Elyns Publishing Group
Explore and Expand

http://elynsgroup.com

Research Article | Journal of Epidemiology and Preventive Medicine | Open Access

Death from Cardiovascular Diseases and Air Pollution in Shiraz, Iran (March 2006-March 2012)

Manizhe Dadbakhsh[1], Narges Khanjani[2,3]* and Abbas Bahrampour[4]

[1]Department of Epidemiology, Faculty of Medicine, Jiroft University of Medical Science, Jiroft, Iran
[2]Research Center for Environmental Health, Faculty of Public Health, Kerman University of Medical Sciences, Kerman, Iran
[3]Monash Centre for Occupational & Environmental Health, School of Public Health and Preventive Medicine, Monash University, Melbourne, Australia
[4]Department of Epidemiology &Biostatistics, Faculty of Public Health, Kerman University of Medical Sciences, Kerman, Iran

Received Date: January 27, 2016, **Accepted Date:** March 31, 2016, **Published Date:** April 08, 2016.

***Corresponding author:** Narges Khanjani, Research Center for Environmental Health, Faculty of Public Health, Kerman University of Medical Sciences, Kerman 76169-13555, Iran, E-mail: n_khanjani@kmu.ac.ir*

Abstract

Background: There is evidence that shows exposure to air pollution might be related to cardiovascular death. This study aimed to estimate the effect of ambient air pollutants on cardiovascular deaths in Shiraz, Iran.

Methods: In this ecological study, we inquired data about the number of cardiovascular deaths by gender and age; and recorded air pollutants data including nitric oxide (NO), carbon monoxide (CO), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), particulate matter (PM_{10}), sulfur dioxide (SO_2), ozone (O_3), methane (CH_4), total hydrocarbons (THC) and nonmethane hydrocarbons (NMHC) from 2006-2012. The association between air pollution and cardiovascular deaths was investigated by time series, cross correlations with and without lags with crude and adjusted negative binomial regression analysis through Minitab16 and Stata 11.

Results: During this period, 17167 cardiovascular deaths occurred in Shiraz. After adjustment for confounding factors, NO and NO_x were significantly related to total cardiovascular deaths; NO, NO_x and SO_2 were significantly related to deaths in women and SO_2 was significantly related to deaths in the age of 18 to 60. NO and NO_x pollutants were related to all cardiovascular deaths that happened one month later.

Conclusion: The results of this study confirm the results of many other studies which show that air pollution can increase cardiovascular death.

Keywords: Cardiovascular Death; Air Pollution; Shiraz; Iran

Introduction

The effects of air pollution on human health have been a major environmental concern. Even before modern studies, events such as the sudden increase of death rates following a short interval of particulate matter and sulfur dioxide increase in London, in 1952 attracted much attention [1]. Recent evidence indicates that long term exposure to air pollution from traffic may lead to preterm death [2] and coronary artery disease [3]. The most important probable adverse acute and choric effects of air pollution include a variety of chronic heart diseases such as palpitation, changes in heart rate, blood pressure, artery constriction, blood coagulation and atherosclerosis [4].

Some epidemiological evidences indicate that air pollution is related to cardiovascular disease exacerbation [5]. Studies have shown that patients with congestive heart failure [6] or a history of myocardial infarction or diabetes [7] are at greater risk of death on days with higher levels of air pollution. Also survivors of myocardial infarction [8] and people with a history of myocardial infarction in exposure to air pollution are at more risk of reoccurrence when exposed to air pollution [9].

Numerous epidemiological studies have shown that exposure to fine particles such as $PM_{2.5}$ is related to cardiovascular diseases [10,11]. In the six cities studies in America, there were significant positive associations between pulmonary and cardiovascular deaths with increased concentrations of ambient particulate matter [12].

Miller et al [13], in the Women's Health Initiative (WHI) study in America found a significant increase in the occurrence and fatality of cardiovascular outcomes by increase in exposure to $PM_{2.5}$. Researchers using data from the Nurses' Health Study in America found that long term exposure to $PM_{2.5}$ is related to death due to coronary heart disease (CHD) [14]. Chuang et al [15], in a cross sectional study on 1023 of elderly people in Taiwan reported that both systolic and diastolic blood pressure were sharply related with annual average levels of various pollutants (PM_{10}, $PM_{2.5}$, O_3, NO_2), however some other studies did not report any relation [16].

According to studies done in Tehran, 70% of deaths in Tehran result from respiratory and cardiovascular problems and these problems are directly or indirectly related to air pollution. Central areas of Tehran have the highest pollution and death; and deaths from cardiovascular disease have shown more sensitivity to air pollution compared with other diseases [17].

Shiraz is one of the major cities of Iran, and has had a high population growth. It doesn't have modern transportation facilities such as subway lines. Private vehicles are the dominant mode of transport. There is a large number of vehicles and heavy traffic in some parts of the city. Also there are factories and industrial workshops that increase the amount and variety of pollutants in this city. Shiraz is located between mountains which block air exchange and is one of the eight major cities in Iran tackling air pollution issues [18].

Due to the increasing development of industry and increasing vehicles which have led to heavy traffic in cities, atmospheric pollutants are increasing in the world and its very apparent signs are destruction of the atmospheric ozone layer and global warming. Due to the importance of increasing cardiovascular disease death and its probable relation with air pollution researchers conducted this study in Shiraz, Iran. Few studies about this topic have been conducted in Iran [19].

Materials and Methods

Study Population, Study Area, Data Collection

This population-based and ecological study was conducted in Shiraz, Iran. Causes of death, age, sex and date of death data were inquired from the Shiraz University of Medical Sciences,

Department of Health from March 2006 - March 2012 (six years). Cardiovascular deaths included recorded deaths resulting from myocardial infarction, stroke, high blood pressure, arterial embolism, thrombosis, aortic aneurysm, dissecting aneurysm, pulmonary embolism, vascular diseases, other heart diseases, cardiovascular diseases, non-rheumatic mitral and aortic valve disorders, acute and sub-acute endocarditis, acute pericarditis, acute myocarditis, cardiomyopathy, heart failure and cardiovascular congenital malformations. The data was anonymous.

The health data was inquired from the Shiraz University Deputy of Health. The reason for death in each individual is recorded based on the death certificate signed by a physician. This information was released from the Shiraz University Deputy of Health after formal communication and acquiring permission from the authorities. All deaths in this city have to be recorded by law. The environmental data was measured by air pollution measuring stations working under the supervision of the Shiraz Province, Environmental Protection Agency. The environmental exposure data and the death data were all from the city of Shiraz. As this was an ecological study and the level of available data was limited, we were not able to match the exact place of residence with the air pollution data.

The authors of this study were not involved in measuring the pollutants. The pollutants are routinely measured and recorded by the Province Environmental Protection Agency (EPA). The air pollutants which were measured at the Shiraz Environmental Protection Agency included nitric oxide (NO), carbon monoxide (CO), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), particulate matter with aerodynamic diameter ≤ 10 μm (PM_{10}), sulfur dioxide (SO_2), ozone (O_3), methane (CH_4), total hydrocarbons (THC) and nonmethane hydrocarbons (NMHC).

The mean daily temperature, relative humidity, rainfall, wind speed and direction were inquired from the Shiraz Meteorology Department from March 2006-March 2012 and were used to adjust for these confounding factors.

Statistical Analyses

The relationship between cardiovascular death and pollutants was investigated in six different gender and age groups which were; all people, men, women, children under 18 years old, adults from 18-60 years old and adults above 60 years old. The population group sizes used in the negative binomial regression were inquired from the Statistical Center of Iran based on the 2006 to 2011 (www.amar.org.ir) data and the years in between were calculated based on 0.03% population growth.

Descriptive results were reported. Also in order to determine the relationship between cardiovascular deaths and pollutants; negative binomial regression analysis was used and the incidence rate ratio (IRR) were computed in univariate and multivariate models. The multivariate model included the dependent variable (cardiovascular deaths), and the independent variables (contaminants and confounding variables temperature and humidity, rainfall, wind direction and speed).

The NO_X variable in this study is the sum of NO and NO_2, and the THC variable is the sum of CH_4 and NMHC and these variables were not used simultaneously in multivariate analyzes.

Air pollution is usually seasonable. There is more CO_2 pollution in the winter and more O_3 in the summer. We used the complete air pollution dataset for the mentioned years. We did not limit our analysis to specific months.

One month, lag times were computed for pollutants and their associations with cardiovascular mortality was determined by Pearson or Spearman correlation coefficients. The data was not normalized. We performed Pearson correlation for normal and Spearman correlation for non-normal data. However, most studies that tested the delayed health effects of contaminants observed the effects in delays of a few days and less than a month [20,21]. Therefore, in this study we only examined the correlation of one-month delay with cardiovascular deaths. Data were analyzed data through Minitab 16 and Stata 11.

Results

Table 1 shows the descriptive statistics of air pollutants under study in Shiraz during the years 2006-2012. Table 2 shows the number of cardiac deaths during 2006-2012.

The total number of cardiovascular deaths in Shiraz during March 2006 to March 2012 was 17167. Table 3 and 4 shows the results of crude and adjusted (for temperature, humidity, rainfall, wind speed and wind direction) negative binomial regression analysis investigating the relation between the monthly average of pollutants with total cardiovascular deaths in different gender and age groups. The NO_X pollutant is a sum of NO and NO_2 and THC is the sum of CH_4 and NMHC. Due to the existence of over-dispersion (variance greater than mean) negative binomial regression analysis was used rather than Poisson regression to analyze the data in this study.

Pollutant	Mean	Median	Minimum	Maximum	SD
CO (ppb[a])	3034.758	2866.15	1205.63	5864	1290.237
PM10 (ug/m^3 [b])	86.143	80.372	28.341	212.007	35.751
NO (ppb)	57.598	48.105	22.79	181.43	30.336
NO2 (ppb)	30.996	28.722	22.11	55.08	7.133
NOx(ppb)	88.235	82.078	44.85	223.53	34.4333
O3 (ppb)	17.49	16.289	4.48	40.18	8.368
SO2 (ppb)	101.531	82.734	3.1	292.74	94.238
CH4 (ppmc[c])	2.416	2.506	0.832	4.449	0.753
NMHC (ppmc)	1.535	1.374	0.538	4.098	0.635
THC (ppmc)	3.989	3.95	1.663	7.887	1.149

Table 1: Level of pollutants in Shiraz during the years 2006 to 2012 ([a] parts per billion, [b] Micrograms per Cubic Meter of air, [c] parts per million carbon).

	Total	Male	Female	Under18 years	18 to 60 years	over 60 years
Number of cardiovascular deaths	17167	9474	7693	154	3055	13958

Table 2: The number of cardiovascular deaths in Shiraz city during March 2006 to March 2012.

Cardiovascular Deaths	Pollutant	Crude IRR* and 95% CI	P	Adjusted IRR* and 95% CI	P
Total people	CO	(1.00008–1.00001) 1.00005	0.013†	(1.00009–0.99998) 1.00004	0.151
	PM_{10}	(1.00094–0.99818) 0.99956	0.535	(1.00321–0.99917) 1.00119	0.245
	NO	(1.00374–1.00046) 1.00210	0.012†	(1.00426–1.00031) 1.00229	0.023†
	NO_2	(1.00956-0.99508) 1.00229	0.553	(1.01228–0.99637) 1.00429	0.289
	NOx	(1.00318–1.00026) 1.00172	0.020†	(1.00358–1.00016) 1.00187	0.032†
	O_3	(0.99832–0.98675) 0.99252	0.012†	(1.01398–0.99418) 1.00403	0.423
	SO_2	(1.00112–1.00006) 1.00059	0.027†	(1.00130–0.99993) 1.00061	0.077
	CH_4	(1.02692–0.89753) 0.96005	0.235	(1.01440–0.88750) 0.94883	0.113
	NMHC	(1.12962–0.95411) 1.03817	0.385	(1.07552–0.87334) 0.96917	0.556
	THC	(1.03078–0.94297) 0.98590	0.532	(1.01309–0.92887) 0.97007	0.170
Male	CO	(1.00009–1.00001) 1.00005	0.004†	(1.00010–0.99999) 1.00004	0.089
	PM_{10}	(1.00086–0.99815) 0.99950	0.477	(1.00302–0.99915) 1.00005	0.270
	NO	(1.00353–1.00032) 1.00193	0.018†	(1.00380–0.99993) 1.00190	0.058
	NO_2	(1.01140–0.99732) 1.00434	0.226	(1.01393–0.99873) 1.00630	0.103
	NOx	(1.00306–1.00022) 1.00164	0.023†	(1.00320–0.99992) 1.00160	0.062
	O_3	(0.99725–0.98602) 0.99162	0.004†	(1.01019–0.99109) 1.00060	0.902
	SO_2	(1.00107–1.00003) 1.00055	0.035†	(1.00100–0.99966) 1.00035	0.308
	CH_4	(1.01224–0.88850) 0.94835	0.111	(1.00187–0.87985) 0.93888	0.057
	NMHC	(1.11921–0.95005) 1.03117	0.463	(1.04735–0.85646) 0.94711	0.290
	THC	(1.02035–0.93589) 0.97725	0.296	(1.00138–0.92120) 0.96045	0.058
Female	CO	(1.00008–0.99999) 1.00004	0.076	(1.00009–0.99996) 1.00002	0.386
	PM_{10}	(1.00126–0.99803) 0.99964	0.670	(1.00376–0.99891) 1.00133	0.279
	NO	(1.00419–1.00038) 1.00228	0.018†	(1.00518–1.00049) 1.00283	0.017†
	NO_2	(1.00820–0.99143) 0.99978	0.960	(1.01150–0.99253) 0.00197	0.683
	NOx	(1.00350–1.00010) 1.00180	0.037†	(1.00428–1.00019) 1.00223	0.032†
	O_3	(1.00046–0.98679) 0.99360	0.068	(1.01986–0.99618) 1.00795	0.186
	SO_2	(1.00124–1.00001) 1.00063	0.044†	(1.00171–1.00008) 1.00089	0.031†
	CH_4	(1.05591–0.90073) 0.97524	0.536	(1.04401–0.88863) 0.96319	0.362
	NMHC	(1.15369–0.94717) 1.04534	0.378	(1.13477–0.88412) 0.00164	0.979
	THC	(1.05037–0.94558) 0.99660	0.899	(1.03668–0.93345) 0.98371	0.540

Table 3: Results of crude and adjusted negative binomial regression, and the effect of pollutants on cardiovascular deaths (ratio of increase in death in month per unit of increase in pollutants monthly average) in total, men and women. (*IRR=Incidence Rate Ratio; † Statistically Significant)

Results of the adjusted analysis showed that nitrogen oxides remained significant in all people, while nitrogen oxides and sulfur dioxide were significant in women.

Results of multivariate analysis showed that dioxide sulfur remained significant in people 18-60, but there was not any significant relation between cardiovascular death and other pollutants.

Table 5 shows the correlation coefficient results between air pollutants and cardiovascular deaths happening one month later.

Results showed that there is a significant relation between increase of cardiovascular deaths and pollutants such as nitrogen oxides, CO, O_3 and SO_2.

Discussion

Air pollution can affect the risk of cardiovascular diseases through mechanisms such as systemic inflammatory and oxidative stress responses, and can lead to increasing atherosclerosis and long-term effects. It can also cause consequences and side effects through changes in vascular function, coagulation, plaque stability and autonomic balance [5]. It has been reported that exposure to air pollution causes increased plasma viscosity and shortened prothrombin time [22]. Animal studies have also shown that exposure to particles increase atherosclerosis [23]. However, in order to explain the positive statistical relation between death due to chronic ischemic heart disease and aerosol exposure, scientists require more information about the biological mechanism and their adverse effects [24]. Some studies assume that nitrogen dioxide is a causal factor for thrombosis [25]. In contrast, the known vasodilating effects of NO and mixtures of PM are highly variable and may have different physiological effects depending on the type of dominant compounds [26]. On the other hand, comparing the relation of death outcomes and exposure to air pollution is difficult, in different studies. The wide disparity in dose-response in these studies is probably related to differences in design, condition, exposure assessment method, measurement scales [27], underlying health status of the population studied, particle composition, relative toxicity, measurement and control of potential confounding factors [28] or differences in exposure sensitivity to pollutants [29].

In an ecological study done by Maheswaran et al [3], in Sheffield, UK, a relation between PM_{10} and increase death from coronary heart disease was found. A study in America has shown that exposure to particle matter (PM) is related to increase heart attacks and stroke [5]. Also there was a relation between death from IHD and NOX and PM_{10} exposure [28]. In our study, there was not a significant relation between PM_{10} in all people, men, women and other age groups with cardiac deaths. This result can be due to low levels of PM_{10} in Shiraz. In this study only 370 days (17%) of the 2190 days studied in these six years had PM_{10} more than the permissible 24 hour limit which is 150 μg/m^3 [30]. In a similar study from Kerman, Iran although the median level of PM_{10} was 118.1 μg/m^3, no significant relation was observed between PM_{10} and cardiovascular death either [19].

Group of Death Cardiac-Vascular	Pollutant	Crude IRR* and 95% CI	P	Adjusted IRR and 95% CI	P
Under 18 years	CO	(1.00024–0.99993) 1.00008	0.274	(1.00034–0.99988) 1.00011	0.323
	PM_{10}	(1.00422–0.99255) 0.99832	0.576	(1.01002–0.99280) 1.00137	0.754
	NO	(1.01036–0.99780) 1.00406	0.203	(1.01055–0.99398) 1.00223	0.596
	NO_2	(1.03772–0.97933) 1.00810	0.585	(1.04005–0.97381) 1.00639	0.704
	NOx	(1.00916–0.99808) 1.00360	0.201	(1.00931–0.99513) 1.00220	0.542
	O_3	(1.01505–0.96695) 0.99071	0.451	(1.05933–0.97634) 1.01699	0.418
	SO_2	(1.00265–0.99836) 1.00050	0.643	(1.00383–0.99810) 1.00096	0.507
	CH_4	(1.21833–0.69778) 0.92268	0.570	(1.12858–0.63827) 0.84873	0.259
	NMHC	(1.49612–0.74736) 1.05742	0.753	(1.35947–0.56069) 0.87306	0.548
	THC	(1.21220–0.83421) 1.00560	0.953	(1.13940–0.78359) 0.94490	0.553
18 to 60 years	CO	(1.00017–1.00007) 1.00012	<0.001†	(1.00023–0.99985) 1.00004	0.621
	PM_{10}	(1.00009–0.99636) 0.99822	0.062	(1.00392–0.99922) 1.00157	0.189
	NO	(1.00410–0.99925) 1.00167	0.176	(1.00260–0.99752) 1.00006	0.962
	NO_2	(1.01123-0.99040) 1.00076	0.886	(1.01490–0.99568) 1.00527	0.282
	NOx	(1.00339–0.99912) 1.00125	0.249	(1.00227–0.99790) 1.00008	0.937
	O_3	(0.98875–0.97384)0.98127	<0.001†	(1.00855–0.98516) 0.99679	0.592
	SO_2	(1.00210–1.00069) 1.00140	<0.001†	(1.00172–1.00001) 1.00086	0.046†
	CH_4	(0.98650–0.82076) 0.89982	0.024†	(1.01281–0.86449) 0.93571	0.100
	NMHC	(1.25904–0.99821) 1.12106	0.054†	(1.05345–0.82559) 0.93258	0.262
	THC	(1.03536–0.91465) 0.97313	0.389	(1.00523–0.90900) 0.95527	0.079
over 60 years	CO	(1.00026–1.00001) 1.00014	0.025†	(1.00009–0.99996) 1.00002	0.386
	PM_{10}	(1.00120–0.99810) 0.99965	0.663	(1.00160–0.98809) 0.99485	0.137
	NO	(1.00431–0.99218) 0.99823	0.568	(1.00419–0.99008) 0.99711	0. 423
	NO_2	(1.02892-0.98262) 1.00550	0.640	(1.03836–0.98723) 1.01247	0.336
	NOx	(1.00459–0.99392) 1.99924	0.783	(1.00523-0.99419) 0.99974	0.928
	O_3	(1.01007–0.97441) 0.99208	0.386	(1.06090–0.99027) 1.02498	0.160
	SO_2	(1.00351–1.00023) 1.00187	0.025†	(1.00441–0.99964) 1.00202	0.095
	CH_4	(1.04123–0.89572) 0.96574	0.364	(1.32293–0.83363) 1.05016	0.678
	NMHC	(1.14513–0.94910) 1.04252	0.870	(1.67269–0.84420) 1.18831	0.323
	THC	(1.04047–0.93600) 0.99011	0.695	(1.20441-0.90169) 1.04212	0.576

Table 4: Results of crude and adjusted negative binomial regression, and the effect of pollutants on cardiovascular deaths (ratio of increase in death in month per unit of increase in pollutants monthly average) in different age groups. (*IRR=Incidence Rate Ratio; †Statistically Significant).

In a study done in Sheffield, England, there was a significant association [rate ratio of 1.17 (95% CI 1.06-1.29)] between nitrogen oxides and excess risk of death from coronary heart diseases [3]. In another study, the elderly were more susceptible to the effects of air pollution. The adjusted rate ratio (RR) for nitrogen dioxide in ischemic stroke in all ages was 1.11, in 40-64 year olds was 1.13 and in 65-79 year olds was 1.23. This result had borderline statistical significance in the 65-79 year age group and no significance in the other age groups [25]. In a cohort study in Canada, a significant increase of 40% was observed in the risk of death due to circulatory diseases in exposure to nitrogen oxides [2]. In the study by Raaschou-Nielsen et al [31], in Denmark, mortality rate ratios (MRRs) in cardiovascular diseases was equal to 1.26 and showed a significant 26% increase in cardiovascular death per doubling of NO_2 concentration after adjustment for confounding factors. However, Filleul et al's [32], study in France, showed no relation between death from cardiopulmonary diseases and NO_2 and the adjusted risk ratio was 1.00 (95% CI 0.98-1.02). In our study, the results of multivariate analysis indicated that nitrogen oxides had a positive relation with cardiovascular death in some groups. The reason might be that the average of Nitrogen oxides (NO_X) was higher in Shiraz than the healthy threshold which is 0.021 ppm [33]. One of the main sources of NO_X in Shiraz is motor vehicles. One of the other sources is natural gas [34] which is used for cooking and heating in Iran. Women might be more exposed and more sensitive to this pollutant, because they are more involved in cooking or using heating devices at home.

In a study in California, the relation between death due to ischemic heart disease (IHD) and ozone was of borderline significance (HR, 1.06; 95%CI, 0.99-1.14) but when the analysis was limited to summer, the risk of death due to ischemic heart diseases increased significantly. However, there was evidence that showed the positive results for ozone and death from ischemic heart diseases may be due to the confounding effects of PM_{10} [28]. In other studies, the relation between cardiovascular admissions in hospitals with ozone in warm months was inconsistent and negative significant associations were observed in Hong Kong [35] and positive significant associations were observed in London [35]. Another study in Five European Cities showed positive significant associations between myocardial infarction readmissions and ozone [36]. Dadbakhsh et al's study in Shiraz, Iran showed that respiratory mortality in individuals over 60 years was positively related to ozone [37]. In study of Hashemi et al's [19] in Kerman, Iran showed only significant correlation between ozone and female cardiovascular mortality (r = 0.31). However other studies didn't find an association between ozone and cardiovascular death [12,38,39]. Also in our study, the results of multivariate analysis showed that the relation between ozone and cardiovascular death was not significant. These inconsistencies between studies require further investigation. The insignificance of ozone in the present study might be due to low levels of ozone (0.017 ppm) in Shiraz in comparison to the healthy threshold (0.05 ppm) [33]. Studies reporting higher levels for ozone did not find a significant health effect [12,38,39].

Group of Death Cardiac-Vascular						
	Total people		Male		Female	
Pollutant	Pearson correlation coefficient (r)	P	Pearson correlation coefficient (r)	P	Pearson correlation coefficient (r)	P
CO	0.041	0.788	- 0.037	0.788	0.111	0.358
PM_{10}	0.128	0.319	0.120	0.319	0.116	0.334
NO_2	0.107	0.702	- 0.046	0.702	0.239	0.045†
O_3	- 0.166	0.640	- 0.056	0.640	- 0.247	0.038†
CH_4	0.021	0.969	- 0.005	0.969	- 0.032	0.790
THC	- 0.093	0.585	- 0.066	0.585	- 0.105	0.384
Pollutant	Spearman correlation coefficients(ρ)	P	Spearman correlation coefficients(ρ)	P	Spearman correlation coefficients(ρ)	P
NO	0.328	0.002†	0.363	0.002†	0.363	0.002†
NO_x	0.321	0.001†	0.385	0.001†	0.385	0.001†
SO_2	0.164	0.165	0.167	0.165	0.167	0.165
NMHC	- 0.098	0.498	- 0.082	0.498	- 0.082	0.498
	18 to 60 years		18 to 60 years		Under 18 years	
Pollutant	Pearson correlation coefficient(r)	P	Pearson correlation coefficient(r)	P	Spearman correlation coefficients(ρ)	P
CO	- 0.043	0.006†	0.320	0.006†	0.150	0.211
PM_{10}	0.159	0.362	- 0.110	0.362	- 0.015	0.899
NO_2	0.132	0.852	- 0.023	0.852	- 0.008	0.946
O_3	- 0.068	<0.001†	- 0.415	<0.001†	- 0.168	0.161
CH_4	0.038	0.081	- 0.209	0.081	- 0.068	0.573
THC	- 0.045	0.076	- 0.212	0.076	- 0.049	0.682
Pollutant	Spearman correlation coefficients(ρ)	P	Spearman correlation coefficients(ρ)	P	Spearman correlation coefficients(ρ)	P
NO	0.220	0.003†	0.344	0.003†	0.109	0.366
NO_x	0.225	0.005†	0.327	0.005†	0.080	0.505
SO_2	0.025	<0.001†	0.420	<0.001†	0.065	0.589
NMHC	- 0.093	0.691	0.048	0.691	- 0.020	0.868

Table 5: Correlation between air pollutants and cardiovascular deaths happening one month later (†Statistically Significant ($p < 0.05$)).

Europe's multi-center study on survivors after their first myocardial infarction showed that the rate ratio (RRs) of cardiac readmission for carbon monoxide was equal to 1.014 for each 200 μg/m^3 increase and statistically nonsignificant [36]. In another ecological study in Sheffield, UK, there were borderline significant associations between carbon monoxide and death from coronary heart disease [3]. However a study done in Shiraz, Iran showed that respiratory mortality in total, males, females, and individuals aged between 18 to 60 years was positively correlated with CO in ambient air [37]. In our study, the results of multivariate analysis didn't show a significant relation between carbon monoxide and cardiovascular deaths which can be due to low levels of carbon monoxides in Shiraz. In this study in only 38 days from 2190 days (which is 1%) of the days under study, the daily CO level was above the 8 hour permissible level for CO which is 9 ppm [30].

In a study from Zhang et al [40], in Beijing, there was a positive significant relation between long term exposure to SO_2 and death due to all causes and death from cardiovascular diseases. However there was not a significant relation between death from cerebrovascular diseases and SO_2. In a study from Filleul et al [32], in France, the adjusted hazard ratio for cardiovascular death from sulfur dioxide SO_2 was not significant either. In another study in California, in the adjusted analysis, the relation between sulfur dioxide and death due to cardiovascular diseases was reverse and not significant [41]. In our study, sulfur dioxide had a positive significant relation with cardiovascular deaths in women and in the 18-60 age groups. The reason for the significant association between SO_2 and cardiovascular deaths in the present study is probably the higher levels of SO_2. In this study the average monthly levels of SO_2 was 101.53 ppb, but in Chen et al's study which did not observe a significant association it was 4.5 ppb (Chen et al, 2005).

Another factor that seems to be important in studies of air pollution is gender. The study of Chen et al [41], in California showed that $PM_{2.5}$ was positively associated with fatal cardiovascular diseases in females, but not males. Also in another study in the US done only on males, no relation was observed between $PM_{2.5}$ and death from CHD [42]. However the results of other studies did not show any difference between two genders [31,38,43]. Recent studies in America have reported a relation between PM and higher risk of death due to CHD in women [13]. In our study, in women, sulfur dioxide and nitrogen oxides had a significant relation with cardiovascular death but such a relation was not observed in men. In a study in Kerman, there was also a relation between respiratory deaths in men and ambient ozone and sulfur dioxide; but this relation was not observed in women [44].

In this study, pollutants such as nitrogen oxides, O_3, SO_2 and CO were associated with cardiovascular deaths happening one month later. This association may be related to the delayed effects of these pollutants and needs further investigations.

As this study was an ecological study, a limitation was that the results cannot be directly inferred to the individual level. Also we were not able to adjust for migrations and population movements.

Conclusions

Evidence about the risk of death due to cardiovascular diseases and air pollution highlights the importance of interventions to reduce air pollution especially in areas with high air pollution. In most Iranian cities including Shiraz the main source of air pollution are motor vehicles.

Acknowledgments

This study was funded and approved by the Research Deputy of Kerman University of Medical Sciences. Researchers did not deal with human subjects or animals. Grant number is 92/251. Aggregated de-identified information was inquired from the Deputy of Health at Shiraz University of Medical Sciences.

References

1. Schwartz J, Marcus A. Mortality and air pollution J London: a time series analysis. Am J Epidemiol. 1990;131(1):185-94.
2. Jerrett M, Finkelstein MM, Brook JR, Arain MA, Kanaroglou P, Stieb DM, et al. A Cohort Study of Traffic-Related Air Pollution and Mortality in Toronto, Ontario, Canada. Environ Health Perspect. 2009;117(5):772-7. doi: 10.1289/ehp.11533.
3. Maheswaran R, Haining RP, Brindley P, Law J, Pearson T, Fryers PR, et al. Outdoor air pollution, mortality, and hospital admissions from coronary heart disease in Sheffield, UK: a small-area level ecological study. Eur Heart J. 2005;26(23):2543-9.
4. Simkhovich BZ, Kleinman MT, Kloner RA. Air Pollution and Cardiovascular InjuryEpidemiology, Toxicology, and Mechanisms. J Am Coll Cardiol. 2008;52(9):719-26. doi: 10.1016/j.jacc.2008.05.029.
5. Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, et al. Particulate matter air pollution and cardiovascular disease an update to the scientific statement from the American heart association. Circulation. 2010;121(21):2331-78. doi: 10.1161/CIR.0b013e3181dbece1.
6. Kwon HJ, Cho SH, Nyberg F, Pershagen G. Effects of ambient air pollution on daily mortality in a cohort of patients with congestive heart failure. Epidemiology. 2001;12(4):413-9.
7. Bateson TF, Schwartz J. Who is sensitive to the effects of particulate air pollution on mortality?: a case-crossover analysis of effect modifiers. Epidemiology. 2004;15(2):143-9.
8. Jokhadar M, Jacobsen SJ, Reeder GS, Weston SA, Roger VL. Sudden death and recurrent ischemic events after myocardial infarction in the community. Am J Epidemiol. 2004;159(11):1040-6.
9. Hellermann JP, Goraya TY, Jacobsen SJ, Weston SA, Reeder GS, Gersh BJ, et al. Incidence of heart failure after myocardial infarction: is it changing over time? Am J Epidemiol. 2003;157(12):1101-7.
10. Zanobetti A, Schwartz J. The effect of particulate air pollution on emergency admissions for myocardial infarction: a multicity case-crossover analysis. Environ Health Perspect. 2005;113(8):978-82.
11. Peters A, Dockery DW, Muller JE, Mittleman MA. Increased particulate air pollution and the triggering of myocardial infarction. Circulation. 2001;103(23):2810-5.
12. Dockery DW, Pope CA 3rd, Xu X, Spengler JD, Ware JH, Fay ME, et al. An association between air pollution and mortality in six US cities. N Engl J Med. 1993;329(24):1753-9.
13. Miller KA, Siscovick DS, Sheppard L, Shepherd K, Sullivan JH, Anderson GL, et al. Long-term exposure to air pollution and incidence of cardiovascular events in women. N Engl J Med. 2007;356(5):447-58.
14. Puett RC, Hart JE, Yanosky JD, Paciorek C, Schwartz J, Suh H, et al. Chronic fine and coarse particulate exposure, mortality, and coronary heart disease in the Nurses' Health Study. Environ Health Perspect. 2009;117(11):1697-701. doi: 10.1289/ehp.0900572.
15. Chuang KJ, Yan YH, Chiu SY, Cheng TJ. Long-term air pollution exposure and risk factors for cardiovascular diseases among the elderly in Taiwan. Occup Environ Med. 2011;68(1):64-8. doi: 10.1136/oem.2009.052704.
16. Madsen C, Nafstad P. Associations between environmental exposure and blood pressure among participants in the Oslo Health Study (HUBRO). Eur J Epidemiol. 2006;21(7):485-91.
17. Gholizadeh, M.H., M. Farajzadeh, and M. Darand, The Correlation Between Air Pollution and Human Mortality in Tehran. Hakim Research Journal, 2009. 12(2): p. 65-71.
18. Environmental Protection Office of Fars. Air pollution. 2015 2015 01 January]; Available from: http://fars.doe.ir/Portal/File/ShowFile.aspx?ID=e855cd66-250e-4642-abbd-21eea74c1ff8.
19. Hashemi SY, Khanjani N, Soltaninejad Y, Momenzadeh R. Air Pollution and Cardiovascular Mortality in Kerman from 2006 to 2011. American Journal of Cardiovascular Disease Research, 2014. 2(2): p. 27-30.
20. Raaschou-Nielsen O, Bak H, Sørensen M, Jensen SS, Ketzel M, Hvidberg M, et al. Air pollution from traffic and risk for lung cancer in three Danish cohorts. Cancer Epidemiol Biomarkers Prev. 2010;19(5):1284-91. doi: 10.1158/1055-9965.EPI-10-0036.
21. Braga AL, Zanobetti A, Schwartz J. The effect of weather on respiratory and cardiovascular deaths in 12 US cities. Environ Health Perspect. 2002;110(9):859-63.
22. Baccarelli A, Zanobetti A, Martinelli I, Grillo P, Hou L, Giacomini S, et al. Effects of exposure to air pollution on blood coagulation. J Thromb Haemost. 2007;5(2):252-60.
23. Araujo JA, Barajas B, Kleinman M, Wang X, Bennett BJ, Gong KW, et al. Ambient particulate pollutants in the ultrafine range promote early atherosclerosis and systemic oxidative stress. Circ Res. 2008;102(5):589-96. doi: 10.1161/CIRCRESAHA.107.164970.
24. Hu Z, Rao KR. Particulate air pollution and chronic ischemic heart disease in the eastern United States: a county level ecological study using satellite aerosol data. Environ Health. 2009;8:26. doi: 10.1186/1476-069X-8-26.
25. Maheswaran R, Pearson T, Smeeton NC, Beevers SD, Campbell MJ, Wolfe CD. Outdoor Air Pollution and Incidence of Ischemic and Hemorrhagic Stroke A Small-Area Level Ecological Study. Stroke. 2012;43(1):22-7. doi: 10.1161/STROKEAHA.110.610238.
26. Sørensen M, Hoffmann B, Hvidberg M, Ketzel M, Jensen SS, Andersen ZJ, et al. Long-term exposure to traffic-related air pollution associated with blood pressure and self-reported hypertension in a Danish cohort. Environ Health Perspect. 2012;120(3):418-24. doi: 10.1289/ehp.1103631.
27. Nafstad P, Håheim LL, Wisløff T, Gram F, Oftedal B, Holme I, et al. Urban air pollution and mortality in a cohort of Norwegian men. Environ Health Perspect. 2004;112(5):610-5.
28. Lipsett MJ, Ostro BD, Reynolds P, Goldberg D, Hertz A, Jerrett M, et al. Long-term exposure to air pollution and cardiorespiratory disease in the California teachers study cohort. Am J Respir Crit Care Med. 2011;184(7):828-35. doi: 10.1164/rccm.201012-2082OC.
29. Hales S, Blakely T, Woodward A. Air pollution and mortality in New Zealand: cohort study. J Epidemiol Community Health. 2012;66(5):468-73. doi: 10.1136/jech.2010.112490.
30. Vark, K., S. Warner, and W. Davis, Air Pollution The origin and control, ed. 1. 2009: nas.
31. Raaschou-Nielsen O, Andersen ZJ, Jensen SS, Ketzel M, Sørensen M, Hansen J, et al. Traffic air pollution and mortality from cardiovascular disease and all causes: a Danish cohort study. Environ Health. 2012;11:60. doi: 10.1186/1476-069X-11-60.
32. Filleul L, Rondeau V, Vandentorren S, Le Moual N, Cantagrel A, Annesi-Maesano I, et al. Twenty five year mortality and air pollution: results from the French PAARC survey. Occup Environ Med. 2005;62(7):453-60.
33. Environment Protection Organization of Iran. Clean air standards. Accessed on: 2013 2 December 2013; Available from: http://doe.ir/Portal/Home/Default.aspx .

34. Amirbagi, H., Principles of Environmental Health Vol. 3. 2010: Andishe Rafiee.

35. Wong CM, Atkinson RW, Anderson HR, Hedley AJ, Ma S, Chau PY, et al. A tale of two cities: effects of air pollution on hospital admissions in Hong Kong and London compared. Environ Health Perspect. 2002;110(1):67-77.

36. von Klot S, Peters A, Aalto P, Bellander T, Berglind N, D'Ippoliti D, et al., Ambient air pollution is associated with increased risk of hospital cardiac readmissions of myocardial infarction survivors in five European cities. Circulation. 2005;112(20):3073-9.

37. Dadbakhsh, MN. Khanjani, Bahrampour A. Death from Respiratory Diseases and Air Pollutants in Shiraz, Iran (2006-2012). Journal of Environment Pollution and Human Health, 2015. 3(1): p. 4-11.

38. Pope CA 3rd, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA. 2002;287(9):1132-41.

39. Jerrett M, Burnett RT, Pope CA 3rd, Ito K, Thurston G, Krewski D, et al. Long-term ozone exposure and mortality. N Engl J Med. 2009;360(11):1085-95. doi: 10.1056/NEJMoa0803894.

40. Zhang J, Song H, Tong S, Li L, Liu B, Wan L. Ambient sulfate concentration and chronic disease mortality in Beijing. Sci Total Environ. 2000;262(1-2):63-71.

41. Chen LH, Knutsen SF, Shavlik D, Beeson WL, Petersen F, Ghamsary M, et al. The association between fatal coronary heart disease and ambient particulate air pollution: Are females at greater risk? Environ Health Perspect. 2005;113(12):1723-9.

42. Puett RC, Hart JE, Suh H, Mittleman M, Laden F. Particulate matter exposures, mortality, and cardiovascular disease in the health professionals follow-up study. Environ Health Perspect. 2011;119(8):1130-5. doi: 10.1289/ehp.1002921.

43. Gan WQ, Koehoorn M, Davies HW, Demers PA, Tamburic L, Brauer M. Long-term exposure to traffic-related air pollution and the risk of coronary heart disease hospitalization and mortality. Environ Health Perspect. 2011;119(4):501-7. doi: 10.1289/ehp.1002511.

44. Khanjani NL. Ranadeh Kalankesh, Mansouri F. Air Pollution and Respiratory Deaths in Kerman, Iran (from 2006 till 2010). Iranian Journal of Epidemiology, 2012. 8(3).

***Corresponding author:** Narges Khanjani, Research Center for Environmental Health, Faculty of Public Health, Kerman University of Medical Sciences, Kerman 76169-13555, Iran, E-mail: n_khanjani@kmu.ac.ir

Received Date: January 27, 2016, **Accepted Date:** March 31, 2016, **Published Date:** April 08, 2016.

Citation: Dadbakhsh M, Khanjani N, Bahrampour A (2016) Death from Cardiovascular Diseases and Air Pollution in Shiraz, Iran (March 2006-March 2012). J Epid Prev Med 2(1): 114.