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The economic burden of mortality and morbidity due to air pollution in Tehran, Iran: a systematic review

Mohammad Hadian[1] · Pouran Raeissi[2] · Touraj Harati Khalilabad[1]

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Abstract

Introduction Today, air pollution is creating a huge economic burden on communities by causing deaths and various diseases. The present study aimed to systematically review the economic burden of mortality and morbidity of air pollution and the methods for measuring these costs in Tehran, Iran.

Method A literature search of online databases (PubMed, Scopus, Web of Sciences, Embase, and Ovid) was searched through August 1, 2019, by using the appropriate English keywords. Also, Iran Medex, Barkat, and Magiran databases were searched for Persian articles.

Results Four English and two Persian studies were included in this review. All the articles investigated the economic burden of mortality due to air pollution, in which five, one, and one studies used value of statistical life, compensation payment, and human capital approach. The economic burden of mortality due to air pollution was estimated at $ 316 million to $ 2630 million. Also, five studies (83%) investigated the economic burden of morbidity due to air pollution, in which three, two, and one studies used the cost of illness, percentage of mortality costs, and willingness to pay methods, respectively. The economic burden of morbidity due to air pollution was estimated at $ 236 million to $ 546 million.

Conclusion By systematically reviewing and emphasizing on different methods of measuring the economic burden of mortality and morbidity caused by air pollution, the results show that air pollution is a serious problem in Tehran. Nevertheless, appropriate methods should be used to measure costs to get robust and reliable results.

Keywords Air pollution · Economic burden · Mortality · Morbidity · Systematic review

Introduction

Today, most of the world's most populous cities face air pollution problem as one of the aspects of environmental pollution (HUA et al. 2019). Iran is a developing country faced with problems caused by air pollution. Air pollution has reached dangerous levels in many cities of Iran, so that the concentration of some pollutant in megacities' Iran was three times higher than national standards and the Air Quality Guideline of the WHO, which are 10 μg/m^3 (ARFAEINIA et al. 2014; HEGER and SARRAF 2018).

Among the different sectors in Tehran, transportation and industry have the most role in emission different pollutants, so that the transport sector alone produced 69% of the total nitrogen oxides (NO_X) emissions, 31% of the total sulfur dioxide (SO_2), 31% of the total carbon dioxide (CO_2), 59% of the total carbon monoxide (CO), and 74% of the total particulate matter ($PM_{2.5\ or\ 10}$) have the highest emissions among other energy-consuming sectors in Tehran (ALLAHYARI et al. 2014).

Exposure to these pollutants results in significant health problems. Air pollution has adverse effects on people's health and leads to premature death, cardiovascular disease, bronchitis, respiratory disorders, and cancer (Liu et al., 2018). In a bitter experience due to air pollution in December 1952 in London, around 3766 people died: most of them were elderly and people with heart and lung diseases. According to the World Bank (WB) report, around 7 million people die annually from diseases attributable to air pollution all around the

✉ Touraj Harati Khalilabad
Harati.t@iums.ac.ir

[1] Department of Health Economics, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran

[2] Department of Health Service Management, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran

world (World Bank 2016). Also, according to the International Institute for Cancer Research (IARC), air pollution considers as the main carcinogen (VINEIS and XUN 2008). Also, one out of every nine and about 9 million of the world's annual deaths are specifically related to air pollution (World Health Organization 2016).

Also, air pollution has had adverse effects on people's health in Tehran. According to a study conducted by Bayati et al., about 3380 deaths were attributed to air pollution ($PM_{2.5}$) in 2017 (BAYAT et al. 2019). Also, a study conducted by the WB estimated 4000 premature mortality due to air pollution in Tehran in 2016 (World Bank 2018). Table 1 shows the annual results of these studies in Tehran.

As noted in Table 1, air pollution has caused enormous economic and health damages in Tehran. Researchers have shown that the cost of treatment, reduce labor productivity, and diseases suffering due to air pollution along with annual deaths can place a heavy economic burden on communities (KOCHI et al. 2008). The statistics show that air pollution generated $ 2.6 billion in economic burdens in terms of mortality and morbidity in the Iranian capital (Tehran) in 2016 (World Bank 2018).

The health economic burden of air pollution is often assessed using different methods. Willingness to pay (WTP) is the common methods to calculate the non-market and indirect economic burden of mortality and morbidity. In this methods, the economic burden estimated based on people's preferences. Also, VOSL is preferred approach based on WTP. Since this method depends on income of person, VOSL will reflect differences between wealthy and poor countries and societies (MENZ and WELSCH 2010).

Cost of illness (COI), compensation payments (CP), human capital approach (HCA), and insurance method are other methods that are market base. In the COI method, the sum of medical expenditures and lost earnings attributable to the morbidity associated with pollution calculated, while in the HCA method only the lost earning due to mortality consider. In other words, in the HCA method, the present value of the future earnings of people died due to air pollution are calculated; in other words, the HCA method calculates the present value of forgone lifetime earnings (ALBERINI and KRUPNICK 2000; DANESH JAFFARI et al. 2015). Also, in the CP method, a fixed annual amount considers as compensation cost for all death due to air pollution. This fixed amount (compensation cost) is determined by the government annually, although this amount is variable based on people's income in the insurance. In this insurance method, compensation payment is determined based on the premiums paid at the time of survival, which depends on the individual's income (DANESH JAFFARI et al. 2015).

Since today air pollution in Tehran has become a serious health hazard, so minimizing the health impacts of air pollution can make communities more aware of the dangers of air pollution. Therefore, this review study aimed to identify the economic burden of health outcomes (mortality and morbidity) due to air pollution in Tehran.

Table 1 Health and economic effects due to air pollution in Tehran

Items survived	Year	
	2016	2017
Average annual concentration $PM_{2.5}$ ($\mu g/m^3$) in free air	32	31
Number of deaths attributed to air pollution	4000	3380
Total economic losses (millions of dollars) (%GDP)	2600	2894

Method

In this systematic review study, the economic burden of mortality and morbidity caused by air pollution was investigated in Tehran. A literature search was conducted in PubMed "Scopus" Web of Sciences, and Embase for English articles, and in Iran Medex, Barkat, and Magiran for Persian articles on August 1, 2019. The appropriate English keywords such as "Cost of illness," "Air pollution," "Economic cost," "Health impact," "Contingent valuation method," "Willingness to pay," "Value of statistical life," and other similar keywords were used to search the articles in the databases. To identify any remaining studies, we hand-searched the bibliographies of all the included studies, relevant review articles, and the Internet. The full search strategy is available in the appendix.

Inclusion and exclusion criteria

All English and Persian language studies that investigated the economic burden of mortality and morbidity caused by air pollution in Tehran until August 1, 2019, were included in the study. All inclusion and exclusion criteria are reported in Table 2.

Data extraction

Three authors (MH, PR, and THK) in this study extracted the data. After removal of duplicates, the remaining articles screening based on title and abstract information by one author (THK). In the second step, the full text of the articles was given to two trained authors (MH and PR) to assess the inclusion. Each article was reviewed by two individuals independently. If authors had opposing opinions about an article, the article was judged by a third reviewer (THK). In the next step, the required parameters and characteristics of each study were described and extracted.

These characteristics are summarized in Table 2. Also, to evaluate the quality of articles, the Consensus on Health

Table 2 Inclusion and exclusion criteria for selected articles in the study

Inclusion criteria	Exclusion criteria
• Study types: Cohort, case-control, or cross-sectional studies, ecologic studies, case-crossover, or time-series studies, WHO, and World Bank report examining the impacts of air pollution on health costs in Tehran • Air pollutants types: Outdoor pollutant such as carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and particulate matter ($PM_{2.5}$ or PM_{10}) that emitted from transport, industry, and household sector and clearly defined human health outcomes • Place and time period: Articles conducted in Tehran and published until August 1, 2019 • Articles languages: English and Persian languages articles.	• Study types: Review and meta-analyses articles; proceeding articles; and policy articles, editorials, and letters—news articles, the poster, case reports, case series studies, conference articles, chapter in books, and any studies types that examining the impacts of multiple pollution together (air, noise …) on health and related costs. • Air pollutants types: Indoor air pollution and gaseous air pollutants that emitted from second-hand smoking, sources of combustion, cooking with solid fuels or farm • Place and time period: Articles not conducted in Tehran and published after August 1, 2019 • Articles languages: Non-English and Non-Persian languages articles

Economic Criteria (CHEC) checklist was applied (EVERS et al. 2005). The CHEC checklist consists of 19 criteria, including the discussions on generalizability of the study result, the cost and outcome identification and valuation, conclusion, ethical issues as well as the potential of conflicts of interest and also, standard elements in reporting an economic evaluation study (study population, competing alternatives, time horizon, study perspective, discount rate, incremental analysis, sensitivity analysis). Each criterion present in the articles was marked as "Yes" and given one mark; so, articles that meet all the criteria get a full quality score (quality score = 19). The checklist is available in the appendix. In this study, based on several health economics expert's opinions articles that had a score of ≥ 8 had adequate quality and were considered in the analysis. To homogeny and comparability of results, all costs in the reviewed articles were converted into a common currency, to the year 2017 by using the purchasing power parities ($ PPP).

Results

Search results

The initial systematic literature search from databases reveals that there were 249 (162 articles in English language and 87 articles in the Persian language) articles, of which 21 articles were duplicated and removed. Also, 237 articles screened based on the title and abstract and 186 articles were excluded since they were considered as irrelevant. After review full text of the articles (51 articles), 42 articles which lacked the eligibility were also excluded. Also, three articles were excluded due to quality score under eight. Finally, six articles (four articles in the English language and two articles in the Persian languages) meet the eligibility criteria to enter the study (Fig. 1).

Articles quality assessment

The results of quality assessment are shown in Appendix Table 5. The CHEC checklist was used to assess the quality of articles in this study. The results of the quality assessment showed that none of the articles gets a full quality score. The highest quality score was obtained in Bayat et al. which 12 out of the 19 items were observed (BAYAT et al. 2019). Also, the lowest quality score was obtained in Atabi et al. which only 4 out of the 19 items of quality assessment checklist were observed (ATABI et al. 2013).

All articles (n = 9, 100%) described the population covered by the study and conclude precisely according to the data. Also, none of the articles (n = 0, 0%) delineated items such as competing alternatives, incremental analysis, and discount rates. In most studies, the study question (n = 8, 88%) and the context (n = 5, 55%) of the study were well posed. Almost in all articles (n = 7, 77%), the perspective of the study was mentioned, except in a study conducted by Rahimi et al. and Atabi et al.; this item was not observed (RAHIMI et al. 2014; ATABI et al. 2013).

Identification and measuring costs and outcomes related to alternatives and also sensitivity analysis only was done by Bayat et al. and did not report in other articles (BAYAT et al. 2019). The proper valuing of the cost item only was observed in the study conducted by Hoseini and Mazraei (HOSEINI and MAZREATI 2004). More than half of the articles reported a clear outcome component, and how they were valued (n = 5, 55%) and measured (n = 7, 77%).

More than half of the articles discussed the generalizability of their results to other settings (n = 5, 55%). On the other hand, only 5 (55%) articles referred to the lack of conflict of interest among authors. Also, almost most of the articles did not elaborate on the ethical aspects except Barjer et al. (BRAJER et al. 2012). Finally, three studies by Atabi et al.,

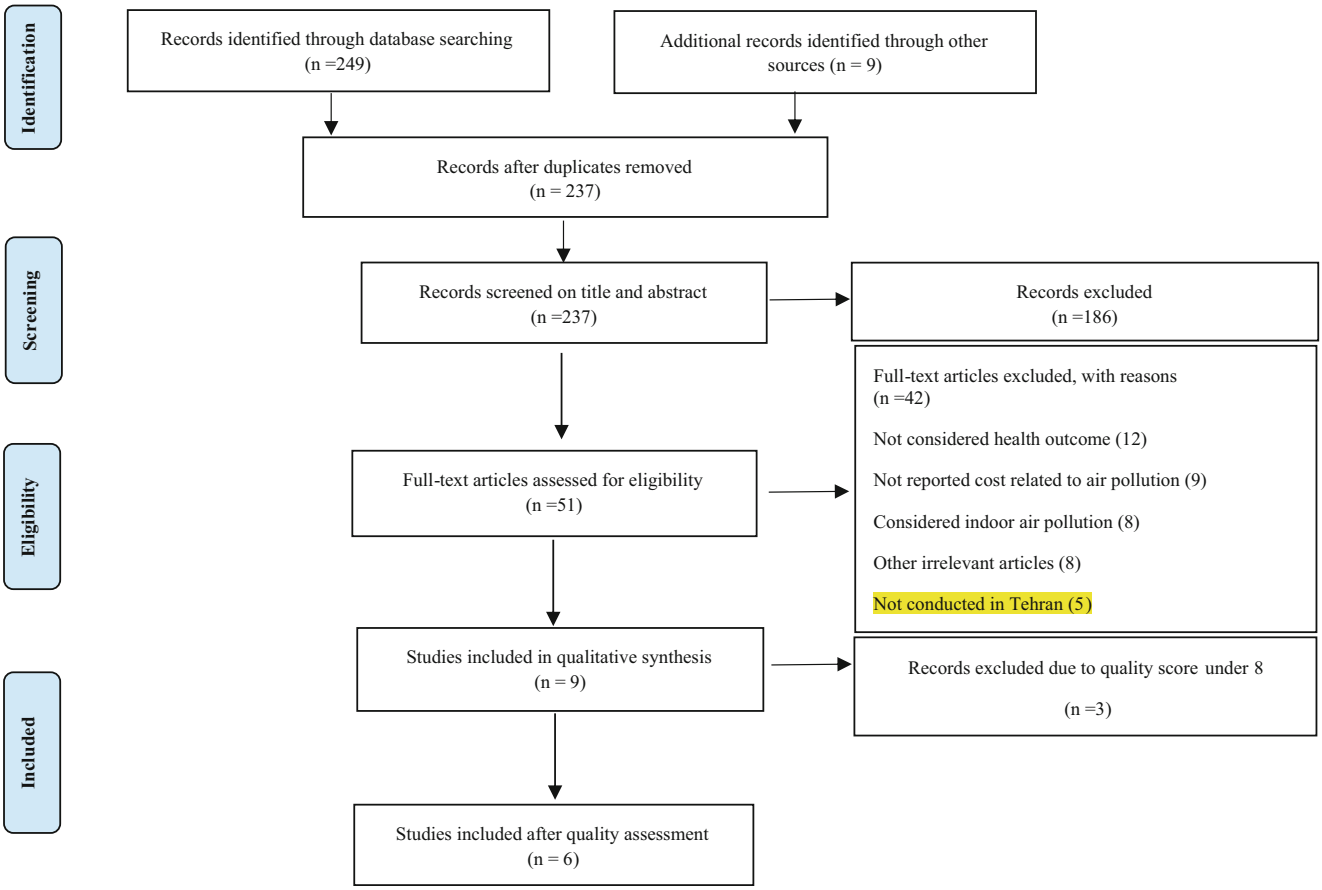

Fig 1 PRISMA flow diagram

Rahimi et al., and Abedi and Alavi Lavasani had a quality score lower than eight and were excluded (ATABI et al. 2013; RAHIMI et al. 2014; Abedi and Alavi Lavasani 2007). Finally, six articles were included in the final analysis. The quality assessment results reported in table 5 in appendix.

Studies characteristics

The summary of studies characteristics listed in Table 3. We can see all the studies have been done in different years. The newest study was published in 2019 by Bayat et al. and the oldest was published in 2004 by Hoseini and Mazreati (HOSEINI and MAZREATI 2004; BAYAT et al. 2019). Overall, these studies reported air pollution data from 2001 to 2017.

In all of the studies, PM is consider as a pollutant (n = 6, 100%) with three studies (50%), also including SO_2 and NO_2 as pollutants. In addition, CO was considered as a pollutant in two (33%) studies.

Health outcomes due to air pollution

All studies included mortality attributed to air pollution as their health outcome. Almost, in the all studies (n = 5, 83%) morbidity along with mortality was considered as another health outcome. In a study by Barjer et al. (2012), only the mortality attributed to air pollution was considered as health outcome (BRAJER et al. 2012).

Taking into account morbidity as another health outcome due to air pollution, two (33%) and three (50%) articles used cardiovascular and respiratory disease as health outcomes respectively.

In one study, symptoms such as cough, dizziness, eye irritation, diarrhea, and nausea were considered as morbidity outcomes (Sadeghi and Torki 2008).

Methods used to estimate the economic burden of health outcomes due to air pollution

Numerous methods have been used in studies to estimate the economic burden of mortality and morbidity caused by air pollution in different studies. The common methods used to estimate the economic costs of mortality were the VOSL, WTP, HCA, the insurance method, and the CP method.

All of studies used the VOSL and WTP to calculate mortality costs (n = 6, 100%). Hoseini and Mazraeti used the CP method in their study to calculate mortality costs due to air pollution (HOSEINI and MAZREATI 2004). The insurance

Table 3 Summary of study characteristics

Author	Year	Pollutant	Health outcome	Costing analysis	Results (m $)	CHEC score
(BRAJER et al. 2012)	2017	PM_{10}	- Mortality: Stroke, COPD, IHD, LRI, LC -Morbidity: NA	Mortality cost: VOSL Morbidity cost: 10% Mortality cost	Mortality cost: 2630 Morbidity cost: 263 Total cost: 2863	12
(Sadeghi and Torki, 2008)	2016	PM_{10}	- Mortality: ischemic heart disease, stroke, chronic obstructive pulmonary disease and lung cancer, acute lower respiratory tract infections -Morbidity: pain, suffering, discomfort	Mortality cost: VOSL Morbidity cost: 10% Mortality cost	-Mortality cost: 2360 -Morbidity cost: 236 Total cost: 2600	8
(HOSEINI and MAZREATI 2004)	2002	CO, PM_{10}, NO_2, SO_2	-Mortality -Mortality cost: benefit estimates due to reduce air pollution concentration to 10 and 15 μg/m^3 = 1689 and 950 -Morbidity: ischemic heart disorders, dysrhythmias, arrhythmia, CVA, COPD, emphysema	Mortality cost: VOSL Morbidity cost: COI	-Mortality cost: 316 -Morbidity cost: 546 Total cost: 862	9
(KARIMZADEGAN et al. 2008)	2001	PM_{10}, SO_2, CO, NO_2	-Mortality -Morbidity: CVA, COPD, arrhythmia, angina pectoris	Mortality cost: VOSL/CP/HCA/insurance morbidity cost: COI	-Mortality cost: VOSL method: 1500, CP method: 101, insurance method: 90, HCA method: 66 - Total mortality cost: 1757 - Total morbidity cost: 491 -Total cost: 2248	11
(World Bank 2018)	2003	SO_2, NO_2	-Mortality -Morbidity: cough, diarrhea, nausea, dizziness	Mortality cost: VOSL Morbidity cost: COI	-Mortality cost: NA -Morbidity cost: NA -Total cost: 1001	8
(BAYAT et al. 2019)	2010	$PM_{2.5}$	Premature mortality	Mortality cost: WTP	-Mortality cost: benefit estimates due to reduce air pollution concentration to 10 and 15 μg/m^3 = 1689 and 950	9

Converted to the year 2017 by using the purchasing power parities

method was used only in one study (HOSEINI and MAZREATI 2004). Also, the HCA only uses in Hoseini and Mazraeti study to estimate the economic burden of mortality caused by air pollution (HOSEINI and MAZREATI 2004).

On the other hand, the common methods used to estimate the economic costs of morbidity were the WTP and COI. Almost most of the studies (n = 3, 50%) used COI to estimate the economic costs of morbidity (HOSEINI and MAZREATI 2004, KARIMZADEGAN et al. 2008, Sadeghi and Torki, 2008). After the COI method, the WTP method was also more applicable, so that two studies (n = 2, 33%) used the WTP method to estimate the economic costs of morbidity (JORLI et al. 2017, Sadeghi and Torki, 2008, KARIMZADEGAN et al. 2008). Also, two studies (n = 2, 33%) consider the percentage of mortality costs method as the measurement tools for costs associated with morbidity attributed to air pollution. In these studies, 10% of mortality costs were considered as morbidity costs (BAYAT et al. 2019; World Bank 2018).

The economic burden of the health outcomes due to air pollution

The economic burden of mortality and morbidity due to air pollution that obtained by review the studies in this systematic review study cover a wide range, depending on the methods used to calculate costs, differences in the studies time.

Overall, the economic burden of mortality due to air pollution ranged from $ 316 million to $ 2630 million. Almost all studies used VOSL to evaluate the costs related to air pollution with the cost ranging from $ 316 million to $ 2630 million. Hoseini and Mazraeti used CP and HCA methods to calculate the mortality costs due to air pollution. The mortality cost calculated using the CP and HCA methods estimated $ 101 million and $ 66 million respectively (HOSEINI and MAZRAETI 2004).

As other methods of calculating mortality costs, Hoseini and Mazraeti used the insurance method to reveal that the cost of mortality due to air pollution was $ 90 million (HOSEINI and MAZREATI 2004).

Overall, the economic burden of morbidity due to air pollution ranged from $ 236 million to $ 546 million. Almost three studies used the COI method to calculate the related costs due to air pollution in which costs estimated $ 491 million and $ 564 million to 34794 million; although, in study conducted by Sadeghi and Torki, the cost of morbidity by using COI method was not mentioned (HOSEINI and MAZRAETI 2004, KARIMZADEGAN et al. 2008, Sadeghi and Torki 2008).

Also, two studies by Bayat et al. and WB in 2018 percentage of mortality costs (10%) considered as a measurement tool to calculate morbidity costs. The results showed that the economic burden of morbidity due to air pollution were $ 236 million and $ 263 million, respectively (BAYAT et al. 2019; World Bank 2018).

Also, some studies applied holistic approaches to measure the economic burden of mortality and morbidity due to air pollution; these studies used more than one method simultaneously. Three studies used VOSL and COI simultaneously and found that the economic burden morbidity and mortality ranged from $ 862 million to $ 2248 million (HOSEINI and MAZRAETI 2004, KARIMZADEGAN et al. 2008, Sadeghi and Torki 2008). One study used CP and COI methods to calculate mortality and morbidity costs simultaneously. In the study of Hosseini et al. (2004), the total economic burden was estimated $ 592 million (HOSEINI and MAZRAETI 2004). Bayat et al. and WB who applied the VOSL and percentage of mortality costs approaches showed a total economic burden of $ 2863 million and $ 2600 million, respectively (BAYAT et al. 2019, World Bank 2018).

Discussion

In this systematic review, the economic burden of mortality and morbidity caused by air pollution in Tehran was investigated. Two Persian articles, three English articles, and one English report were considered and included in this review after quality assessment.

Tehran, as the capital of Iran, is one of the most crowded capitals in the world in which air pollution is a severe challenge. Population growth, low-quality fuel, and overuse of fossil fuels have led to worsening air pollution status in this city (KERMANI et al. 2016; HOSSEINI and SHAHBAZI 2016; HABIBI et al. 2017). Due to the growing trend of industrialization, more people are facing health problems caused by air pollution in Tehran. Hence, many national and international studies have been investigating health effects due to air pollution. Khaniabadi et al., Dehghan et al., and Yousefian et al. are as studies have recently studied the health losses due to air pollution in Tehran (DEHGHAN et al. 2018; KHANIABADI et al. 2019; YOUSEFIAN et al. 2018).

In this study, the number of articles that examined the effects of air pollution on mortality was higher than the articles that considered morbidity as a health outcome. Due to difficulties in measuring the morbidity due to air pollution as a health outcome, most studies hade measured mortality due to air pollution as a health outcome. A study conducted by Hadei et al in Tehran estimated the number of deaths attributed to PM10, PM2.5, O3, NO2, and SO_2 over 3 years (2013–2016) was 4192, 4336, 1363, 2830, and 1216, respectively (HADEI et al. 2017). Also, in another study, an estimated 7146 adult (age ≥ 25 years) deaths are attributable to PM2.5 in 2017 (BAYAT et al. 2019).

With regard to morbidity due to air pollution, most studies have considered a cardiovascular disease and subsequently respiratory diseases as a health outcome (HADEI et al. 2017; RABIEI et al. 2017; KHAJAVI et al. 2019). The destructive effects of pollutants such as PM or CO on the cardiovascular and respiratory system have been recognized since many years ago. Different pollutants by destroying lung cells caused various respiratory and heart diseases. These pollutants penetrate deep into the lungs and trigger systemic effects, mediated through oxidative stress and inflammatory pathways, and has been classified as a human carcinogen by the WHO (WHO, 2013).

In a study conducted by Shahi et al., the findings showed that respiratory and cardiovascular admissions to the emergency department in Tehran have a significant association with increasing pollutant levels (Shahi et al., 2014). Also, another study showed that the relative risk of angina pectoris increased with higher pollutant levels in the 2 days before admission to the hospital (HOSSEINPOOR et al. 2005).

With regard to pollutant types, the findings of this study showed that PM was the most frequently investigated among all pollutants. The five studies only used $PM_{10\ or\ 2.5}$ as a pollutant to measure the health and economic effect of air pollution (BAYAT et al. 2019; BRAJER et al. 2012; World Bank 2005; World Bank 2018). According to the findings of other studies, PM has a greater impact on health compared to other pollutants such as SO_2, NO_2, and CO (YAP et al. 2019); also, $PM_{2.5}$ was more strongly associated with heart and respiratory diseases (BELL 2012).

Due to smaller size, this pollutant (PM) is more likely to penetrate the lungs and even the bloodstream, and therefore create more negative health outcomes (SIOUTAS et al. 2005). However, some studies have shown that other pollutants (SO_2, NO_2, and CO) are closely related to health consequences such as mortality and mortality due to air pollution (NWAGBARA and RASIAH 2015; ZHAO et al. 2014; RAZA et al. 2013; KIM et al. 2014).

Also, the findings of this study showed that air pollution caused severe problems in the Tehran health sector. Deaths due to air pollution impose an enormous economic burden on society. The results showed that overall, air pollution imposes a high economic burden by using different methods in various studies in Tehran ($ 862 million to $ 2863 million approximately 0.8 to 2.5% of Tehran's GDP in 2017).

In terms of the economic burden of air pollution, due to the different estimating methods in the included studies on the Tehran population, our results revealed a wide range of economic burden. While some included studied used several estimating methods together.

For example, a study conducted by WB estimated the economic burden of mortality and morbidity due to air pollution in Tehran as $ 2600 million in 2016 (World Bank 2018), while another study that conducted by Bayat et al. estimated that air pollution impose $ 2863 million economic burden due to air pollution in 2017 in Tehran (BAYAT et al. 2019). In two studies, changes in the amount of exposure and concentration of pollutants and changes in the number of population at risk along with differences in the method of measuring economic burden are as the reasons for differences in the results of various studies in Tehran.

Regarding various methods of measuring the economic burden of mortality due to air pollution, the findings of this study showed that the studies used VOSL, WTP, HCA, and CP methods to measure the economic burden so that the use of these methods has resulted in a wide range of economic burden. VOSL and WTP methods are based on the preferences of people. These methods alongside direct costs implicitly include indirect costs such as suffering from health outcomes. Therefore, these methods result in higher estimates of the mortality and morbidity burden due to air pollution in comparison to other methods. These methods are easily applicable in developing countries. VOSL and WTP for developing countries can be easily obtained by adjusting in developed countries based on the income level of two countries (or by considering purchasing power parity). However, the use of this method in Iran should be implemented more carefully due to the high difference in income levels between developing countries such as Iran and high-income countries. On the other hand, the HCA has been used only in the study by Hosseini and Mazreati in 2004 (HOSEINI and MAZREATI 2004). The HCA method has its disadvantages along with its simplicity. This method only considers the morbidity and mortality costs for official working people and does not consider these costs for retired, unemployed, and housewives. In underdeveloped countries where a large proportion of the population has informal jobs, the disadvantages are doubled. Therefore, the use of HCA method estimates the cost mortality less than the actual amount and also less than WTP and VOSL methods.

The CP method was also used in one study that conducted by Hosseini and Mazreati (HOSEINI and MAZREATI 2004). This method is used only to calculate the economic burden of mortality due to air pollution. Although it is simpler and easier to calculate than other methods, unlike the WTP method, the CP method does not pay attention to the people willingness to pay and preferences. Also, unlike the HCA method, the mortality cost (compensation payment) is a fixed amount and the same for everyone regardless of the age, income, and employment status that set annually by governments. Also, the CP amount is used only in Iran and the results cannot be used and compared with other countries. So, based on differences in method, results in studies that used WTP and VOSL were higher than the HCA and CP. In addition, these methods have an advantage over other methods because it covers all the dimensions of the cost of air pollution. For this reason, most national and international studies have used these methods (WTP and VOSL) to estimate the economic burden of mortality and morbidity due to air pollution (MARTINEZ et al. 2018; JORLI et al. 2017; LU et al. 2016; FOULADI FARD et al. 2016). Also, many researchers have stated that WTP-based method is best appropriated for estimating economic burden due to air pollution and has become the standard approach in countries for valuing mortality risks associated with pollution (CROPPER 2000, Publishing et al. 2012).

In addition to mortality, air pollution imposes costs on the health system by causing morbidities. However, these costs are lower than mortality costs. Results showed that imposed economic burden of mortality due to air pollution was greater than morbidity economic burden. In our review, all studies applied WTP method to estimate economic burden of mortality due air pollution and people usually have high WTP to decrease risk of mortality in compare with WTP for decreasing morbidity (NARAIN and SALL 2016). In other hand, COI is the most method that used to calculate economic burden that only includes direct cost and did not consider indirect cost. Therefore, this has led to lower estimates of morbidity costs than mortality costs.

In a study conducted by Karimzadegan, the results showed that the results of the WTP method for calculate mortality costs were far higher than the results of COI method for calculate morbidity costs in Tehran (KARIMZADEGAN et al. 2008). Also, in another study conducted by Li, similar results were obtained (LI et al. 2016).

The economic burden of morbidity ranged from $ 236 million to $ 546 million in this study. Results of a study that conducted by Barwick et al. showed that illnesses disease costs due to air pollution were close to $ 42 billion in China, which was equal to approximately 50% of mortality costs due to air pollution (BARWICK et al. 2018).

According to a different study conducted in Macedonia, the costs of hospitalization due to cardiovascular and respiratory diseases due to air pollution were estimated at range from € 570 to € 1470 million (Hunt et al. 2016).

Also, to calculate the morbidity cost due to air pollution most of the articles in this study used COI method, two studies used the WTP method to calculate the economic burden of morbidity, in which the costs obtained by using the WTP method are higher than many studies using the COI method. The COI method often covers direct medical costs, including medications, equipment, and treatments, and usually ignores the intangible costs of suffering caused by illness. Unlike the COI

method, the patient suffering illness usually includes disease costs based on patient preference in the WTP method. Therefore, results in studies that used WTP were higher than the COI costs in studies that used COI or WTP to measure morbidity economic burden due to air pollution (World Bank 2005).

Also, out of the eight studies that calculated the economic burden of morbidity from air pollution, two studies considered the percentage of mortality economic burden to calculate the costs of morbidity (BAYAT et al. 2019; World Bank 2018). In studies conducted in developed countries, they are mostly accounted for 10% of the mortality cost due to air pollution as morbidity costs (Hunt et al. 2016; NARAIN and SALL 2016). So, due to drawbacks of the COI method (disregard the suffering, pain, and opportunity cost) and difficulties and biases in calculating WTP to prevent diseases caused by air pollution in Tehran, it is therefore considering a percentage of the mortality economic burden as the morbidity economic burden can be a useful and valuable method.

Finally, it is suggested that in addition to the study of outdoor pollutants, the effects of indoor pollution will also be studied to investigate thoroughly the health losses caused by air pollution in the country in future studies. Also, using more comprehensive methods to measure the costs of air pollution and taking into account the suffering and other intangible costs of illness caused by air pollution can be more efficient.

Conclusion

The main purpose of this study is to review the health costs caused by air pollution in Tehran. By systematically reviewing the article's results and emphasizing on different methods of measuring the costs of mortality and morbidity caused by air pollution, the results show that air pollution is a serious problem in Tehran. Therefore, this article does not seek to provide the necessary solutions to reduce air pollution but by monetizing the health effects of air pollution; it allows policymakers to make accurate and appropriate decisions.

Based on the results of various studies, the exact economic burden of morbidity and mortality due to air pollution cannot be accurately quantified by different methods; but with applying comprehensive methods such as WTP and VOSL, these problems can be overcome as much as possible. Also, the use of other costing methods along with WTP and VOSL methods can be more effective.

Accordingly, the use of precise methods in measuring and assessing the health losses caused by air pollution and applying these methods in evaluating air pollution control programs can further help the country to improve air quality and reduce the health and economic loss caused by air pollution.

Authors' contributions THK had the idea for the article, MH and PR performed the literature search and data analysis, and THK performed drafted and critically revised. All authors reviewed and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix 1. Search strategy:

("Air pollution" OR Pollution OR "Particulate matter" OR "Air quality" OR "Airborne particulate matter" OR "Particulate air pollutants" OR "Ambient particulate matter" OR Pollutant) AND (Health OR "Risk assessment" OR "Health risk assessment" OR "Benefit-Risk assessment" OR "Benefit risk assessment" OR "Risk benefit assessment" OR "Cardiovascular disease" OR Hospitalization OR "Health related outcome" OR Mortality OR Morbidity OR Admission OR "Emergency room" OR Death OR "Health impact" OR "Health burden") AND ("Economic cost" OR "Economic impact" OR "Economic burden" OR Cost OR "Economic evaluation" OR "cost of illness" OR "Economic outcome" OR "Cost of disease" OR "Monetary impact" OR "Monetary burden" OR "Monetary valuation" OR "Financial burden" OR "Health economic loss" OR "External cost" OR "Economic valuation" OR "Contingent valuation method" OR "Value of statistical life" OR "Willingness to pay") AND ("Islamic Republic of Iran" OR Iran)

Appendix 2

Table 4 Quality assessment checklist of Consensus on Health Economic Criteria (CHEC) and quality assessment results

	CHEC-list	YES	NO
1.	Is the study population clearly described?		
2.	Are competing alternatives clearly described?		
3.	Is a well-defined research question posed in answerable form?		

Table 4 (continued)

	CHEC-list	YES	NO
4.	Is the economic study design appropriate to the stated objective?		
5.	Is the chosen time horizon appropriate in order to include relevant costs and consequences?		
6.	Is the actual perspective chosen appropriate?		
7.	Are all important and relevant costs for each alternative identified?		
8.	Are all costs measured appropriately in physical units?		
9.	Are costs valued appropriately?		
10.	Are all important and relevant outcomes for each alternative identified?		
11.	Are all outcomes measured appropriately?		
12.	Are outcomes valued appropriately?		
13.	Is an incremental analysis of costs and outcomes of alternatives performed?		
14.	Are all future costs and outcomes discounted appropriately?		
15.	Are all important variables, whose values are uncertain, appropriately subjected to sensitivity analysis?		
16.	Do the conclusions follow from the data reported?		
17.	Does the study discuss the generalizability of the results to other settings and patient/client groups?		
18.	Does the article indicate that there is no potential conflict of interest of study researcher(s) and funder(s)?		
19.	Are ethical and distributional issues discussed appropriately?		

Appendix 3

Table 5 Quality assessment of articles based on CHEC checklists

Question Author	1	2	3	4	5	6	7	8	9	10	11	12	12	13	14	15	16	17	18	19	Score
(BRAJER et al. 2012)	Y	N	Y	Y	N	Y	N	N	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	9
(KARIMZADEGAN et al. 2008)	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	9
(ATABI et al. 2013)	Y	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	4*
(HOSEINI and MAZREATI 2004)	Y	N	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	N	N	N	Y	Y	Y	N	11
(Sadeghi and Torki, 2008)	Y	N	Y	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	8
(World Bank 2018)	Y	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	N	N	N	Y	N	N	N	8
(BAYAT et al. 2019)	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	Y	Y	N	N	N	12
(World Bank 2005)	Y	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	N	N	N	Y	Y	N	N	9
(RAHIMI et al. 2014)	Y	N	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	N	Y	N	Y	N	*5
(Abedi and Alavi Lavasani 2007)	Y	N	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	5*

*Article excluded due to quality score lower than 8. *Y*, yes; *N*, no

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