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Estimation of health and economic benefits of air pollution abatement for Turkey in 1990 and 1993

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An average of 15 million residents of the major cities in Turkey were exposed to particulate matter (PM_{10}) and SO_2 levels above the World Health Organization (WHO) standards in the 1990–1993 period. An assessment of the health effects due to particulate matter (PM_{10}) and exposure to sulphur dioxide (SO_2) suggests that, if annual PM_{10} and SO_2 levels were reduced to WHO standards, this could have brought a reduction of 5940 and 5480 hospital admissions for respiratory diseases, 121,400 and 112,100 emergency room visits, 8.26 and 6.85 million restricted activity days and 57,000 and 73,000 cases of low respiratory symptoms in children 0–12 years of age in 1990 and 1993 respectively. The estimated annual economic value of avoiding these effects is nearly 0.12% and 0.08% of the 1990 and 1993 gross national product (GNP). Furthermore, the results show that, by attaining WHO air pollution standards, 3310 and 3060 lives could have been saved in 1990 and 1993 respectively.

Keywords: Air pollution; Economic benefits; Health benefits

Introduction

About 15 million people living in Turkey's most industrialized urban areas were exposed to particulate matter (PM_{10}) and sulphur dioxide (SO_2) levels which exceeded the World Health Organization (WHO) standards in 1990 and 1993. Hence, one-third of the Turkish population was affected by major air pollution emissions and will be affected in the future due to the average annual urban population growth rate of 5% which is further enhanced by an urbanization rate of 5.9% (Statistical Yearbook of Turkey, 1994).

The major sources of air pollution are the combustion of fossil fuels, lead additives in gasoline and heavy industries in the region. Air pollution is exacerbated by the use of high sulphur fuel oil (often with 3% sulphur content), old vehicle technology with no emission control equipment and often poorly operated, if any, industrial abatement technology.

The objective of this study was to assess the health and economic benefits of reducing PM_{10} and SO_2 levels to the WHO standards in Turkey's major towns in 1990 and 1993. The cities which experienced the highest air pollution levels in 1990 and 1993 are identified, and the health and economic benefits are estimated and discussed.

Urban air pollution in the major cities of Turkey

According to the Turkish State Statistic Department's report, the most populated cities in 1990 were Ankara, Bursa, Istanbul and Izmir. These cities are the location of the majority of manufacturing industry (see Table 1) (Annual Manufacturing Industry Statistics, 1990; Statistical Yearbook of Turkey, 1994). Istanbul, with about 7 million population, supported 42.35% of the manufacturing industry in 1990. The industries in Istanbul are mostly concentrated on metal, equipment and textile production. Izmir and Bursa supported 10.1% and 5.26% of the total industrial activity respectively, including textiles, manufacture of food, beverage and tobacco production. Erzurum and Sivas, with respective shares of 1.4% and 0.2% of industrial activity, were minor contributors to industrial production.

Air pollution has been monitored in Turkey since 1980. Sulphur dioxide (SO_2) and particulate matter (PM_{10}) are measured daily in the major towns (Statistical Yearbook of Turkey, 1994). In all the cities, the levels of SO_2 and PM_{10} exceeded the WHO standards in all years between 1990 and 1993. The WHO ambient air quality standards for annual averages are 70 μg/m^3 for PM_{10} and 50 μg/m^3 for SO_2. The

Table 1 Population and number of industries in the major cities of Turkey, 1990

City	Population in provincial and district centre ($\times 10^6$)	Number of industries (%)
Ankara	2.84	4.30
Bursa	1.16	5.26
Erzurum	0.4	1.40
Istanbul	6.75	42.35
Izmir	2.13	10.10
Kayseri	0.60	1.28
Sivas	0.38	0.20
Others	54.31	35.11
Total	68.57	100

Source: Statistical Yearbook of Turkey, 1994.

annual average air pollution measured in the major cities of Turkey is given in Table 2.

The highest levels of PM_{10} and SO_2 were measured in Sivas and Kayseri during the 1990–1993 period. In these cities, the population is around 400,000–600,000 and the industrial activity is low (Table 1). Hence, the low quality coal and high sulphur content petroleum consumption in households and transportation seem to be responsible for the high concentrations of PM_{10} and SO_2. The next highest PM_{10} and SO_2 concentrations were measured in Istanbul, with the largest population and highest industrial activity (see Table 1 and Table 2).

The annual average PM_{10} level decreased by 22%, 47% and 26%, while the level of SO_2 decreased by 58%, 28% and 15%, in Ankara, Bursa and Istanbul between 1990 and 1993. Bursa experienced a PM_{10} level below the WHO standards in 1993. Erzurum, Izmir, Kayseri and Sivas experienced increases of 83%, 30%, 76% and 8.3% in PM_{10} and of 90%, 47%, 13% and 4% in SO_2 levels between 1990 and 1993 (Table 2).

The high concentration of air pollutants in many developing countries leads to increased illness, particularly among individuals suffering from respiratory problems, and causes premature death among the elderly. The air pollutants of greatest concern are carbon monoxide, hydrocarbons, sulphur oxides, nitrogen oxides, suspended particulate matter, lead and secondary pollutants such as ozone. However, since only PM_{10} and SO_2 are monitored systematically in Turkey, the health effects associated with these are assessed.

Health benefit estimation

Epidemiologic studies provide dose–response relationships between ambient level concentrations of PM_{10} and SO_2 and several health outcomes, including premature mortality (PM), respiratory hospital admissions (RHA), emergency room visits (ERV), restricted activity days for adults (RAD), lower respiratory illness for children (LRI), asthma attacks and chronic diseases. The studies which have found statistically significant relationships between the measures of PM_{10} and SO_2 and the above-mentioned health effects have been conducted in several different cities and seasons, thereby incorporating a wide range of climates and population.

Studies linking PM_{10} to mortality indicate that a 10 μg/m^3 change in PM_{10} results in an increased premature mortality between 0.31% and 1.49%, with a mean value of 0.96% (Ostro, 1990, 1993; Schwartz, 1991; Pope *et al*, 1992). Plagiannakos and Parker (1988) found a statistically significant relationship between RHA and ambient sulphate levels. Samet *et al* (1981) analysed the relationship between ERV and air pollution levels. A regression analysis was performed and daily ERV values were regressed on the maximum temperature and each of the pollutants in separate runs. The study's results indicated that the PM_{10} and SO_2 coefficients were statistically significant and were highly correlated with the daily ERV. RAD include days spent in bed, days missed from work and other days when activities are significantly restricted due to illness Ostro (1983) identified a statistically significant relationship between the PM_{10} level and RAD. Dockery *et al* (1989) related PM_{10} and SO_2 levels to chronic cough and bronchitis in children.

Furthermore, studies also indicate that SO_2, acting alone or as a surrogate for other sulphur-related species, is associated with increased risk of mortality (Krzyzanowski and Wojtyniak, 1982; Hatzakis *et al*, 1986; Chinn *et al*, 1989; Derriennic *et al*, 1989). Studies that provide evidence of the effect of SO_2 on the respiratory system include Bates and Sizto (1983), Dodge *et al* (1985), Charpin *et al* (1988), Schwartz *et al* (1988) and Ponka (1990).

Ostro (1994) used these studies to generate dose–response information and formulated the health impact of a pollutant as follows

$$dH_i = b \times POP_i \times dA$$

Table 2 Annual average SO_2 and PM_{10} emission levels (μg/m^3)

City	1990		1991		1992		1993	
	SO_2	PM_{10}	SO_2	PM_{10}	SO_2	PM_{10}	SO_2	PM_{10}
Ankara	170	103	125	83	163	100	72	80
Bursa	185	89	224	101	181	78	133	47
Erzurum	145	87	176	98	189	129	276	159
Istanbul	241	118	284	131	247	92	204	87
Izmir	96	77	92	81	162	148	141	100
Kayseri	161	79	141	74	149	66	182	139
Sivas	260	144	193	169	197	145	269	156
WHO standard	50	70	50	70	50	70	50	70

Table 3 Estimated increment in annual health effects associated with unit change in PM_{10} and SO_2 levels

	PM_{10}					SO_2	
	PM/100,000	RHA/100,000	ERV/100,000	RAD/person	LRI/child	PM/100,000	RS/1000 children
Low	0.45	0.66	12.83	0.040	0.0008	0.02	0.010
Medium	0.67	1.2	23.54	0.058	0.0016	0.05	0.018
High	0.91	1.56	34.25	0.090	0.0024	0.12	0.026

PM, premature mortality; RHA, respiratory hospital admission; RAD, restricted activity days; LRI, lower respiratory illness; ERV, emergency room visit; RS, respiratory symptoms.

Table 4 Abatement levels of SO_2 and PM_{10} needed to reach WHO standards ($\mu g/m^3$)

City	1990 (d*A*)		1993 (d*A*)	
	SO_2	PM_{10}	SO_2	PM_{10}
Ankara	120	33	22	10
Bursa	135	19	83	–
Erzurum	95	17	226	89
Istanbul	191	48	154	17
Izmir	46	7	91	30
Kayseri	111	9	132	69
Sivas	210	74	219	86

where dH_i is the change in population risk of health effect i, b is the slope of the dose–response curve, POP_i is the population at risk of health effect i, dA is the change in air pollution under consideration and i is the health effect, such as PM, RHA, ERV, RAD and LRI.

Here, as in other studies, the same dose–response coefficients are adopted to assess the health impacts of SO_2 and PM_{10} for the Turkish urban population. The dose–response coefficients are based on both time-series and cross-section epidemiologic analyses from the USA, Canada and the UK. The use of these results implicitly assumes a similar distribution of baseline factors—health status, chemical composition of pollutants, occupational exposure, seasonality, time spent out of doors, general activity—and that results from other studies can be applied to the study area. This study, like other similar studies on other countries, does not take individuals' defensive actions into account (ie immunization) and does not consider market losses associated with sickness, such as pain and suffering.

Health and economic benefits—results

The health effects associated with PM_{10} and SO_2 abatement are computed on the basis of the medium dose–response coefficients (b) depicted in Table 3. The population at risk (POP_i) is reported in Table 1. The abatement levels (dA) that are needed to reach WHO standards are shown in Table 4.

The levels of PM, RHA, ERV, RAD and LRI are computed. The estimates of health effects achieved by reaching WHO standards for PM_{10} and SO_2 levels are provided in Table 5 and Table 6.

The results indicate that, if the annual PM_{10} level had been reduced to the WHO standard (70 $\mu g/m^3$), this could have reduced premature mortality cases by 3310 and 3060 in 1990 and 1993 respectively. Furthermore, it could have reduced RHA by 5900 and 5400 and ERV by 121,400 and 112,100 in 1990 and 1993 respectively. When assessing the RAD for the population of age 12 and above, the results showed that the

Table 5 Estimated total health effects associated with PM_{10} level reduction to WHO guidelines in 1990 and 1993

City	PM	RHA	ERV	RAD×10[6] for 12 years and above	LRI×10[3] for 0–12 years
Ankara	608[a], 135[b]	1087, 243	22231, 4975	1.42, 0.33	107, 21
Bursa	118, –	212, –	4328, –	0.29, –	19, –
Erzurum	69, 602	123, 1079	2517, 22053	0.11, 1.02	10, 88
Istanbul	2106, 735	3771, 1316	77110, 26951	0.56, 2.00	334, 119
Izmir	36, 564	65, 1010	1320, 20679	0.10, 1.54	0.00, 81
Kayseri	25, 504	45, 902	921, 18459	0.05, 1.03	0.00, 75
Sivas	355, 520	635, 931	12985, 19045	0.62, 0.92	54, 73
Total	3317, 3060	5938, 5481	121412, 112162	8.26, 6.85	524, 457
Rate of change	−7.75%	−7.69%	−7.62%	−17.07%	−12.78%

[a]First value, 1990.
[b]Second value, 1993.
PM, premature mortality; RHA, respiratory hospital admission; RAD, restricted activity days; LRI, lower respiratory illness; ERV, emergency room visit.

Table 6 Estimated increment in health effects associated with SO_2 level reduction to WHO guidelines in 1990 and 1993

City	Premature mortality	Respiratory symptoms for children aged 0–12 years
Ankara	163[a], 34[b]	1226, 225
Bursa	75, 53	816, 577
Erzurum	18, 50	356, 974
Istanbul	619, 574	3483, 3229
Izmir	47, 107	54, 844
Kayseri	32, 44	410, 561
Sivas	39, 38	736, 722
Total	993, 900	7084, 7132
Rate of change (%)	−9.36	−0.67

[a]First value, 1990.
[b]Second value, 1993.

Table 7 Doctor's fee per person (annual average prices, TL)

City	1990	1993
Ankara	53646	161979
Bursa	NA	NA
Erzurum	21264	150625
Istanbul	44118	94479
Izmir	41256	92474
Kayseri	NA	NA
Sivas	NA	NA

Source: Statistical Yearbook of Turkey, 1994 (p. 590).

required abatement could have avoided 8.26 and 6.85 million lost working days. The LRI for children aged between 0 and 12 years could have been decreased by 524,000 and 457,000 in 1990 and 1993 respectively.

Table 6 depicts the estimated health effects associated with SO_2 levels measured in 1990 and 1993. If the SO_2 levels had been reduced to the WHO standards (50 $\mu g/m^3$), this could have brought a reduction of 993 and 900 cases of premature mortality and 7080 and 7130 cases of respiratory symptoms among children aged between 0 and 12 years in 1990 and 1993 respectively.

Economic evaluation

The direct annual loss of output caused by absenteeism arising from air pollution is computed by multiplying the estimates of the days lost in 1990 and 1993 due to sickness by the average daily wages. These average daily wages were 28,585 TL and 130,063 TL in urban areas for 1990 and 1993 respectively (Statistical Yearbook of Turkey, 1994). To attach an economic value to RHA, the annual average prices of the doctor's fees were used (see Table 7). The ERV fees were based on the private hospital recordings, ie 167,640 TL/visit/person and 480,000 TL/visit/person in 1990 and 1993 respectively. For the non-available information on doctor's fees in Bursa, Kayseri and Sivas, we used the closest city's prices. The Istanbul price was used for Bursa, whereas doctor's fees in Erzurum were applied for Kayseri and Sivas.

The results indicate that a decrease in PM_{10} and SO_2 levels to WHO standards would have resulted in a total of 48.57×10^{10} TL and 154.08×10^{10} TL savings in 1990 and 1993 respectively (Table 8). The total health cost is estimated to be 0.12% and 0.08% of 1990 and 1993 gross national product (GNP) respectively. This is rather low when compared with the health costs estimated for the UK (1% of GNP) in 1993 (Pearce, 1996).

Conclusions

The health and economic benefits of air quality improvements were estimated. The computations are based on the dose–response coefficients established in several studies. Since the air pollution levels decreased in the most populated and industrialized cities, such as Istanbul, Ankara and Bursa, the health effects and the associated economic costs improved between 1990 and 1993. More specifically, we observed an average 8% decrease in the levels of RHA and ERV due to air quality improvement. The premature mortality rate decreased by 7.75% and 9.36% due to a decrease in the PM_{10} and SO_2 levels. These improvements also brought a 32% decrease in the economic costs.

The results have several implications. One is that an improvement in air quality can lead to both health and economic benefits to society. Furthermore, we should emphasize that, if more comprehensive and accurate air pollution data (ie ozone, lead) become available, more effects can be evaluated.

Table 8 Estimated economic cost associated with PM_{10} and SO_2 level reduction to WHO guidelines in 1990 and 1993

City	RAD ($\times 10^{10}$ TL)	RHA and ERV ($\times 10^6$ TL)	Respiratory symptoms (RS) for children aged 0–12 years ($\times 10^6$ TL)
Ankara	1.20[a], 1.01[b]	3321.1, 2244.5	65.77, 36.44
Bursa	1.48, –	379.2, –	43.77, 93.46
Erzurum	0.37, 13.50	200.1, 5302.5	7.57, 146.71
Istanbul	40.57, 60.07	12136.96, 12801.6	153.66, 305.07
Izmir	0.57, 36.05	178.75, 8452.9	2.22, 78.04
Kayseri	0.26, 22.05	100.6, 6093.3	8.71, 84.50
Sivas	2.12, 13.15	1097.9, 39746.2	15.65, 108.75
Total	46.54, 145.83	17414.63, 74640.9	297.35, 852.95

[a]First value, 1990.
[b]Second value, 1993.

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