

Relationship between Air Pollutants and Mortality from Cardiorespiratory Diseases in Mashhad: A Step Towards Increasing Citizens' Awareness of Adverse Effects of Pollutants

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ارتباط آلاینده‌های هوای شهر مشهد با مرگ‌ومیر ناشی از بیماری‌های قلبی و عروقی و تنفسی، گامی در راستای شناخت و آگاهی شهروندان از اثرات منفی آلاینده‌ها

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Abstract:

Air pollution in different cities of the world is a complex mixture of toxic components, including particulate matter (PM), mainly produced by combustion processes. A cross-sectional analytical study was conducted to investigate the relationship between air pollutants and mortality from cardiorespiratory diseases in Mashhad. To this end, the data on mortality from cardiorespiratory diseases in 2012-2013 were obtained from Razavi Khorasan Health Organization. The mean daily concentration of air pollutants, including carbon monoxide (CO), PM with a diameter of 10 micrometers or less (PM₁₀), and PM_{2.5} was calculated. The results of data analysis showed that there was a relationship between PM₁₀ concentration and the rate of mortality from cardiovascular diseases in men. In addition, a significant relationship was observed between PM₁₀ concentration and the rate of mortality from respiratory diseases in both men and women. The results indicated that there was a significant relationship between PM_{2.5} concentration and the rate of mortality from cardiorespiratory diseases in both men and women. There was also a significant relationship between CO concentration and the rate of mortality from respiratory diseases in women. The results demonstrated that PM_{2.5} has the greatest effect on mortality from cardiorespiratory diseases. The study findings were reported within the context of environmental communication by using the media tools to raise public awareness of the adverse effects of pollutants.

Keywords: Air Pollution, Cardiorespiratory Diseases, Mortality, Awareness.

چکیده:

آلودگی هوا در شهرهای جهان، مخلوط پیچیده‌ای از اجزای سمی است که عمدتاً محصول فرآیندهای احتراق است و ذرات معلق (PM) عضو همیشه حاضر این مخلوط هستند. مطالعه حاضر به بررسی ارتباط آلاینده‌های هوا با میزان مرگ‌ومیر ناشی از بیماری‌های قلبی و عروقی و تنفسی در مشهد می‌پردازد. طی یک مطالعه مقطعی تحلیلی میزان مرگ‌ومیر بر اثر بیماری قلبی و عروقی از سازمان بهداشت استان خراسان در بازه زمانی (۱۳۹۱-۱۳۹۲) دریافت گردید. سپس میانگین روزانه آلودگی هوا شامل مونوکسید کربن، CO، مواد معلق با قطر کمتر از ۱۰ میکرون PM₁₀، مواد معلق با قطر کمتر از ۲/۵ میکرون PM_{2.5} اخذ گردید. نتایج مورد تجزیه و تحلیل آماری قرار گرفت. ذرات معلق PM₁₀ دارای ارتباط معنی‌داری با میزان مرگ‌ومیر ناشی از بیماری‌های قلبی و عروقی در مردان است. همچنین این ذرات دارای ارتباط معنی‌داری با میزان مرگ‌ومیر ناشی از بیماری‌های تنفسی در مردان و زنان بود. علاوه بر این ارتباط معنی‌داری بین میزان ذرات معلق PM_{2.5} و میزان مرگ‌ومیر ناشی از بیماری‌های قلبی و عروقی و میزان مرگ‌ومیر ناشی از بیماری‌های تنفسی در مردان و زنان مشاهده شد. همچنین ارتباط معنی‌داری بین ذرات CO و میزان مرگ‌ومیر ناشی از بیماری‌های تنفسی در زنان مشاهده شد. ذرات معلق PM_{2.5} دارای بیشترین تأثیر در مرگ‌ومیر توسط بیماری‌های قلبی و عروقی و تنفسی می‌باشند. نتایج این پژوهش در چارچوب ارتباطات محیط‌زیستی و استفاده از ابزار رسانه برای ارتقای آگاهی و شناخت عمومی از اثرات آلاینده‌ها، گزارش شده است.

واژه‌های کلیدی: آلودگی هوا، بیماری قلبی و عروقی، بیماری تنفسی، مرگ‌ومیر، شناخت و آگاهی.

Introduction

The number of studies on the health effects of air pollution has significantly increased over the past 15-10 years. It is now well established that exposure to air pollution is associated with a wide range of acute and chronic health problems from minor physiological disorders to mortality from cardiorespiratory diseases (Pope III, 2006; Bascom, 1996). Air pollution in different cities of the world is a complex mixture of toxic components, including particulate matter (PM), mainly produced by combustion processes (Cohen, 2005). PM is a mixture of liquid and solid particles with different sizes and chemical compositions. Fuel combustion of mobile sources (such as cars, trucks, and buses) and stationary sources (such as power plants and boilers) is the main source of PM in large cities. However, dusty roads, biomass burning, manufacturing processes, and primary pollutants from diesel engines are also involved in PM production (Ostro, 2004). Many PM-related health effects have been reported, such as mortality, lung cancer, hospitalization due to cardiorespiratory diseases, visiting the emergency units or doctor's office, deterioration of respiratory symptoms, absenteeism, restricted daily activities, and acute and chronic bronchitis (WHO, 2003). Many studies around the world have shown the relationship between non-accidental daily mortality and PM (Zmirou, 1998; Goldberg, 2001). Epidemiological studies in Europe and around the world over the past decade have indicated that one-day and the several-day mean of PM are associated with total mortality and mortality from cardiorespiratory diseases (Schwartz, 1999; Dominici, 2002). PM₁₀, PM_{2.5}, black fume, and sulfates seem to have the highest association with mortality and prevalence of diseases (Ostro, 2004). Group studies have demonstrated that long-term exposure to PM results in a substantial reduction in life

expectancy, mainly due to mortality from cardiorespiratory diseases (Anderson, 2004). It is believed that PM_{2.5} is a more serious threat than PM₁₀ to human health because smaller particles are more likely to accumulate on deeper layers of lungs. Moreover, studies have shown that small particles are able to penetrate into the deepest layers of the body (Ostro, 2004). PM_{2.5} seriously threatens human health and increases the rate of mortality from cardiorespiratory diseases and lung cancer (Anderson, 2004; Ostro, 2004).

World Health Organization (WHO) estimates show that about 800,000 premature deaths caused by air pollution occur annually around the world (Goldberg, 2001). WHO's an estimation of the global burden of diseases (GBD) caused by air pollution indicates that 89% of all deaths attributed to air pollution were caused by cardiorespiratory diseases (Cohen, 2004). According to death data of Behesht-e Zahra Organization (2007), about 43% of all non-accidental deaths in 2006 were caused by cardiorespiratory diseases. The data published by this organization also demonstrate that more than 90% of deaths caused by cardiorespiratory diseases in Tehran were related to individuals aged over 30 years (Behesht-e Zahra Organization, 2007).

Epidemiological studies have shown that the 24-hour high mean of air pollution is associated with an increased rate of mortality from cardiorespiratory diseases and all other causes of death (Bascom, 1996; Schwartz, 1991). However, little information is available on the effects of short-term exposure to air pollution. Many studies have reported that adverse effects of increased concentration of PM, CO, and other pollutants include increased admission to hospital and emergency units for respiratory diseases. In addition, numerous studies conducted in the US, Canada, and Europe have shown that

increased concentration of PM and CO leads to an increase in hospital admission for cardiovascular diseases. These findings indicate that air pollution is a risk factor for both respiratory diseases and acute coronary events, including acute coronary syndrome (ACS) and myocardial infarction (MI) (Jaakkola, 2001).

Polluted air inhalation can aggravate acute heart attacks through lung inflammation and increasing coagulability due to protein C deficiency (Schwartz, 1995). The increased concentration of reactive plasma protein has been observed in healthy individuals after a period of exposure to polluted air (Peters *et al.*, 2001). Increased heart rate and increased risk of disruption of the implantable cardioverter-defibrillator (ICD) indicate the automatic response of the nervous system to exposure to air pollutants, especially CO (Routledge and Ayres, 2005). Peters *et al.* showed that the risk of MI is associated with the high PM_{2.5} concentration within one to three hours just before MI in hospital (Peters *et al.*, 2001).

In another study, Joneidy *et al.* (2006) investigated the relationship between the number of deaths caused by cardiorespiratory diseases attributed to Tehran air pollution and PM concentration. In this study, PM_{2.5} concentration, as an indicator of air pollution, was equal to 11.34 µg/m³ in 2006, which was calculated using the PM₁₀-PM_{2.5} ratio (0.5) and the mean daily concentration of PM₁₀. Their estimates demonstrated that the number of deaths attributable to PM contamination was equal to 5388 cases (CI 95%: 7505-2360), accounting for 39.90% of all deaths caused by cardiorespiratory diseases among individuals aged over 30 years in Tehran in 2006. Their findings suggested a weak but significant correlation between PM concentration and the rate of mortality from cardiorespiratory diseases (Joneidy *et al.*, 2009).

Malekafzali (2001) reported that there was a significant relationship between the concentration of SO₂, CO, and PM₁₀ and mortality rate. Ghorbani *et al.* (2007) studied the relationship between exposure to air pollution and the onset of ACS attacks in 250 patients admitted to hospitals of Tehran and reported a significant positive relationship between the occurrence of ACS and the 24-hour mean of CO (CI 95%: 1.34-1.03, OR:18.1) per unit increase in CO. However, the relationship between ACS and the 24-hour mean of PM₁₀ (CI 95%: 1.01-0.99, OR: 1.005) was not statistically significant. There was also a significant difference between men and women in terms of the relationship between the 24-hour mean of CO and ACS, as women were more sensitive than men (CI 95%: 2.26-1.25, OR: 1.75). However, the relationship between ACS and the 24-hour mean of PM₁₀ did not change by effect-moderating variables. Their findings showed that the increased 24-hour mean of CO increases the risk of ACS, which is greater in women. The results showed no significant relationship between ACS and the 24-hour mean of PM₁₀ (Ghorbani *et al.*, 2007).

Farajzadeh (2008) showed that most of the deaths occur during the cold months of the year. Gholizadeh (2009) also reported that there is a high correlation between air pollution and mortality rate in the fall. Shireepour (2009) showed that the maximum SO₂ level occurs in the winter, while the maximum O₃ level occurs during spring and summer.

In a study conducted by Azhdarpour *et al.* (2011) in Shiraz, Iran, it was shown that there is a significant relationship between car accidents and air pollutants, such as CO, SO₂, NO, NO₂, O₃, and PM (p<0.05). The results on CO indicate that the number of accidents increases by 1.1 times per unit increase in CO. They also found a significant relationship between respiratory diseases and NO level,

although such a significant relationship was not observed between respiratory diseases and other pollutants. In addition, there was a significant relationship between cardiovascular diseases and the concentration of NO_2 and SO_2 . It can be generally concluded that the number of accidents substantially increases with the increase in the concentration of NO_2 , O_3 , and NO (Azhdarpour et al., 2011).

The results reported by Alidadi et al. (2013) for the city of Mashhad in Iran showed that there is a significant relationship between air pollutants and mortality from cardiorespiratory diseases. The Pearson correlation coefficient between cardiovascular diseases in women and concentration of NO_2 , SO_2 , CO , and NO was obtained as 0.447, 0.404, 0.397, and 0.323, respectively, with a significance level of 1%. There was a significant relationship between SO_2 concentration and respiratory diseases in men, with a Pearson correlation coefficient of 0.639. Their results also showed that the mortality rate was higher in men than women. The highest correlation between pollutants and mortality was observed in December-January, and there was an increasing trend in the concentration of pollutants over December, January, February, and March. They also reported that there was an increase in the rate of mortality from cardiorespiratory diseases with the increase in the concentration of pollutants during the study period (Alidadi et al., 2013).

In a study conducted by Delangizan and Motlagh in Kermanshah in 2011, it was shown that a 1% increase in haze-borne air pollution increases the rate of hospitalization due to cardiovascular diseases and respiratory diseases by about 5% and 1%, respectively, and the rate of mortality from cardiovascular diseases by about 3%. The relationship between haze and mortality from respiratory diseases was positive but statistically

insignificant. Their results indicated that the rate of hospitalization due to cardiorespiratory diseases is highly sensitive to haze concentration. This sensitivity increased from 2010 to 2011 and was greater for men than women. During the second and third quarters of 2011, there was at least a 29% increase in mortality from cardiovascular diseases for every 100% increase in haze concentration (Delangizan and Motlagh, 2013).

Levy et al. (2001) found no significant relationship between $\text{PM}_{2.5}$ concentration and cardiac arrest outside the hospital. Yang *et al.* (2014) reported that SO_2 and CO have the greatest impact on mortality from respiratory diseases.

In a study conducted by Amiri in 2011 in Karaj, it was shown that the 8-hour mean O_3 concentration and the mean annual PM_{10} concentration were about 17 and 3.9 times, respectively, above the Iranian national standard and WHO guidelines. Total mortality caused by PM_{10} and O_3 in Karaj during the study period was estimated as 282 and 164, respectively, accounting for about 3.9% and 1.53% of all deaths in Karaj (except for deaths from road accidents). The mean cases attributed to O_3 for chronic obstructive pulmonary disease (COPD) was 58, and the mean cases attributed to PM_{10} for hospitalization due to cardiovascular diseases was obtained as 492. The findings indicate that air pollution in Karaj accounted for the lion's share of mortality and hospitalization cases from January 2012 to January 2013. Therefore, relevant authorities should use appropriate, sustainable, and applicable solutions based on comprehensive scientific research to control the air pollution crisis in Karaj (Amiri, 2013).

Some studies have shown that the rate of mortality from lung cancer and cardiovascular diseases caused by air pollution is high among Chinese, Koreans, and Iranians (Chen, 2017; Khaniabadi, 2017; Badyda, 2016). Another

study indicates that there is a relationship between long-term exposure to $PM_{2.5}$ and increased rate of mortality from cardiovascular diseases and increased rate of hospitalization due to respiratory conditions (Kollanus, 2016).

There is also a relationship between short-term exposure to $PM_{2.5}$ and the increased rate of mortality from cardiovascular diseases (Chen, 2017). The findings of Miri (2016) showed that $PM_{2.5}$ concentration is more effective than O_3 , NO_2 , SO_2 , and PM_{10} in increasing the mortality rate.

Some studies have demonstrated that acute effects of pollutants vary in different seasons and geographical conditions (Miri, 2016). However, another study suggested the need for further longitudinal studies to prove the relationship between mortality from cardiovascular diseases and the concentration of pollutants (Kim, 2017).

Nowadays, various pollutants are released into the air through motor vehicles, industries, and commercial and domestic sources in Tehran and many industrialized and large cities around the world, especially in developing countries (Mo, 1997).

Although technological development has brought various achievements to human life, technological tools sometimes produce and discharge unwanted and often harmful waste into the environment. Given the threat of pollution to human health, it is necessary to increase society's knowledge and awareness of different aspects of this issue in order to prevent or reduce environmental hazards of air pollution. Hence, the present study aims to investigate the relationship between air pollutants and mortality from cardiorespiratory diseases in Mashhad.

Methodology

A descriptive-analytical study was conducted on all people of Mashhad as the statistical population. The data on mortality from

cardiorespiratory diseases in 2012-2013 were obtained from Razavi Khorasan Health Organization. In addition, the mean daily concentration of air pollutants, including CO , SO_2 , O_3 , PM_{10} , and $PM_{2.5}$, were received from Razavi Khorasan Department of Environment and Mashhad Air Quality Control Company.

The annual concentration of air pollutants was obtained from different measurement stations. The number of deaths from cardiorespiratory diseases for each month of the year was then obtained from Mashhad Emergency Center in order to find the relationship between environmental pollutants and the rate of mortality from cardiorespiratory diseases. Descriptive and inferential statistical methods were employed to study the effects of air pollutants on the rate of mortality from cardiorespiratory diseases, and the results were extracted using Kendall's Tau rank correlation coefficient.

Findings

In a descriptive-analytical study, the rate of mortality from cardiorespiratory diseases and the mean daily concentration of air pollutants, including CO , SO_2 , O_3 , PM_{10} , and $PM_{2.5}$, in 2012-2013 were investigated.

The mean values of variables and their descriptive indices (mean and standard deviation) are shown in Table 1. As shown in this table, the mean number of deaths from respiratory diseases was more than that of cardiovascular diseases. In addition, the mean number of deaths among men was relatively more than that of women.

Based on the results shown in Table 2, there is a positive and significant relationship between PM_{10} concentration and the rate of mortality from cardiovascular diseases among men in Mashhad. However, no significant relationship was observed between PM_{10} concentration and the rate of mortality from cardiovascular diseases among women in this city.

Table 1. Descriptive indices of research variables

Variable	Mean	Standard deviation
PM _{2.5}	78.71	15.80
PM ₁₀	47.15	14.01
CO	3.67	0.58
Male mortality from respiratory diseases	39	5.91
Female mortality from respiratory diseases	38	3.37
Male mortality from cardiovascular diseases	16	2.88
Female mortality from cardiovascular diseases	15	2.54

Table 2. The relationship between the concentration of PM₁₀, PM_{2.5}, and CO and the rate of mortality from cardiovascular diseases in men and women (Kendall's Tau rank correlation coefficient)

Variable		Kendall's Tau rank correlation	Significance level	Sample size
PM ₁₀	Male	0.259	0.024	12
	Female	0.050	0.660	12
PM _{2.5}	Male	0.240	0.037	12
	Female	0.281	0.013	12
CO	Male	0.155	0.177	12
	Female	0.017	0.883	12

Table 3. The relationship between the concentration of PM₁₀, PM_{2.5}, and CO and the rate of mortality from respiratory diseases in men and women (Kendall's Tau rank correlation coefficient)

Variable		Kendall's Tau rank correlation	Significance level	Sample size
PM ₁₀	Male	0.682	0.001	12
	Female	0.860	0.001	12
PM _{2.5}	Male	0.467	0.001	12
	Female	0.414	0.001	12
CO	Male	0.167	0.141	12
	Female	0.276	0.017	12

Table 2 shows that there was a significant and positive relationship between PM_{2.5} concentration and the rate of mortality from cardiovascular diseases among both men and women in Mashhad. In other words, it can be stated that the higher the PM_{2.5} concentration, the higher the rate of mortality from cardiovascular diseases in men and women. The results also indicated that there was no

significant relationship between CO concentration and the rate of mortality from cardiovascular diseases among men and women in Mashhad.

The results presented in Table 3 show that there was a positive and significant relationship between PM₁₀ concentration and the rate of mortality from respiratory diseases among men and women in Mashhad. In fact, the higher the PM₁₀ concentration, the higher the rate of mortality from respiratory diseases among both men and women.

The results also demonstrated that there was a positive and significant relationship between PM_{2.5} concentration and the rate of mortality from respiratory diseases among men and women in Mashhad. It can be thus concluded that the higher the PM_{2.5} concentration, the higher the rate of mortality from respiratory diseases among both men and women in this city.

Table 3 shows that there was no significant relationship between CO concentration and the rate of mortality from respiratory diseases among men in Mashhad, whereas a positive and significant relationship was found between CO concentration and the rate of mortality from respiratory diseases among women in this city. In fact, the higher the CO concentration, the higher the rate of mortality from respiratory diseases among women.

Discussion and conclusion

The study findings showed that there was a significant relationship between PM₁₀ concentration and the rate of mortality from cardiovascular diseases among men, but not women, in Mashhad. In addition, there was a significant relationship between PM₁₀ concentration and the rate of mortality from respiratory diseases among both men and women of Mashhad. The results also indicated that there was a significant relationship between PM_{2.5} concentration and the rate of mortality from cardiorespiratory diseases

among both men and women of Mashhad. In this study, no significant relationship was observed between CO concentration and the rate of mortality from cardiovascular diseases among men and women. The results also demonstrated that there was a significant relationship between CO concentration and the rate of mortality from respiratory diseases among women, whereas such a significant relationship was not found between CO concentration and the rate of mortality from respiratory diseases among men.

The study findings suggested that the most important air pollutants in Mashhad are PM_{2.5}, PM₁₀, and CO, in the order of significance. It was also observed that men are more sensitive than women to PM₁₀ in terms of affliction with cardiovascular disease, and women are more sensitive than men to CO in respiratory diseases. The results demonstrated that the risk of affliction with cardiovascular diseases was higher than that of respiratory diseases at high concentrations of PM_{2.5} and PM₁₀. These results are consistent with the findings of Peters *et al.* (2011) concerning the relationship between the risk of myocardial infarction and PM_{2.5} concentration and Joneidy *et al.* (2006) about the significant correlation between PM_{2.5} concentration and the rate of mortality from cardiorespiratory diseases. The results of this study are also consistent with the findings of Malekafzali (2001) about the relationship between PM₁₀ concentration and mortality rate, as well as those reported by Alidadi (2013) in terms of the significant relationship between the concentration of pollutants and affliction with cardiorespiratory diseases. In this study, there was a significant relationship between PM_{2.5} concentration and mortality from cardiovascular diseases. This is not consistent with the results of Levy *et al.* (2001) who observed no significant relationship between PM_{2.5} concentration and cardiac arrest outside the hospital. No significant relationship was

observed between CO concentration and the rate of mortality from cardiorespiratory diseases in this study, which is not consistent with the findings of Ghorbani *et al.* (2007). In this study, there was a significant relationship between the concentration of PM_{2.5} and PM₁₀ and the rate of mortality from cardiorespiratory diseases. However, the relationship between PM₁₀ concentration and the rate of mortality from cardiovascular diseases was not statistically significant among women, which indicates the greater risk of PM₁₀ for men. The higher sensitivity of women to CO can be considered the reason for the greater susceptibility of women's respiratory and pulmonary tract to smoke and pollutants.

The study findings concerning the significance of CO is not consistent with the results of Yang *et al.* (2004). The present study suggested that CO have the least effect on mortality from cardiorespiratory diseases. This difference can be attributed to climatic and racial changes or the sample size. Many biological effects indicate that elevated levels of CO lead to cardiac events. First, inhalation of CO particles causes the activation of cytokines by alveolar macrophages and epithelial cells and the utilization of inflammatory cells. In addition, increased concentration of plasma C-reactive protein in exposure to CO has been observed in previous studies.

The results of this study about the insignificant relationship between haze concentration and the rate of mortality from respiratory diseases are not consistent with the findings of Delangizan (2011). This difference can be attributed to climatic and racial changes or the sample size. The differences between the results of studies conducted in different cities and countries can be attributed to the confounding factors such as geographical location, temperature, humidity, air pressure, smoking, job, seasonal changes, socioeconomic stresses, duration of exposure

to the outside environment, and cultural issues such as low frequency of visiting a physician,

especially in chronic diseases, angina pectoris, and COPD.

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