact on environmental degradation in the short term, but both population size and urbanization increase environmental degradation in the long run. Thus, research on one of the most important and largest Asian cities, Tehran, will help clarify this issue. Tehran, as one of the most polluted metropolises in the world with a population of millions, in recent years has always faced the challenge of air pollution, the effects of which on the health of citizens have been identified (Shirazi and Harding 2001; Hosseinpoor et al. 2005; Atash 2007; Brajer et al. 2012; Kermani et al. 2018; Dehghan et al. 2018; Yarahmadi et al. 2018; Jamaati et al. 2018). The most important pollutants in Tehran are particulate matters of PM_{10} and $PM_{2.5}$, CO, O_3, SO_2 and, NO_2. The current study seeks to investigate the correlation between air pollution and life expectancy by examining data related to health and pollutants (PM_{10} and $PM_{2.5}$, CO, O_3, SO_2, and NO_2) in the Tehran metropolis during 2000–2020. The purpose of this paper is to find out what is the relationship between each of the air pollutants and life expectancy in Tehran.

Literature review

Inadequate air quality is one of the main risk factors for global disease (Akhtar and Palagiano 2018). Although this problem is growing rapidly in developing countries (West et al. 2016), the health impacts of air pollution have also been recorded in developed countries that are exposed to very little air pollution (Shi et al. 2016). For example, urban air quality reflects a major public health burden and a long-standing concern of European citizens. Air pollution is associated with a wide range of diseases, symptoms and, info clinical diseases that disrupt the health and quality of life in European cities. Aphekom project, which aims to provide new, clear, and meaningful information about the health effects of air pollution in Europe, shows that European citizens are still exposed to concentrations beyond WHO recommendations. Aphekom provided documentary estimates showing a reduction in urban air pollution that will lead to significant gains in health and financial growth in Europe (Pascal et al. 2013).

Much of the evidence for the association between long-term exposure to air pollution and mortality comes from studies in North American countries, and differences in results are based on exposure contrasts between and within different communities (Abbey et al. 1999; Dockery et al. 1993; Gan et al. 2011; Lepeule et al. 2012; Lipsett et al. 2011; Pope et al. 2004; Puett et al. 2008). Although the harmful effects of air pollution have been proven in many Western countries, limited studies have been conducted in Asia. Time-series studies on mortality and health in several Asian cities can play a significant role in the global literature on the health impacts of air pollution. First, they provide direct evidence of the impact of air pollution in areas where there are few studies. Second, because they are exposed to different conditions and populations, mortality studies in Asian cities can shed light on factors probably altering the health impacts of air pollution. In addition, multi-city studies conducted in Asia, especially when analyzed using a common protocol, can provide stronger estimates of the impact of air pollution than individual studies, as well as provide relevant and supportive estimates of the local effects of environmental conditions on decision-makers (Wong et al. 2008).

There are several studies on the health impacts of air pollution in Tehran. Yarahmadi et al. (2018) examined the mortality rate due to lung cancer and chronic obstructive pulmonary disease (COPD) in over 30-year-old adults with long-term exposure to $PM_{2.5}$ in Tehran from March 2013 to March 2016, the results of which revealed that the annual mortality rate due to $PM_{2.5}$ decreased from 2013 to 2016, and this decrease in mortality is related to the corresponding decrease in $PM_{2.5}$ concentrations.

Kermani et al. (2018) examined the relationship between mortality and air pollutants in Tehran in the years 2005–2014 and concluded that the greatest health impacts in Tehran were related to the relevant particulate matter. High concentrations of air pollutants, especially particulate matter such as PM_{10} and $PM_{2.5}$, can increase mortality and cardiovascular and respiratory diseases. According to this study, a large number of residents of Tehran have lost their lives due to exposure to air pollutants. Therefore, appropriate health and environmental measures must be taken to control and manage air pollution.

Dehghan et al. (2018) found that the air pollutants (O_3, NO_2, PM_{10}, and $PM_{2.5}$) are associated with respiratory death in Tehran, and reducing ambient air pollution can save lives in Tehran.

Previous studies in Tehran have mainly investigated only cases of deaths and pollutants, but not the effects of pollutants on life expectancy. Therefore, research on the impacts of air pollution on life expectancy in Tehran as one of the most important and largest Asian cities can create a new trend in studies.

Materials and methods

Life expectancy is mainly related to health indicators, but these indicators alone are not effective in increasing or decreasing life expectancy in a city. There are other indicators in this regard that can reduce this issue. Among these indicators, air pollution is very important, especially in metropolitan areas, which is considered in this article (Fig. 1). Data on air pollution for a twenty-one-year period from 2020 to 2000 are studied in Tehran. Data are analyzed using the Pearson correlation coefficient, which indicates the intensity of the relationship as well as the type of relationship (direct or inverse). Pearson correlation coefficient is a parametric method and has been used for data with normal distribution or a large numbers of data (21-year period).

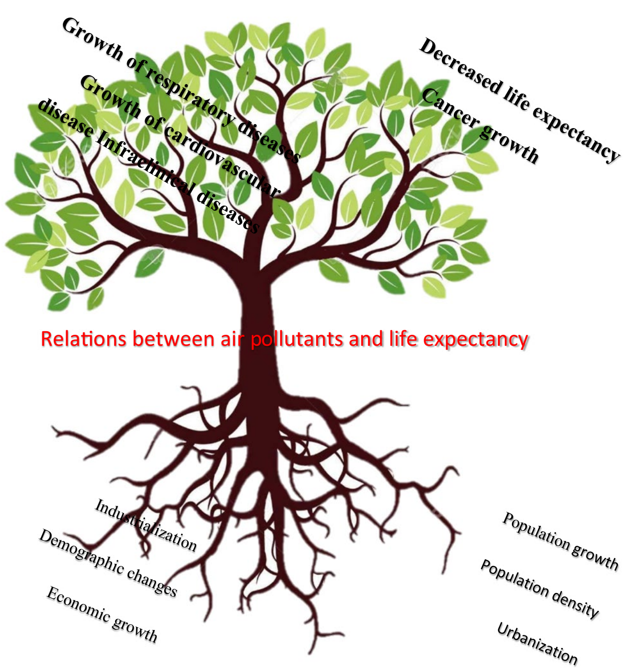


Fig. 1 Problem tree analysis

Results and discussion

Results

Life expectancy analysis of tehran

Along with the direct correlation between air pollution and mortality rate, life expectancy is an important parameter to express the cultural, social, and economic and health status of any society. Life expectancy has become one of the indicators of fluctuations in health inequalities in various societies. Life expectancy is also affected by health components. According to the latest census results (2016), life expectancy in Iran is estimated at 72.5 years for men and 75.5 years for women. As shown in Fig. 2, this index is growing in Iran.

The life expectancy index in Tehran also has an increasing trend. As shown in Fig. 3, this trend was 70.18 years in 2000 and increased to 77.53 in 2020. Compared to global standards, this growth is very high in Tehran due to the concentration of health and medical facilities and services, hospitals and clinics, the growth of education, increasing per capita income when comparing with other parts of the country.

Analysis of the correlation between air pollution and life expectancy

Recently, there has been an emphasis on the correlation between life expectancy and long-term air quality changes (Pope et al. 2009; Crouse et al. 2012; Correia et al. 2013). Lelieveld et al. (2020) compared different global risk factors and found that ambient air pollution is the leading cause of excess mortality and loss of life expectancy (LLE), especially through cardiovascular diseases (CVDs). Globally, LLE due to air pollution surpasses HIV/AIDS, parasitic, vector-borne, and other infectious diseases by a large margin. Wu et al. (2020) assessed the association between annual changes in particulate matter levels ($PM_{2.5}$) and changes in life expectancy in an urban population of China from 2013 to 2017 and concluded that lower $PM_{2.5}$ air pollution may be associated with increased life expectancy in East China. Kelly (2017) also presented a model of observations in 111 countries, showing that there is a negative correlation between the average exposure to air pollution and life expectancy. However, Kelly noted that there may be other control variables that are important in explaining life expectancy changes in these countries.

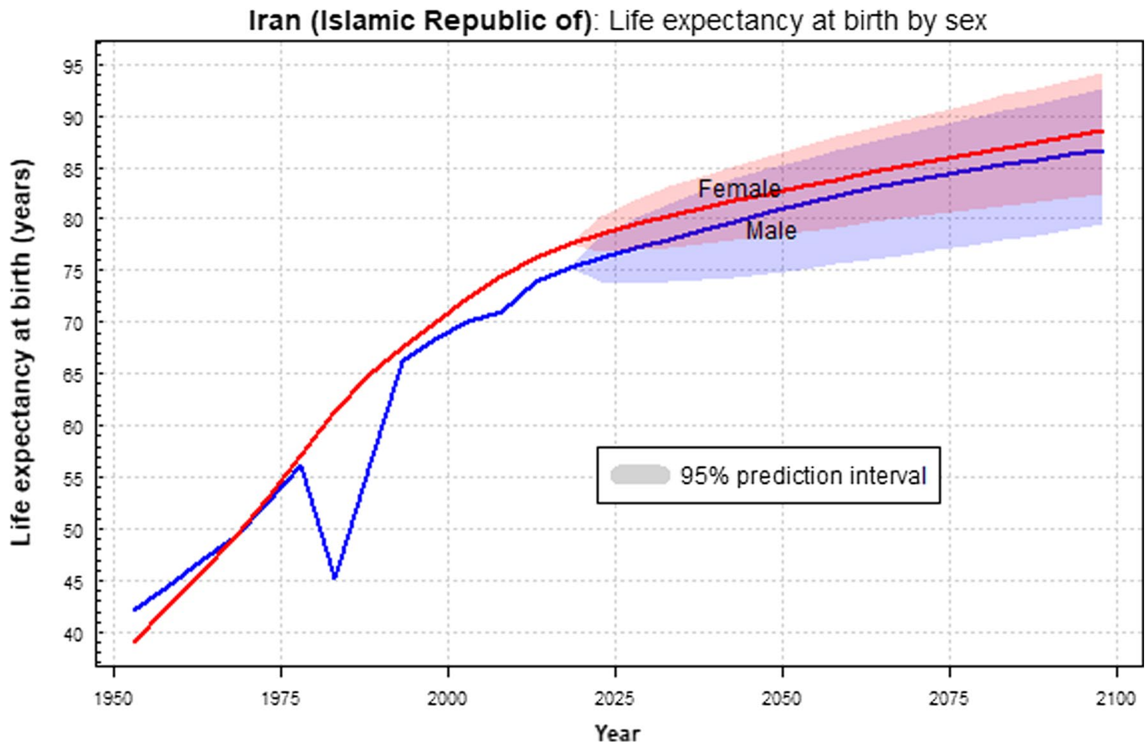
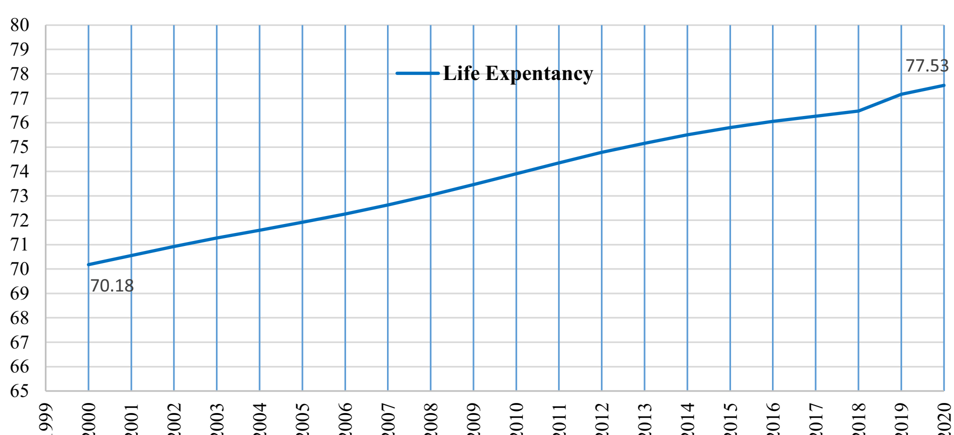


Fig. 2 Life expectancy at birth by sex in Iran *: Medium-variant projections for 2020–2100 are shown as thin colored lines, and uncertainty is shown in lighter shades for 95 percent prediction intervals *Source* United Nations, Department of Economic and Social Affairs, Population Division World Population Prospects 2019, Volume II: Demographic Profiles

Fig. 3 Life expectancy at birth in Tehran, 2000–2020



According to Fig. 4, long-term analyzes (2000–2020) between AQI and life expectancy index demonstrates no correct and significant correlation between increased air pollution and decreased or increased life expectancy. The AQI diagram is not a uniform, linear trend, but life expectancy is an uptrend. In analyzing the AQI trend, it should be noted that when the climatic conditions of Tehran have had rainy years, this index has normally decreased, and vice versa, when the city has had low rainfall years, the AQI index has also increased. However, as stated in life expectancy analysis, increased life expectancy should be sought in the growth of other health, treatment, and nutrition control variables.

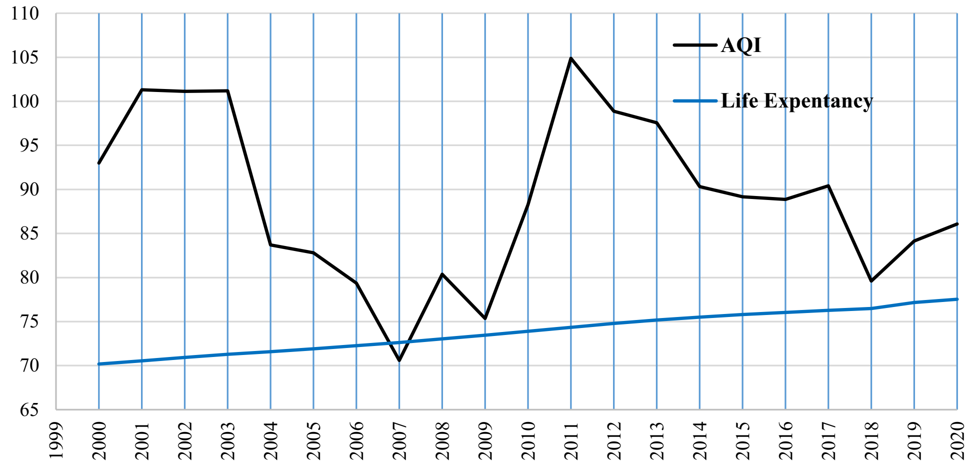


Fig. 4 AQI and life expectancy trends in Tehran, 2000–2020

Table 1 Correlations between life expectancy an air quality index, 2000–2020

		Life expectancy
CO	Pearson Correlation	-0.944^{**}
	Sig. (1-tailed)	0.000
	N	21
O_3	Pearson Correlation	0.504^{*}
	Sig. (1-tailed)	0.012
	N	20
NO_2	Pearson Correlation	0.945^{**}
	Sig. (1-tailed)	0.000
	N	20
SO_2	Pearson Correlation	-0.821^{**}
	Sig. (1-tailed)	0.000
	N	20
PM_{10}	Pearson Correlation	-0.255
	Sig0. (1-tailed)	0.132
	N	21
$PM_{2.5}$	Pearson Correlation	-0.879^{**}
	Sig. (1-tailed)	0.000
	N	11

**Correlation is significant at the level of 0.01 (2-tailed)

*Correlation is significant at the level of 0.05 (1-tailed)

Table 2 Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	$PM_{2.5}$, O_3, NO_2, CO, PM_{10}, SO_2[b]		Enter

[a]Dependent Variable: Life expectancy

[b]All requested variables entered

Table 1 presents the correlation matrix for these two variables. According to Table 1, the R-value of correlation between the levels of air pollutants and life expectancy is described as follows.

The correlation coefficient between CO level and life expectancy is -0.944, which shows the negative correlation between these two variables, i.e., with increasing CO, life expectancy does not increase. The correlation obtained is very weak and insignificant, and the negative value is a reason for the inconsistent correlation.

The correlation coefficient between SO_2 level and life expectancy is -0.821, which shows the negative correlation between these two variables, i.e., with increasing SO_2, the life expectancy does not increase. The correlation obtained is very weak and insignificant; and a negative value is a reason for the inconsistent correlation.

The correlation coefficient between the level of PM10 and life expectancy is -0.255, which indicates the negative correlation between these two variables, i.e., with the increase of PM10, life expectancy does not increase. The correlation obtained is very weak and insignificant and the negative value is a reason for the inconsistent correlation.

Here, the correlation coefficient between the level of $PM_{2.5}$ and life expectancy is -0.879, which shows the negative correlation between these two variables, i.e., with the increase of $PM_{2.5}$, life expectancy does not increase. The correlation obtained is very weak and insignificant, and the negative value is a reason for the inconsistent correlation.

It should be noted that the correlation coefficient is not a function of simple linear changes in the analyzes performed. In this study, the description of the correlation coefficient depends on the research topic and is interpreted according to the specific context and conditions of the research.

Table 3 Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.978[a]	0.957	0.891	0.37185

[a]Predictors: (Constant), PM $_{2.5}$, O_3, NO_2, CO, PM_{10}, SO_2

[b]Dependent Variable: Life expectancy

Therefore, in determining the correlation between the two variables mentioned in Table 1, it is necessary to pay attention to all aspects in order to determine the impact of these variables on life expectancy without the intervention of other factors. Therefore, the correlation between the two independent variables of O_3 and NO_2 is not true.

Regression analysis

In this study, regression analysis of these data helps us to understand how the value of the dependent variable (life expectancy) changes by altering each of the independent variables ($PM_{2.5}$, O_3, NO_2, CO, $PM_{10,}$ and SO_2) and keeping constant other independent variables. As shown in Table 2, the Enter Method is used for regression in this study. In this method, all independent variables are entered into the model simultaneously to determine the effect of all influential and non-influential variables on the dependent variable.

According to further analysis in Tables 3, the coefficient of determination (R-squared) and generalized coefficient of determination (adjusted R-squared) shows what percentage of the changes in the dependent variable is explained by independent variables and by this regression model. Here, using adjusted R-squared, we can say that 89.1% of the dependent variable changes are explained by independent variables, which is a large value and is considered a fit model.

Table 4 shows the regression analysis of variance to check the certainty of the linear correlation between the dependent variable and the independent variables. The statistical hypotheses of the significant test for the whole regression model are as follows:

- H_0: there is no trend in this time series.
- H_a: there is a trend in this time series.

In this table, a value of Sig less than 0.05 confirms the hypothesis that the correlation between the two variables is linear.

The concept of correlation in the regression test means whether the correlation obtained between the dependent variable and the independent variables in this study is random or there is a correlation. Whether the number obtained is significant or not is more important than the correlation

Table 4 ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig
1	Regression	12.190	6	2.032	14.693	0.000[b]
	Residual	0.553	4	0.138		
	Total	12.743	10			

[a]Dependent Variable: Life expectancy

[b]Predictors: (Constant), PM $_{2.5}$, O_3, NO_2, CO, PM_{10}, SO_2

Table 5 Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig	95.0% Confidence Interval for B	
		B	Std. Error				Lower Bound	Upper Bound
1	(Constant)	78.782	3.351		23.511	0.000	69.478	88.085
	CO	−0.022	0.027	−0.140	−0.822	0.000	−0.098	0.053
	O3	0.046	0.027	0.218	1.683	0.000	−0.030	0.122
	NO2	0.036	0.043	0.248	0.844	0.000	−0.083	0.155
	SO2	−0.094	0.125	−0.803	−0.756	0.000	−0.440	0.252
	PM10	−0.225	0.183	−0.773	−10.224	0.000	−0.734	0.285
	PM 2.5	0.107	0.168	0.861	0.635	0.000	−0.361	0.574

[a]Dependent Variable: Life expectancy

coefficient itself. Therefore, first the significance of the whole linear regression model is confirmed, then linear regression is performed. Of course, it should be noted that with linear regression, one can only guess about the linearity of the relationship between variables.

Table 5 and column B present the constant values and coefficients of the independent variables in the regression model, respectively. In this equation, the regression of coefficients includes two categories of unstandardized coefficients (B) and standardized coefficients (Beta). In the unstandardized coefficients, the scales of variables are not the same, while in the standardized coefficients, the scales of variables are the same and it is possible to compare variables. Therefore, in this study, the standardized coefficients are used to compare the effects of independent variables on the dependent variable. For one unit of change in the level of pollutants in the city, 0.003351 units of change are created in life expectancy. This is considered assuming that the other control variables are constant.

Conclusion

Life expectancy at birth is the average number of years a person is expected to live from birth and is mainly influenced by a person's social status and genetic characteristics. This index shows that each person belonging to a certain generation will live an average of how many years until the end of life. Life expectancy at birth is an important indicator of the cultural, social, and economic and health status of any society. The World Health Organization (WHO) estimates the human development index, which is one of the most important indicators of development of countries and cities, using the life expectancy index along with indicators of per capita income, gross national product, and literacy rate.

Although several studies have been conducted on the correlation between air pollution and life expectancy in different communities, the study of the correlation between the two in Tehran is a new topic and requires more scrutiny to understand the possible effects of these two variables. Therefore, the importance of the study is that it has evaluated the trends of changes in air pollutants and life expectancy in Tehran. Tehran is one of the most polluted metropolises in the world in terms of air quality, which includes a population of 8,938,686 people, and the health of this population is always in danger of increasing levels of air pollutants and spends many days of the year in a state of alert.

Tehran has the longest life expectancy in Iran due to the concentration of facilities, infrastructure, and more attention of people to medical affairs. The impacts of growing economic conditions, increasing and concentrating health services, increasing welfare, and improving lifestyles have increased life expectancy. Hence, with this growth, the long-term impact of air pollution on life expectancy must be estimated. As the life expectancy index of Tehran reaches international standards, it seems that the impact of air pollution on life expectancy will be better calculated.

The overall results of this study are consistent with studies by Wu et al. (2020) in East China, Bennett et al. (2019) in the USA, Kelly (2017) on a global scale in 111 countries, Dockery et al. (2019) in Mexico City, Ebenstein et al. (2017) in China, Greenstone and Fan (2019) in Indonesia, Jorgenson et al. (2020) in the USA, Lelieveld et al. (2020) on a global scale, Balakrishnan et al. (2019) in India, and de Keijzer et al. (2017) in Spain. Lelieveld et al. (2020) assessed the mortality rate attributed to ambient air pollution on a global scale and concluded that ambient air pollution is one of the major health hazards in the world, causing significant mortality and loss of life expectancy, especially through cardiovascular disease. Balakrishnan et al. (2019) estimated that if the level of air pollution in India was less than the minimum amount of health loss, the average life expectancy in 2017 was 1.7 years higher. According to the Air Quality Life Index, Greenstone and Fan (2019) reported that an average Indonesian can lose life expectancy up to 1.2 years at current pollution levels.

However, the differences are related to the extent and intensity of the impact of each pollutant on life expectancy. Regarding the severity of $PM_{2.5}$, Wu et al. (2020) in East China confirm that reducing air pollution levels of $PM_{2.5}$ may be associated with increased life expectancy. A decrease of 10 $\mu g/m^3$ in $PM_{2.5}$ was associated with a 0.18-year increase in life expectancy. Dockery et al. (2019) also showed that the air quality in Mexico City is associated with increased life expectancy. Each decrease of 10 $\mu g/m^3$ in the mean annual $PM_{2.5}$ level was associated with an increase in life expectancy of 0.89 ± 0.38 years ($p = 0.028$). Independently, each decrease of 10 ppb in the mean maximum seasonal O_3 level was associated with an increase of 0.24 ± 0.08 years ($p = 0.004$). On the other hand, according to Bennett et al. (2019) estimates, the recent decline in pollution with $PM_{2.5}$ in the USA has led to public health benefits. However, their estimates show that current concentrations of $PM_{2.5}$ are associated with the effects of mortality and loss of life expectancy, and these effects are greater in cities with lower incomes and higher poverty rates. This study is in-line with the study of Kelly (2017), which reports a negative correlation between the average exposure to air pollution and life expectancy via the study of 111 countries. Kelly estimates that life expectancy decreases by an average of 0.04 years per additional μg/m^3 exposed to air pollution with $PM_{2.5}$.

As for the effect of PM_{10} on life expectancy, Ebenstein et al. (2017) in China indicated that a 10-μg/m^3 increase in PM_{10} levels reduces life expectancy by 0.64 years. The negative effect of PM_{10} on life expectancy has also been demonstrated in our study, although the correlation coefficient seems to be weak. Jorgenson et al. (2020) also found that the detrimental effects of fine particulate matter on life expectancy in the USA are particularly evident, especially in states with very high levels of income inequality and black populations.

According to de Keijzer et al. (2017) in Spain, the air pollution concentrations were associated with a significant reduction in life expectancy. An increase of 5 μg/m^3 at PM_{10}, NO_2, and O_3 levels or 2 μg/m^3 at $PM_{2.5}$ level resulted in the loss of life expectancy of 0.90, 0.13, 0.09, 0.17, 0.20, and 0.64, respectively. As mentioned, there are other control variables that are important in explaining life expectancy changes in different countries and cities, and Tehran is no exception.

Although life expectancy estimates in different areas of Tehran are higher than national values, inequality in these values, especially between affluent and deprived areas of the city is significant and obvious. It is noteworthy that the concentration of air pollutants is higher in deprived areas of the city, which are mainly the southern and central areas of the city. This issue should be addressed in other studies.

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Ethical standards This article does not contain any studies with human participants or animals performed by any of the authors.

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