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# Investigation of the Effect of Long-Term Exposure to Outdoor Air Pollution on Deaths in Konya with AirQ+ Software

## Konya'da Dış Ortam Hava Kirliliğine Uzun Süre Maruziyetin Ölümler Üzerine Etkisinin AirQ+ Yazılımı ile İncelenmesi

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***ÖZ***

*Dış ortam hava kirliliği, halk sağlığına yönelik en büyük çevresel risklerden biridir ve düşük, orta ve yüksek gelirli ülkelerde herkesi etkileyen bir sorundur. Partikül madde (PM), havada asılı duran katı ve sıvı partiküllerin karışımından oluşan yaygın bir hava kirleticisidir. PM2.5 ve PM10 en yaygın olanlarıdır ve sağlıkla ilgilidir. Dünya Sağlık Örgütü, Partikül Maddeyi 2013 yılında kanserojen olarak ilan etti. Bu çalışmanın amacı, Konya'da 30 yaş ve üstü yetişkin ölümlerinin ne kadarının PM2.5 kirleticisinin neden olduğu dış hava kirliliğine bağlanabileceğini hesaplamaktır. PM10 ve PM2.5'e atfedilen ölüm vakalarını hesaplamak için AirQ+ yazılımı kullanıldı. Sonuçlar, 2017'de 2163, 2018'de 1582 ve 2019'da 1278 erken ölümün, bölgedeki PM2.5 konsantrasyonunun tavsiye edilen 10 µg/m3 eşiğini aşmaması halinde önlenebileceğini göstermektedir. Konya'da hava kirliliği düzeyi oldukça yüksektir. AirQ+ yazılımı kullanılarak yapılan hesaplamada, Türkiye'de daha önce yapılan araştırmalara benzer şekilde 30 yaş ve üstü nüfusta hava kirliliğine bağlı ölüm oranı yüksek çıkmıştır. Elde edilen bulgular hava kirliliğini önleyerek birçok erken ölümün önlenebileceğini göstermektedir.*

***Anahtar Kelimeler: Hava Kirliliği, Mortalite, Erken Ölümler, AirQ+, Partikül Madde***

***ABSTRACT***

*Outdoor air pollution is one of the biggest environmental risks to public health and a problem that affects everyone in low-, middle- and high-income countries. Particulate matter (PM) is a common air pollutant consisting of a mixture of solid and liquid particles suspended in the air. PM2.5 and PM10 are the most common and are health related. The World Health Organization declared Particulate Matter (PM) as a carcinogen in 2013. The aim of this study was to calculate how much of the adult deaths aged 30 and over in Konya can be attributed to outdoor air pollution caused by PM2.5 pollutant. AirQ+ software was used to calculate the cases of deaths attributed to PM10 and PM2.5. The results show that 2163 premature deaths in 2017, 1582 in 2018 and 1278 in 2019 from long-term exposure to PM2.5 could be prevented if the PM2.5 concentration in the region does not exceed the recommended threshold of 10 µg/m3. Air pollution level is quite high in Konya. In the calculation made using AirQ+ software, the death rate attributable to air pollution in the population aged 30 and over was high, similar to previous studies in Turkey. The findings show that many premature deaths can be prevented by preventing air pollution.*

***Keywords: Air Pollution, Mortality, Premature Deaths, AirQ+, Particulate Matter***

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## INTRODUCTION

One of the biggest environmental risks to public health is outdoor air pollution. This problem is affecting all countries, regardless of low, middle, and high income. These early deaths are mostly the result of diseases such as ischemic heart disease, stroke, chronic obstructive pulmonary disease, acute lower respiratory tract infections and cancers, which are caused by long-term exposure to fine particulate matter (WHO, 2022).

Particulate matter (PM), sulphur dioxide (SO2), ozone (O3), nitrogen dioxide (NO2) and carbon monoxide (CO), are among the important pollutants that threaten health by creating air pollution. These pollutants can cause serious health problems with short or long-term exposure indoors or outdoors. The pollutants included in the WHO global air quality guidelines are (WHO, 2023);

*Particulate Matter (PM):* They are respirable particles and consist of sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. PM can be of different size and is generally defined by their aerodynamic diameter. PM particles with diameters between 2.5 µm and 10 µm are coarse particles and consist of wind-blown dust such as pollen and sea spray. Finer particles such as PM2.5 can be formed in power plants, industries or as a result of chemical reactions between gases. The largest source of particulate matter indoors is the combustion of polluting fuels in furnaces, inefficient stoves or space heaters. Other activities such as cooking and water heating in the home environment can also lead to the formation of particulate matter pollution. The main sources of outdoor air pollution are location-specific and can be caused by different situations. However, it mainly occurs as a result of industrial activities, construction sites, traffic and transportation, waste incineration units and fires.

*Sulfur Dioxide (SO2):* SO2 is a colorless gas with a pungent odor that dissolves easily in water. It mostly comes out of the burning of coal and oil. Exposure to SO2 has been shown to be associated with increased hospital and emergency room admissions for asthma.

*Ozone (O3):* Ground-level ozone is formed by reacting with gases in the presence of sunlight. Ozone (O3) is an important component of smog. The highest ozone levels occur in sunny weather. Ozone can also be produced by household appliances such as portable air cleaners.

*Nitrogen Dioxide (NO2):* NO2 is a gas released from the high-temperature combustion of fuels in the heating, transportation, and industrial and power generation sectors. Exposure to nitrogen dioxide can cause or exacerbate asthma and other respiratory diseases.

*Carbon Monoxide (CO):* Carbon monoxide is produced by the incomplete combustion of carbonaceous fuels such as wood, petroleum, charcoal, and natural gas. It is a colorless, odorless and tasteless poisonous gas.

Particulate matter (PM), which was declared a carcinogen by WHO in 2013, is the most common air pollutant. The mass concentration of particles less than 2.5 µm in diameter is called PM2.5. PM2.5, often referred to as fine PM, also includes very fine particles less than 0.1 µm in diameter. In most places in Europe PM2.5 accounts for 50-70% of PM10. The WHO recommends limit values for PM2.5 emissions for the protection of health; accordingly, the annual average of the PM 2.5 pollutant should be kept below 10 µg/m3 and the 24-hour average 25 µg/m3. (WHO, 2013a; WHO, 2013b).

Health problems caused by air pollution and other environmental pollution bring great economic costs to countries. Pollution is a preventable problem and pollution control provides significant economic benefits. Despite all the negative effects of environmental pollution and its controllability, it has been largely neglected in health and development plans. In addition, the effects of pollution

have been ignored in the estimates of the global burden of disease (Landrigan and Fuller, 2015). While researchers have long demonstrated that air pollution causes large numbers of premature deaths, in the past the association between exposure and health outcomes was thought to be less strong. Recent research suggests that a given level of exposure causes more deaths than previous research (Roser,2021).

Outdoor air pollution is a major concern for Turkey as well. Measurements show that inhaled air across the country is harmful to health. PM2,5 and PM10 concentrations are well above the standard limit values determined by the EU and WHO for the protection of health (TTB 2015). The National Air Quality Monitoring Network was established throughout Turkey by the Ministry of Environment, Urbanization and Climate Change. At the established air pollution measurement stations, the measurements of the contaminants such as particulate matter and sulfur dioxide are made. The data collected at the measurement stations is published at www.havaizleme.gov.tr (T.C. Çevre Şehircilik ve İklim Değişikliği Bakanlığı, 2023).

Konya is a province located in the south of the Central Anatolian Region, a large part of which has a plateau feature with wide plains. It is the province with the largest surface area in Turkey. The southeast, south and southwest directions of Konya are surrounded by the Taurus Mountains and their extensions (Konya il Kültür ve Turizm Müdürlüğü, 2023). The fact that the city of Konya is surrounded by mountain ranges affects the air movement and wind formation in this region. Especially in winter, polluted air cannot get out of the city and causes intense air pollution in the city center (Çiftçi et al., 2013 ). The purpose of this study was to determine adult deaths attributable to air pollution in Konya city.

**MATERIAL AND METHODS**

This ecological study was carried out in the city center of Konya. In the study, hourly PM10 values of Konya Karkent and Karatay stations for the years 2017, 2018 and 2019 were used from the website of the Ministry of Environment, Urbanization and Climate Change www.havaizleme.gov.tr. In these two stations, continuous and sufficient measurements were made in the relevant years. The average value of the years, of which at least 75% of the 8760 (365*24) measurements required to be measured annually was taken. The results were compared with WHO's annual PM10 average upper limit value. The PM 2.5 values used in the study were calculated by multiplying the 0.67 coefficient recommended by WHO for Turkey with the PM10 values (WHO, 2016).

Air Quality Measurement Stations in Konya are also connected to the national air monitoring network and the data can be monitored instantly. Parameters such as particulate matter, sulfur dioxide, nitrogen oxide, ozone, and carbon monoxide are measured at stations established for the detection and monitoring of air pollution originating from heating, industry, and traffic. There is only one station that measures air pollution originating from industry and is located in Karatay Karkent Region.

AirQ+ software was used for analysis. AirQ+ is a software tool developed by the WHO Regional Office for Europe (WHO, 2021). Its purpose is to determine the burden of disease caused by air pollution, such as illness, health care use, premature deaths, and other effects on health. AirQ+ includes a variety of methodologies to assess the health effects of exposure to outdoor air pollution. With the AirQ+ software, the effects of outdoor pollutants such as PM10, PM2.5, NO2, O3 and BC on health can be evaluated, as well as the effects of domestic air pollution caused by the use of solid fuels. Mortality and morbidity data from both acute and chronic health problems are used for calculations.

To assess outdoor air pollution, some data must be entered into the AirQ+ program. These; (a) air quality data (mean PM10 concentration for long-term exposure effects), (b) population at risk data (total number of adults ≥ 30 years old), (c) health data (death rate in the population studied), and (d) a cut-off value (10 µg). (WHO, 2018). To calculate the average PM2.5 concentration for each year, the annual average PM10 values converted to PM2.5 were added up and divided by the number of stations.

Adult population aged 30 and over in the central districts between 2017, 2018 and 2019 were included in the study. Population data of 30 years and over for the relevant years were obtained from the TUIK website (TUIK, 2023). Using crude death rates to estimate the effects of air pollution can potentially distort the estimation of the number of attributable deaths. For this reason, external causes of death that are not related to environmental factors such as traffic accidents and poisonings were excluded from the total number of deaths aged 30 years and over. In addition, the number of deaths and the number of populations consisted of the same age category.

**RESULTS**

In the study, the data of two stations in the city center were evaluated. Karkent station was not included in the evaluation as it could not meet at least 75% of the 8760 (365*24) measurements required annually in 2019. Annual and 3-year PM averages of the stations were determined to be well above the WHO's upper limit for PM10 and PM2.5. The highest values were in 2017 (Karatay: 84.04; Karkent 61.37) (Table 1).

Table 1. Air pollution statistics (PM10) for two stations

| | **2017** | | **2018** | | **2019** | |
|---|---|---|---|---|---|---|
| | Karkent | Karatay | Karkent | Karatay | Karkent | Karatay |
| **PM 2.5** | 41.12 | 56,30 | 36.54 | 39.22 | 35.48 | 31.28 |
| **Mean, PM10 µg/m$^3$** | 61,37 | 84,04 | 54,53 | 58,54 | 52,95 | 46,68 |
| **SD** | 55,09 | 105,86 | 42,34 | 60,70 | 40,52 | 51,04 |
| **Min µg/m$^3$** | 1,37 | 0,01 | 5,02 | 0,02 | 0,57 | 0,00 |
| **Max µg/m$^3$** | 662,17 | 1.000,00 | 493,29 | 711,98 | 425,78 | 1.000,00 |
| **Number measured** | 8.621 | 7.054 | 8.219 | 7.995 | 6.488 | 7.954 |
| **Number must be measured** | 8.760 | 8.760 | 8.760 | 8.760 | 8.760 | 8.760 |
| **Monitoring Efficiency (%)** | 98,41 | 80,53 | 93,82 | 91,27 | 74,06 | 90,80 |

The results show that there were 2163 premature deaths in 2017, 1582 in 2018 and 1278 in 2019. Such a number of deaths would have been prevented had the PM2.5 concentration level did not exceed the maximum acceptable 10 µg/m3 threshold in the specified years in the region where the measurements were made. (Table 2).

Table 2. AirQ+ results for outdoor pollutant PM2.5 and adult mortality

| | **2017** | **2018** | **2019** |
|---|---|---|---|
| | Central (min-max) | Central (min-max) | Central (min-max) |
| **Estimated Attributable Proportion** | 20.77 % (14.09-26.56) | 15.44% (10.36-19.93) | 12.02% (8.01-15.61) |
| **Estimated number of Attributable Cases** | 2,163 (1,467-2,765) | 1,582 (1,061-2,042) | 1,278 (852-1,660) |
| **Estimated number of Attributable Cases per 100,000** | 193.55(131.24-247.43) | 138.48 (92.90-178.78) | 109.79 (73.16-142.60) |

## DISCUSSION

In this study, using the annual average data of the two stations in the center of Konya, it was calculated with AirQ+ software how much of the deaths, excluding accidents and poisoning, could be attributed to PM2.5 air pollutant in the population at risk.

In the analysis evaluating air pollution in cities using the PM 2.5 database of the WHO, it has been shown that Turkey is among the countries most affected by air pollution in the European Region. While cities in India and China were among the most polluted countries in the world, eight out of every 10 cities in Europe were located in Turkey (HEAL 2017). According to the European Union annual limit values, in 8 of the 39 cities (Düzce, Çorum, Erzurum, Amasya, Konya, Sakarya, Iğdır, Bursa) where adequate measurements are made, it is seen that the average fine particulate matter exceeds the limits (Temiz Hava Hakkı Platformu, 2022). In the study where Altunok and Eskiocak (2020) evaluated the data of 6 stations in Trakya, it was determined that the annual averages at all stations were at least 2 times the WHO annual upper limit (20 µg/m3). Nikoonahad et al. (2017) investigated the trend of PM10 concentrations in the Iranian city of Ilam from 2012 to 2015 and its impact on the health of residents. According to the results obtained, it was stated that the annual average PM10 concentrations in all years were higher than the WHO guideline (Nikoonahad, 2017).

Air pollution is recognized as a preventable global public health problem that causes morbidity and mortality. Studies have shown that exposure to air pollution, especially in cities, is associated with deaths from heart diseases, respiratory tract infections, COPD, lung cancer and stroke in adults (Hajizadeh, 2020). Evidence-based studies have shown that long-term exposure to fine particulate air pollution is an important risk factor for deaths from lung cancer and cardiopulmonary cancers. It is stated that every 10 µg/m3 increase in mean PM2.5 levels over a long period of time is associated with 4%, 6%, and 8% increase in all-cause cardiopulmonary and lung cancer deaths (Pope et al., 2002).

In this study, the natural death rate for adults aged 30 years and older was calculated per 100 000. The death rates for 2017, 2018 and 2019 were 193,55; 138,48 and 109,79, respectively. It is seen that

mortality rates attributed to PM2.5 are also high in other cities of Turkey. In the study of Kahraman and Sivri (2022), the death rate per 100000 was 1239 for Balıkesir, 1006 for Sakarya, 912 for Bursa, 907 for Tekirdağ, 753 for Kocaeli and 696 for Istanbul. In a nationwide study by Pala et al. (2021) with 2018 PM2.5 data, it was determined that there were 44,617 premature deaths in the population at risk (Pala et al, 2021). In other words, if the annual average concentration of air quality was at the level determined by WHO, so many deaths would have been prevented. It has been determined that a significant part of the stations in Turkey cannot collect sufficient data annually, and direct PM2.5 measurement can be made at very few stations. In addition, there is no specific national limit for PM2.5 in Turkey and the limit value for PM10 is 40 µg/m3, which is well above the WHO threshold.

**Limitations**

Although AirQ+ is easy to use, this model has some limitations. AirQ+ software considers the PM2.5 concentration in the environment as the exposure concentration of the population at risk. It also only considers PM concentration, not chemical content. In addition, the epidemiological data used in the model were obtained by meta-analysis of studies conducted outside of Turkey. Therefore, this affects the accuracy of the results.

Although this study reveals the effect of air pollution on deaths, it does not provide information about the causality of this effect. The data were obtained from the air monitoring website, not by measurement, and were assumed to represent the province of Konya. Since PM2.5 measurements cannot be made directly at most of the air quality measurement stations in Turkey, WHO's country-specific PM10 to PM2.5 conversion factor is used to calculate this value. In this case, approximate values are often obtained instead of actual PM2.5 values. It is assumed that the obtained data are close to real values.

## CONCLUSION AND RECOMMENDATIONS

Regular PM2.5 measurements were not made in the relevant years at the stations where the study data were taken. When the years of measurements were evaluated, it was determined that the death rate due to air pollution was high in the population aged 30 and over. Similar results were obtained in previous studies in Turkey. Research shows that preventing air pollution can prevent many premature deaths.

The institutions of the country, the administrators of the cities, and the politicians in the field of environment and health have important duties in combating air pollution and the health consequences of this pollution. Appropriate strategies should be developed to combat the problem by monitoring the level of air pollution of the country and regions with appropriate data and being aware of the health problems to be attributed to air pollution.

WHO offers successful policy recommendations for reducing air pollution for many areas (World Health Organization, 2022). These; use of industrial clean technologies in industry, improvement of urban and agricultural waste management; on energy, ensuring access to clean and affordable energy for cooking, heating and lighting; regarding transportation, giving priority to pedestrian and bicycle paths in cities, providing urban transportation in fast and clean energy mode, encouraging freight and passenger transportation by rail; in urban planning increasing energy efficiency by making cities greener; increasing the use of renewable energy sources such as solar, wind, hydroelectricity for energy production; developing strategies for waste reduction, separation, recycling and reuse in municipal and agricultural waste management.

WHO also has recommendations for the health sector. Putting healthcare on a low-carbon development path can support more flexible and cost-effective service delivery as well as reduced environmental health risks for patients, healthcare workers and public. The health care sector can demonstrate public leadership in promoting climate-friendly policies and at the same time improve health care delivery.

It is recommended that national and global commissions be established to raise the issue and address the effects of air pollution on health and economy. These commissions can draw the attention of politicians to the issue by revealing the magnitude of the effects of pollution with solid and scientific data. In addition, they can help raise awareness in public about diseases caused by air pollution and the high cost of their treatment.

***Compliance with Ethical Standard***

***Conflict of Interests:*** *There is no conflict of interest.*

***Ethics Committee Approval:*** *Ethics committee approval is not required for this study.*

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