# *Trends in health burden of ambient particulate matter pollution in Iran, 1990–2010: findings from the global burden of disease study 2010*

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RESEARCH ARTICLE

# Trends in health burden of ambient particulate matter pollution in Iran, 1990–2010: findings from the global burden of disease study 2010

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**Abstract** This paper aims to report the assessment of trends in deaths and disability-adjusted life years (DALYs) attributed to ambient particulate matter (PM) pollution from 1990 to 2010 by sex and age in Iran. We used the data of the Global Burden of Disease (GBD) 2010 Study, and then we extracted its data on Iran for the years 1990, 2005, and 2010. The proportion of deaths and the DALYs caused by specific risk factors were assessed by using the comparative risk assessment and calculating the attributed burden of exposure level to each risk factor compared with the theoretical minimum level of risk exposure. Uncertainties in distribution of exposure, relative risks, and relevant outcomes calculation were

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disseminated into the estimates of the attributable deaths and DALYs. We found that the age-standardized death rate attributed to ambient PM pollution decreased to 27.90 cases per 100,000 populations from 1990 to 2010 [86, 95 % uncertainty interval (UI) 76–97 to 62; 95 % UI 54–71 per 100,000 populations, respectively]. This was mainly because of greater decrease in cardiovascular diseases (CVDs) than in the other diseases attributed to PM pollution. Despite a decrease in the total DALYs and mortality rate attributed to PM pollution, the death percent increased by 6.94 %, 95 % UI 6.06–7.90 % from 1990 to 2010. The number of the DALYs and death in age groups of more than 70 years increased in 2010 compared to that in 1990. The median percent change of the DALYs and death for all age groups shows that the DALYs and death increased by 6 % (95 % UI 8–19 %) and 45 % (95 % UI 30–60 %), respectively, in 2010 in comparison to that in 1990. The increase in the DALYs and mortality attributable to PM pollution emphasizes the necessity of the effective interventions for improving air quality, as well as for increasing the public awareness to reduce the exposure of vulnerable age groups to PM pollution.

**Keywords** Air pollution · Particulate matter · Burden of diseases · Mortality · Disability-adjusted life years · Iran

## Introduction

Ambient air pollution is a global health problem that imposes greater health burden to developing countries than developed countries (Cohen et al. 2005). As a priority, the Global Burden of Disease (GBD) project, conducted in 2010 by the Institute for Health Metrics and Evaluation (located at University of Washington in Seattle), aimed to generate a comprehensive set of attributed estimates of mortality and morbidity by age, sex, and region at global level (Murray et al. 2012a, 2012b). One of the risk factors studied in this project was the ambient particulate matter (PM) pollution of particulates smaller than 2.5 μm in aerodynamic diameter ($PM_{2.5}$). The burden of disease (BOD) attributable to ambient air pollution is estimated in terms of deaths and disability-adjusted life years (DALYs) as part of the World Health Organization (WHO) GBD Comparative Risk Assessment. GBD project revealed several acute and chronic adverse health effects of air pollutants; it showed that $PM_{2.5}$ may cause about 0.8 million (1.2 %) premature deaths and 6.4 million (0.5 %) years of life lost (YLL) at global level. It is of special concern that this burden happens mainly in developing countries; 65 % of which occurs in Asia (Cohen et al. 2005).

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Similar to many other developing countries, Iran is facing demographic and epidemiological transition, resulting in urbanization and industrialization, which in turn have increased the level of air pollutants. However, limited experience exists on the environmental BOD in Iran. Estimates based on national exposure and WHO country health statistics in 2004 reported that 19 % of the total burden was related to air pollution (WHO 2009).

It is necessary to update the information on the trends of environmental BOD. Therefore, by using the data of GBD 2010 study (Murray et al. 2012a), this paper aims to report the trends in deaths and DALYs attributed to ambient $PM_{2.5}$ pollution by sex and age from 1990 to 2010 for Iran.

## Materials and methods

We used the data from GBD 2010 project for Iran for the years 1990, 2005, and 2010. This project was a systematic effort for data gathering and estimation processing to calculate the global and regional comparative risk assessment of deaths and DALYs caused by different risk factors, as described before (Murray et al. 2012a, 2012b; Wang et al. 2012; Lozano et al. 2012; Salomon et al. 2012a; Salomon et al. 2012b; Vos et al. 2012; Murray et al. 2012b; Lim et al. 2012). BOD, injuries, and risk factors are expressed in DALYs, a summary measurement of population health gap. DALYs for a disease or health condition are calculated as the sum of the years of life lost due to premature mortality (YLL) in the population and years of life lost due to disability (YLD) (Petersen and Ogawa 2000; Murray. 1994). In the GBD 2010 project, the comparative risk assessment approach was used to estimate the proportion of infectious diseases (as diarrhea, lower respiratory infections, meningitis, and other common Infectious diseases), neoplasms, cardiovascular diseases (CVDs), and chronic respiratory diseases burden or death caused by exposure to ambient PM pollution. Further details about the data and methods used for specific risk factors including ambient PM pollution are also available (Lim et al. 2012).

Using the population attributable fraction (PAF), this paper presents the trends in deaths and DALYs attributed to ambient PM pollution by sex and age from 1990 to 2010 for Iran. This approach considered the fraction by which the occurrence of interested outcomes changed under a sustained alternative and more favorable exposure distribution. Death and disease burden attributable to risk factors (PAF) were computed by comparing the current distribution of exposure to the theoretical minimum risk counterfactual distribution of the exposure for each year, sex, age group, and cause. Uncertainty in the estimates was also calculated with the following equations in the simulation analysis:

$$PAF = \frac{Attributable\ population\ risk - Factual\ population\ risk}{Total\ population\ risk}$$

and

$$PAF = \frac{Counterfactual\ population\ risk}{Factual\ population\ risk}$$

To assess the full effects of exposure distributions of ambient $PM_{2.5}$ following the comparative risk assessment protocol and in accordance with the basic approach of the GBD 2010, five main steps were used for estimating the disease burden attributable to risk factors (Burnett et al. 2014). First, risk–outcome pairs were selected to be included in the analysis based on causal association criteria. The cause-specific mortality was extracted from available published cohort studies (Lim et al. 2012).

The second step was estimation of exposure distribution to each risk factor; it was obtained through a systematic search for published and unpublished data sources (Lim et al. 2012).

Statistical models including space-time/Gaussian process regression model or meta-regression were designed to use available data for estimation of the exposure distributions in countries, for several years, and for different age groups. Using average of satellite and chemistry transport estimates, the estimation of exposure distributions of ambient $PM_{2.5}$ was modeled (Lim et al. 2012).

A wide range of covariates in databases that were generated in the GBD 2010 project was verified and used for estimating the risk factor exposure distribution.

In the third step, using recent relevant meta-analyses of international evidence, the effect size of ambient $PM_{2.5}$ for outcomes' specific mortality was considered. For each risk–outcome pair, the relative risk was estimated for each unit of exposure.

In the fourth step, the theoretical minimum risk exposure distributions were assessed for counterfactual comparison, they were applied as 5.8–8.8 $\mu g/m^c$ for ambient PM pollution. The exposure distribution was compared to an alternative (counterfactual) distribution (theoretical minimum risk). As it is not possible to achieve no PM exposure even in pristine environments, zero exposure is not a practical counterfactual level for ambient PM pollution (Brauer et al. 2012). Moreover as the available evidence of epidemiological studies support a continuous reduction in risks of the chosen distribution, and considering distribution that is theoretically possible at the population level, the lowest safe level of exposure to $PM_{2.5}$ is not clearly identified (Lim et al. 2012). Uncertainty in the estimates is presented as 95 % uncertainty interval (UI).

## Results

In children with less than 5 years of age, there was no case of neoplasm, or cardiovascular or chronic pulmonary disease attributed to ambient PM pollution. In all age groups except the age group aged less than 5, there was no case with infectious disease attributed to ambient PM pollution. Table 1 presents the cause-specific DALY rates per 100,000 populations attributed to ambient PM pollution in different age groups from 1990 to 2010 in Iran. The DALY rates due to infectious diseases attributed to ambient PM air pollution has a decreasing trend from 1990 to 2010. Regarding cancers and CVDs attributed to ambient PM pollution, the general DALY rates decreased from 1990 to 2000, but it had a small increase after 2005. All ages DALY rate due to chronic respiratory diseases increased from 1990 to 2010.

From 1990 to 2010, the age-standardized death rate attributed to ambient PM pollution decreased to 27.90 cases/100,000 population (from 86 (95 % UI 76–97) to 62 (95 % UI 54–71, respectively). This was mainly because of decrease in CVDs than in the other diseases attributed to PM pollution. The CVD-specific age-standardized death rate attributed to ambient PM air pollution had a decreasing trend between 1990 and 2010 (from 81 to 59 cases per 100,000 populations, respectively). Table 2 presents the cause-specific death rates per 100,000 populations attributed to PM pollution in different age groups between 1990 and 2010.

Although, from 1990 to 2010, the YLD rate for all causes due to PM pollution increased from 36 (95 % UI 22–58) to 48 (95 % UI 29–76), the YLD rate did not change for most diseases except for the chronic respiratory diseases, which had a small increase (Table 3).

Despite the decrease in the total DALYs and mortality rate attributed to the PM pollution, from 1990 to 2010, the all-cause mortality increased by 6.94 % (95 % UI 6.06–7.90). As presented in Table 4, there was no increase in the percent of the all cause DALYs attributed to PM pollution in comparison with total DALYs (3.22, 95 % UI 2.79–3.74, and 3.8, 95 % UI 3.22–7.81, respectively).

Figures 1 and 2 present the median percent change of the number of DALYs and deaths rate caused by ambient PM pollution between 1990 and 2010 by age groups. Although the median percent change of DALYs and death rate decreased in those aged less than 40 years, this decrease was more prominent in the age group of under 5 (death number median percent change, −79 %, 95 % UI −87 to 67 %; and DALY number median percent change, −76 %, 95 % UI −86 to 66 %). Moreover, in the age group of more than 70 years, the number of DALYs and death increased in 2010 compared to 1990.

**Table 1** DALY rate per 100,000 population [95 % UI] attributed to ambient particular matter pollution in Iran by cause in different age groups from 1990 to 2010

| | | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Both genders | | | | | | |
| <5 years | Infectious diseases[a] | 1677 [1068, 2363] | 1018 [667, 1458] | 669 [435, 950] | 641 [402, 933] | 538 [313, 829] |
| | Neoplasms | – | – | – | – | – |
| | CVD[b] | – | – | – | – | – |
| | All causes | 1677 [1068, 2363] | 1018 [667, 1458] | 669 [435, 950] | 641 [402, 933] | 538 [313, 829] |
| 15–49 years | Infectious diseases[a] | – | – | – | – | – |
| | Neoplasms | 14 [3, 24] | 12 [3, 20] | 9 [2, 15] | 8 [2, 13] | 8 [2, 13] |
| | CVD[b] | 744 [625, 875] | 723 [598, 841] | 599 [505, 692] | 426 [363, 494] | 416 [334, 506] |
| | CRD[c] | 19 [6, 40] | 18 [6, 37] | 17 [5, 35] | 16 [5, 36] | 17 [5, 37] |
| | All causes | 777 [655, 911] | 753 [623, 869] | 625 [529, 718] | 449 [385, 521] | 441 [358, 529] |
| 50–70 years | Infectious diseases[a] | – | – | – | – | – |
| | Neoplasms | 171 [39, 284] | 149 [34, 244] | 119 [28, 192] | 96 [22, 156] | 91 [22, 155] |
| | CVD[b] | 5200 [4308, 6122] | 5281 [4405, 6152] | 4958 [4189, 5730] | 3941 [3320, 4556] | 3428 [2816, 4055] |
| | CRD[c] | 131 [48, 246] | 126 [45, 236] | 120 [44, 223] | 104 [37, 198] | 94 [34, 180] |
| | All causes | 5502 [4623, 6429] | 5556 [4703, 6410] | 5197 [4409, 5979] | 4141 [3522, 4767] | 3612 [2995, 4234] |
| >70 years | Infectious diseases[a] | – | – | – | – | – |
| | Neoplasms | 275 [61, 469] | 259 [60, 430] | 212 [51, 344] | 165 [41, 272] | 167 [44, 283] |
| | CVD[b] | 8740 [7085, 10,625] | 8801 [7076, 10,609] | 8663 [7069, 10,321] | 7573 [6270, 9077] | 6915 [5580, 8398] |
| | CRD[c] | 286 [104, 511] | 262 [96, 464] | 276 [103, 490] | 283 [106, 503] | 267 [103, 482] |
| | All causes | 9300 [7608, 11,265] | 9322 [7569, 11,182] | 9150 [7564, 10,807] | 8021 [6678, 9492] | 7349 [6041, 8838] |
| All ages | Infectious diseases[a] | 280 [178, 394] | 134 [87, 191] | 66 [43, 93] | 54 [34, 79] | 45 [26, 69] |
| | Neoplasms | 26 [6, 44] | 24 [5, 39] | 21 [5, 34] | 20 [5, 32] | 21 [5, 35] |
| | CVD[b] | 949 [848, 1069] | 988 [878, 1092] | 992 [889, 1085] | 900 [811, 988] | 906 [789, 1012] |
| | CRD[c] | 25 [9, 49] | 25 [9, 48] | 27 [10, 51] | 29 [10, 58] | 31 [11, 61] |
| | All causes | 1280 [1135, 1444] | 1171 [1050, 1295] | 1106 [999, 1215] | 1003 [909, 1104] | 1003 [878, 1118] |
| Age-standardized | Infectious diseases[a] | 154 [98, 217] | 98 [64, 140] | 63 [41, 89] | 57 [36, 83] | 48 [28, 74] |
| | Neoplasms | 52 [12, 86] | 45 [10, 74] | 37 [9, 59] | 30 [7, 49] | 29 [7, 49] |
| | CVD[b] | 1823 [1634, 2056] | 1814 [1627, 2012] | 1687 [1507, 1848] | 1356 [1217, 1493] | 1213 [1061, 1359] |
| | CRD[c] | 50 [18, 94] | 47 [17, 89] | 46 [17, 86] | 43 [15, 83] | 40 [14, 77] |
| | All causes | 2079 [1863, 2314] | 2004 [1797, 2209] | 1832 [1649, 2012] | 1486 [1339, 1640] | 1331 [1172, 1478] |

[a] Diarrhea, lower respiratory infections, meningitis, and other common infectious diseases

[b] Cardiovascular and circulatory diseases

[c] Chronic respiratory diseases

## Discussion

The findings of this study indicate that from 1990 to 2010, the DALYs and mortality attributed to ambient PM pollution increased significantly among Iranian population, notably in elderly individuals. This escalating change in mortality and DALYs attributable to ambient PM in the last two decades in Iran serves as confirmatory evidence that the BOD due to air pollutants is substantial in our community. Iran is experiencing an epidemiological transition along with aging of its population. It is estimated that in the near future, the BOD will increase among Iranians mainly because of non-communicable diseases (NCDs) (Khajehkazemi et al. 2013). Given the well-documented association of air pollutants, mainly PM, with NCDs (Khajehkazemi et al. 2013; Bahadar et al. 2014), air quality improvement should be considered as a health priority in Iran.

For the first time, the GBD 2010 study considered ambient air pollution among the top ten risks in the world and the top five to six risks in the low- and middle-income countries of Asia. It estimated that in 2010, two thirds of the global burden, including 2.1 million premature deaths and 52 million years of healthy life lost, has been due to ambient air pollutants (Murray et al. 2012b).

A systematic review of the GBD estimates from chemicals revealed that in 2004, 4.9 million deaths (8.3 % of total) and

**Table 2** Deaths rate per 100,000 population [95 % UI] attributed to ambient particular matter pollution in Iran by cause in different age groups from 1990 to 2010

| | | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Both genders | | | | | | |
| <5 years | Infectious diseases[a] | 19 [12, 27] | 12 [8, 17] | 8 [5, 11] | 7 [4, 11] | 6 [4, 9] |
| | Neoplasms | – | – | – | – | – |
| | CVD[b] | – | – | – | – | – |
| | CRD[c] | – | – | – | – | – |
| | All causes | 19 [12, 27] | 12 [8, 17] | 8 [5, 11] | 7 [4, 11] | 6 [4, 9] |
| 15–49 years | Infectious diseases[a] | – | – | – | – | – |
| | Neoplasms | 0 [0, 1] | 0 [0, 0] | 0 [0, 0] | 0 [0, 0] | 0 [0, 0] |
| | CVD[b] | 15 [13, 18] | 15 [12, 18] | 13 [11, 15] | 9 [8, 11] | 9 [7, 11] |
| | CRD[c] | 0 [0, 0] | 0 [0, 0] | 0 [0, 0] | 0 [0, 0] | 0 [0, 0] |
| | All causes | 16 [13, 19] | 16 [13, 18] | 13 [11, 15] | 9 [8, 11] | 9 [7, 11] |
| 50–70 years | Infectious diseases[a] | – | – | – | – | – |
| | Neoplasms | 7 [1, 11] | 6 [1, 9] | 5 [1, 7] | 4 [1, 6] | 3 [1, 6] |
| | CVD[b] | 192 [158, 227] | 197 [163, 230] | 184 [154, 214] | 144 [120, 167] | 122 [100, 143] |
| | CRD[c] | 3 [1, 5] | 3 [1, 4] | 3 [1, 4] | 2 [1, 3] | 2 [1, 3] |
| | All causes | 201 [168, 236] | 205 [172, 238] | 191 [161, 221] | 149 [126, 172] | 127 [105, 149] |
| >70 years | Infectious diseases[a] | – | – | – | – | – |
| | Neoplasms | 20 [4, 34] | 19 [4, 31] | 16 [4, 26] | 13 [3, 21] | 14 [4, 23] |
| | CVD[b] | 670 [544, 808] | 667 [546, 799] | 679 [554, 804] | 619 [508, 747] | 604 [483, 741] |
| | CRD[c] | 16 [6, 27] | 14 [5, 24] | 16 [6, 26] | 18 [7, 29] | 17 [7, 30] |
| | All causes | 706 [581, 848] | 700 [577, 834] | 711 [590, 838] | 649 [538, 778] | 635 [515, 773] |
| All ages | Infectious diseases[a] | 3 [2, 5] | 2 [1, 2] | 1 [0, 1] | 1 [0, 1] | 1 [0, 1] |
| | Neoplasms | 1 [0, 2] | 1 [0, 2] | 1 [0, 2] | 1 [0, 1] | 1 [0, 2] |
| | CVD[b] | 36 [32, 40] | 39 [35, 43] | 41 [37, 46] | 40 [36, 45] | 41 [36, 47] |
| | CRD[c] | 1 [0, 1] | 1 [0, 1] | 1 [0, 1] | 1 [0, 1] | 1 [0, 1] |
| | All causes | 41 [36, 45] | 42 [38, 47] | 44 [39, 48] | 43 [38, 48] | 44 [38, 50] |
| Age-standardized | Infectious diseases[a] | 2 [1, 3] | 1 [1, 2] | 1 [0, 1] | 1 [0, 1] | 1 [0, 1] |
| | Neoplasms | 2 [1, 4] | 2 [0, 4] | 2 [0, 3] | 1 [0, 2] | 1 [0, 2] |
| | CVD[b] | 81 [71, 92] | 81 [72, 91] | 78 [68, 86] | 65 [57, 73] | 59 [51, 68] |
| | CRD[c] | 2 [1, 3] | 1 [1, 2] | 1 [1, 2] | 1 [1, 2] | 1 [1, 2] |
| | All causes | 86 [76, 97] | 86 [76, 96] | 82 [72, 91] | 68 [60, 76] | 62 [54, 71] |

[a] Diarrhea, lower respiratory infections, meningitis, and other common infectious diseases

[b] Cardiovascular and circulatory diseases

[c] Chronic respiratory diseases

86 million DALYs (5.7 % of total) were attributable to environmental exposure, with outdoor air pollution as one of the largest contributors (Prüss-Ustün et al. 2011). According to WHO, in 2004, urban air pollution, mainly from combustion sources, caused about 1,152,000 deaths and 8,747,000 DALYs at global level (Cohen et al. 2004; U.S. National Research Council 1990). It should be taken into account that such adverse health effects depend on the exposure, which is in turn related to the pollution level and the number of individuals involved, as well as to the frequency and duration of their contact with pollutants, i.e., the number of person-hours of exposure (U.S. National Research Council 1990). Therefore, it is likely that such estimates of the burden would underestimate the BOD.

Moreover, many adverse outcomes of air pollutants would become evident after many years and might have transgenerational effects (Khajehkazemi et al. 2013; Bernal and Jirtle. 2010); therefore, the long-term BOD attributable to ambient air pollution would be much higher than the current estimates.

PM pollution consists of a number of components, containing acids, organic chemicals, metals, and particles of dust or soil. In addition to the well-known respiratory effects (Grunig et al. 2014; Vawda et al. 2014; Valavanidis et al. 2013), PM

**Table 3** YLD rate per 100,000 population [95 % UI] attributed to ambient particular matter pollution in Iran by cause in different age groups from 1990 to 2010

| | | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| <5 years | Infectious diseases[a] | 24 [6, 69] | 19 [6, 43] | 19 [6, 46] | 20 [5, 58] | 20 [4, 56] |
| | Neoplasms | – | – | – | – | – |
| | CVD[b] | – | – | – | – | – |
| | CRD[c] | – | – | – | – | – |
| | All causes | 24 [6, 69] | 19 [6, 43] | 19 [6, 46] | 20 [5, 58] | 20 [4, 56] |
| 15–49 years | Infectious diseases[a] | – | – | – | – | – |
| | Neoplasms | – | – | – | – | – |
| | CVD[b] | 17 [11, 26] | 18 [12, 26] | 17 [11, 26] | 18 [12, 27] | 19 [13, 29] |
| | CRD[c] | 13 [3, 32] | 13 [3, 30] | 12 [3, 29] | 12 [3, 29] | 13 [3, 31] |
| | All causes | 30 [17, 52] | 31 [18, 51] | 30 [17, 49] | 30 [17, 50] | 32 [19, 55] |
| 50–70 years | Infectious diseases[a] | – | – | – | – | – |
| | Neoplasms | – | – | – | – | – |
| | CVD[b] | 109 [70, 160] | 116 [76, 166] | 114 [75, 162] | 107 [69, 156] | 104 [68, 153] |
| | CRD[c] | 57 [14, 134] | 58 [16, 135] | 55 [15, 128] | 51 [13, 120] | 48 [11, 116] |
| | All causes | 167 [103, 262] | 175 [110, 272] | 170 [107, 262] | 159 [98, 241] | 152 [93, 239] |
| >70 years | Infectious diseases[a] | – | – | – | – | – |
| | Neoplasms | 3 [1, 6] | 3 [1, 5] | 2 [0, 4] | 2 [1, 4] | 2 [1, 5] |
| | CVD[b] | 141 [92, 207] | 135 [91, 194] | 143 [97, 205] | 149 [101, 216] | 148 [99, 215] |
| | CRD[c] | 92 [23, 218] | 85 [23, 196] | 86 [23, 198] | 87 [22, 206] | 84 [20, 200] |
| | All causes | 236 [139, 392] | 223 [135, 359] | 231 [140, 361] | 238 [143, 372] | 234 [142, 374] |
| All ages | Infectious diseases[a] | 4 [1, 11] | 2 [1, 6] | 2 [1, 5] | 2 [0, 5] | 2 [0, 5] |
| | Neoplasms | – | – | – | – | – |
| | CVD[b] | 20 [13, 29] | 21 [14, 31] | 23 [16, 33] | 26 [18, 38] | 29 [20, 42] |
| | CRD[c] | 13 [3, 30] | 13 [3, 30] | 14 [4, 32] | 15 [4, 36] | 17 [4, 40] |
| | All causes | 36 [22, 58] | 37 [22, 59] | 39 [24, 61] | 43 [26, 68] | 48 [29, 76] |
| Age-standardized | Infectious diseases[a] | 2 [0, 6] | 2 [1, 4] | 2 [1, 4] | 2 [0, 5] | 2 [0, 5] |
| | Neoplasms | – | – | – | – | – |
| | CVD[b] | 37 [25, 54] | 38 [26, 55] | 38 [26, 54] | 38 [25, 54] | 37 [25, 53] |
| | CRD[c] | 23 [6, 55] | 23 [6, 53] | 22 [6, 51] | 21 [5, 50] | 20 [5, 48] |
| | All causes | 63 [38, 101] | 63 [39, 100] | 62 [39, 97] | 61 [37, 93] | 59 [36, 93] |

[a] Diarrhea, lower respiratory infections, meningitis, and other common infectious diseases

[b] Cardiovascular and circulatory diseases

[c] Chronic respiratory diseases

has diverse non-respiratory health hazards related to NCDs and risk factors(Nemmar et al. 2013; Weichenthal et al. 2013; Loane et al. 2013; Brook et al. 2010). Moreover, PM exposure may have adverse outcomes from early life including congenital anomalies, increased risk of abortion, preterm delivery, intrauterine growth retardation, and stillbirth (Lim et al. 2012; Stieb et al. 2012; Kelishadi and Poursafa 2010; Shah and Balkhair 2011). Some of these conditions, as low birth weight, have lifelong effects, notably on the incidence of NCDs (Barker 2004; Ibanez et al. 2011). If such long-term effects could be considered, the attributable risk of PM on DALYs and mortality would become much greater than the current estimates.

The human blood vessel endothelium is a sensitive target for PM. The interactions of the inflammation and coagulation systems are the major mechanisms involved in impairment of endothelial function and eventually CVDs. The effect of PM on inflammation, oxidative stress, CVDs, and risk factors is well documented (Valavanidis et al. 2013; Kelishadi et al. 2009; Poursafa et al. 2014; Qorbani et al. 2012). It is suggested that differences in the extent of the response to PM is influenced by the variations in the susceptibility of different persons. Elderly individuals are vulnerable to various hazards of air pollutants (Shumake et al. 2013; Barnett et al. 2006; Larrieu et al. 2007). In the current study, the greater increase in the DALYs and mortality of individuals with more than

**Table 4** Percent of total DALYs and death attributed to ambient particulate matter pollution in Iran by cause from 1990 to 2010

| All age – both gender | | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| DALYs | Infectious diseases[a] | 7.73 [5.15, 10.5] | 7.08 [4.79, 9.64] | 5.8 [3.84, 8.06] | 5.72 [3.65, 7.98] | 5.25 [3.23, 7.81] |
| | Neoplasms | 1.72 [0.43, 2.8] | 1.59 [0.39, 2.52] | 1.49 [0.38, 2.35] | 1.48 [0.38, 2.37] | 1.55 [0.41, 2.54] |
| | CVD[b] | 16.94 [14.8, 19.35] | 18.76 [16.97, 20.8] | 20.03 [18.36, 21.92] | 20.38 [18.63, 22.32] | 20.71 [18.9, 22.64] |
| | CRD[c] | 1.61 [0.59, 2.95] | 2.06 [0.74, 3.76] | 2.36 [0.87, 4.27] | 2.57 [0.97, 4.7] | 2.8 [1.02, 5.15] |
| | All causes | 3.22 [2.79, 3.74] | 3.78 [3.33, 4.32] | 3.97 [3.49, 4.47] | 3.7 [3.24, 4.16] | 3.8 [3.22, 4.34] |
| Death | Infectious diseases[a] | 7.26 [4.9, 9.96] | 6.15 [4.12, 8.42] | 4.53 [3.03, 6.26] | 4.05 [2.55, 5.79] | 3.36 [1.98, 5.12] |
| | Neoplasms | 2.13 [0.53, 3.48] | 1.95 [0.48, 3.11] | 1.81 [0.46, 2.85] | 1.74 [0.45, 2.8] | 1.81 [0.5, 2.97] |
| | CVD[b] | 19.16 [17.25, 21.22] | 19.68 [17.8, 21.59] | 19.58 [17.71, 21.53] | 18.86 [16.91, 20.86] | 18.57 [16.54, 20.74] |
| | CRD[c] | 2.77 [1.04, 4.67] | 3.39 [1.29, 5.59] | 3.82 [1.45, 6.19] | 4.31 [1.67, 7.13] | 4.52 [1.81, 7.53] |
| | All causes | 6.94 [6.06, 7.9] | 8.76 [7.78, 9.8] | 9.39 [8.4, 10.38] | 9.08 [8.01, 10.12] | 9.18 [7.96, 10.3] |

[a] Diarrhea, lower respiratory infections, meningitis, and other common infectious diseases

[b] Cardiovascular and circulatory diseases

[c] Chronic respiratory diseases

70 years of age is suggested to be because of the underlying chronic diseases of this age group and their higher vulnerability and susceptibility to PM hazards.

The estimates made here should be viewed as tentative. Some data include gaps, and some estimates have uncertainties and may be imperfect in some instances. Moreover, the burden might be underestimated and limited to some major diseases included in this study; considering diverse health effects over time would result in higher burden. In Iran, the exposure estimations for many risk factors were affected by limitations in data sources. For air pollution, the main source of data was high-resolution satellite data. Thus, different nationally representative data sources for ambient PM pollution in Iran were neglected as population-based epidemiological studies, as well as national and sub-national health surveys including Tehran Air Quality Cooperation data, and Iran's Environment Protection Organization data. Because of the incomplete data for risk factor exposure for many populations, statistical models were used to produce a complete set of current exposure distributions; therefore, the estimations might be more model-driven than data-driven.

Due to the limitations of the GBD 2010 study, National and Sub-national Burden of Disease (NASBOD) study is being conducted in Iran to calculate the BOD, injuries, and risk factors from 1990 to 2013 at national and sub-national levels (Farzadfar et al. 2014). The distribution of diseases and risk factors at sub-national level would result in selecting the health priorities and interventions for main health problems among sub-national people, and notifying policy makers for public health strategies. National and sub-national Environmental Burden of Disease in Iran is a part of the NASBOD study that aims to estimate the prevalence and burden of ambient PM pollution at the national and sub-national levels between 1990 and 2013 (Amini et al. 2014).

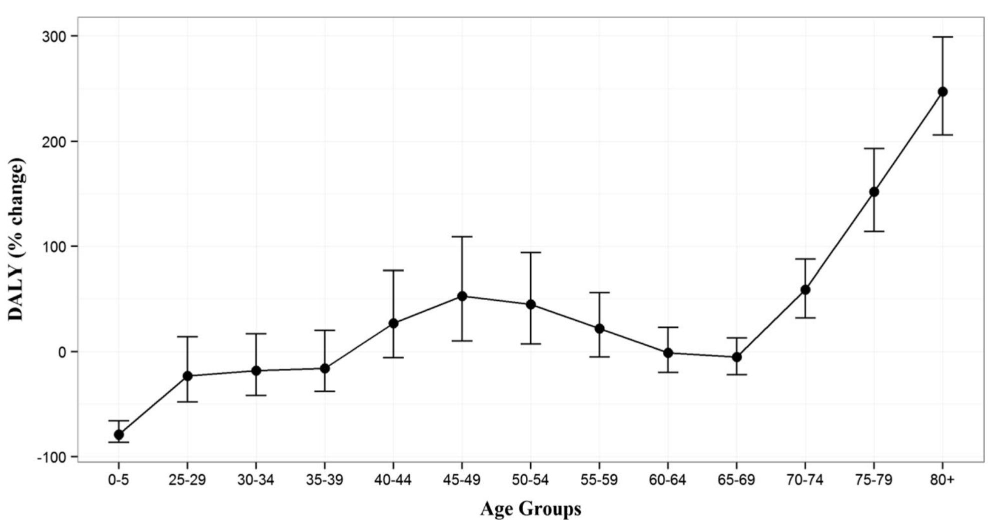


**Fig. 1** Median percent change and its uncertainty interval of DALYs attributed to ambient PM pollution in Iran between 1990 and 2010 by age groups

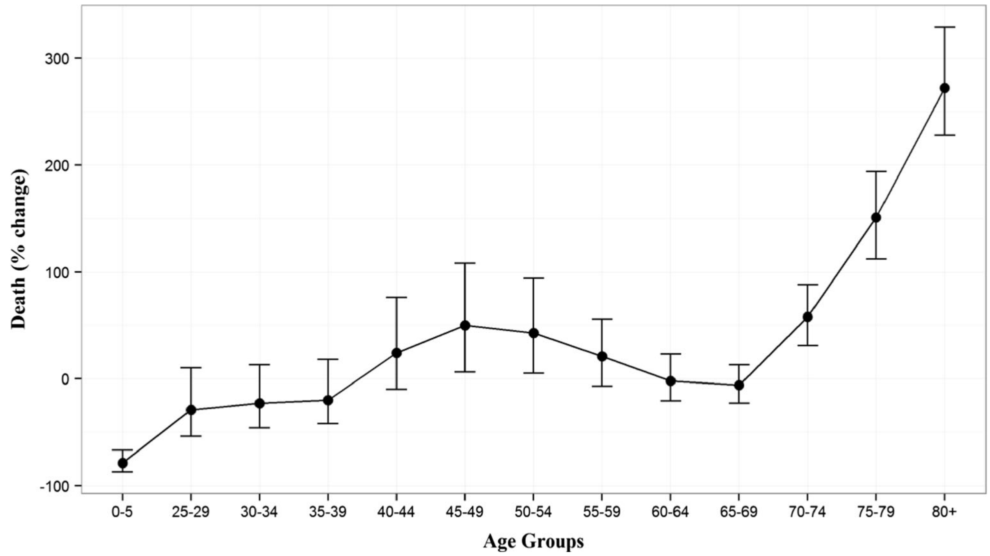


**Fig. 2** Median percent change of death and its uncertainty interval attributed to ambient PM pollution in Iran between 1990 and 2010 by age groups

## Conclusion

The increase in the DALYs and mortality attributable to PM pollution in Iran reinforces the importance of implementing effective interventions for improving air quality, as well as for increasing the public awareness for reducing the exposure of vulnerable age groups to PM pollution. Medical and abatement research studies would pin down more accurately the impact of the PM pollution and cost-effective ways to reduce this burden.

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