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Determination of Ozone-induced mortality in Aydın province, Turkey in 2022 using AIRQ+ Modeling

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Abstract
Fuels for energy production and road traffic are the main causes of air pollution. According to 2020 data from the World Health Organization (WHO), the number of deaths from air pollution is 6.7 million per year. Ozone has harmful effects if it is above the limit value. Our aim is to investigate the effect of ozone on mortality when it exceeds the limit value at ground level. In our study, we used data from Aydın province, which has the highest average ground-level ozone level in Turkey. From the Air Quality Monitoring website of the Ministry of Environment and Urbanization, we collected data from 4 stations in Aydın province and divided by the number of stations to obtain the average ground-level O_3 value. We used the World Health Organization AIRQ+ 2.2 program to calculate ozone-related mortality. Ministry of Environment, Urbanization and Climate Change Air Quality Monitoring website, we calculated the average O_3 value as 64.73 µg/m³ between 01.03.2022-30.08.2022, which is the 6 months with the highest amount of O_3 at ground level in Aydın province. According to the results obtained in the AIRQ+ program, the estimated attributable mortality rate was 0.47% (CI 95%, RR: 0-0.93), the estimated number of deaths from attributable cases was 22 (CI 95%, RR: 0-44) and the estimated number of deaths from attributable cases per 100000 population at risk was 1.92 (CI 95%, RR: 0-3.80). The long-term effect of ground-level ozone appears to be undeniable in increasing the number of deaths.

Keywords
Ozone, Air Pollution, AIRQ+ Modeling, Mortality

Introduction

Air pollution is one of the common problems all over the world. Air pollution is one of the most challenging environmental problems. Fuels for energy production and road traffic are the main causes of air pollution and constitute an important source of emissions (Rovira et al., 2020). According to the 2020 data of the World Health Organization (WHO), the number of deaths caused by air pollution at home has been determined to be 3.2 million. The number of under-five deaths was determined as 237000. The number of deaths caused by indoor and outdoor air pollution has been determined as 6.7 million per year. Air pollution mainly causes ischemic heart disease, stroke, lung Cancer and chronic Obstructive Pulmonary Disease (COPD) (WHO, 2023). Ozone (O_3) is one of the important pollutants due to its effects on human health. Ozone is a component of photochemical fog and has a detrimental effect on natural materials, vegetation, manufactured goods and public health. Ozone is one of the greenhouse gases. It causes climate change and global warming. It is an important chemical in the troposphere. Ozone is an important precursor of hydroxyl radical (OH) in the lower layers of the atmosphere. Daily, seasonal and.

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annual variations in O_3 levels can be observed as a result of meteorological effects. Due to high emissions of ozone precursors in cities, high ozone levels can be observed in urban and downwind locations. Ozone levels are also increasing due to high temperatures and solar radiation. Although ozone precursor levels are lower on weekends, the weekend level of ozone can be observed higher than the weekday level. Similar findings have been found in many studies. The mechanism of the effect of the weekend on ozone formation has not been fully established (Alghamdi, 2014). While ozone is beneficial (wound healing, antimicrobial effect, increase in blood oxygen level), it also has harmful effects if it is above the limit value Our aim is to investigate the possible risks of ozone to human health and its effect on mortality when it exceeds the limit value at ground level. Aydın province is one of the provinces with the highest ground-level ozone level in Turkey. Aydın province has an area of 8007 km². The Aegean Sea forms the western part of Aydın province. The height above the sea is 40 m. Aydın province consists of 17 districts. Its economy is based on agriculture. It has an agriculture-based industry. It is influenced by the Mediterranean climate. The vegetation consists of scrub and forest. There are also olive, citrus, chestnut and fig trees. There are pine and similar plants in the countryside .

Figure 1.
Geographical Location of Aydın Province in Turkey

Materials and Methods

Since we use 6-month data in the AIRQ+ program, we calculated the mid-year average population and number of deaths using data from the address-based population registration system of the Turkish Statistical Institute. The average mid-year population of Aydın is 1154972. In 2022, the average number of mid-year deaths in Aydın is 4859. The mid-year average number of deaths due to external injuries and poisoning is 152. The average number of deaths due to all other causes is 4707 (TÜİK, 2023). We reached the average O_3 value at ground level by collecting the data of four stations in Aydın province from the Air Quality Monitoring website of the Turkish Ministry of Environment and Urbanization (UHKİA, 2024) and dividing it by the number of stations. To calculate O_3-related mortality in the AIRQ+ program, it was calculated as the six consecutive months with the highest six-month average O_3 concentration during the peak season. We calculated the average O_3 value as 64,7 µg/m³ between 01.03.2022-30.08.2022, which is the 6 months with the highest amount of O_3 at ground level in Aydın province, on the Air Quality Monitoring site of the Turkish Ministry of Environment, Urbanization and Climate Change for 2022. The World Health Organization's (WHO) AIRQ+ 2.2 program was used to calculate mortality from O_3.

IBM SPSS Statistics 27.0 program was used to prepare the graphics.

Results and Discussions

The limit value of O_3 recommended by the World Health Organization (WHO) at ground level (WHO) was accepted as 60 µg/m³. The relative risk coefficient of the AIRQ+ program for deaths caused

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by O_3 was determined as 1.01 (95% CI: 1-1.02). The total crude mortality rate in the population at risk was calculated as 408 per 100000. According to the results obtained in the AIRQ+ program, the estimated attributable mortality rate was 0.47% (CI 95%, RR: 0-0.93), the estimated number of deaths from attributed cases was 22 (CI 95%, RR: 0-44), and the estimated number of deaths from attributable cases per 100000 population at risk was 1.92 (CI 95%, RR: 0-3.80). The data for Aydın province and four districts on the relevant dates on the Ministry of Environment and Urbanization Air Quality Monitoring website are given in the table 1.

Table 1
Air ozone level statistics of 4 districts of Aydın province

Station	Parameter	Unit	Min. Value	Max. Value	Mean Value	Data Quantity
Soke	O3	µg/m3	19,59	72,27	42,01	176
Nazilli	O3	µg/m3	25,6	99,95	45,68	178
Didim	O3	µg/m3	56,12	181,27	96,48	167
Efeler	O3	µg/m3	24,71	118,6	76,37	179

In a study conducted in Ahvaz, Iran, the total rate and number of respiratory deaths due to ozone exposure were determined as 6.17% and 173, respectively (Naghan et al., 2022). Similar to our study, it seems to have an effect on mortality. Glad et al. examined the health effects of ambient ozone concentration on human health. Every 20 µg/m³ increase in ozone can increase hospital admission by 2.5%. Similar to our study, it increases hospital admissions as an effect on mortality. Bell et al. studied the health effects of ozone in 95 megacities in the United States. They reported that every 10 ppb increase in ozone can increase hospitalizations and daily deaths. Similarly, in our study, it is seen that every 10 µg/m³ ozone level increase significantly increases mortality. Shavrina et al. found a significant association between ozone exposure and increased hospital admissions and respiratory diseases. Gryparis et al. in a study conducted in 23 European cities, they found a significant association between the number of hospitalisations and cardiovascular disease for every 10 µg/m³ increase in ground-level ozone levels and found that this increase in ozone caused a 1.13% and 0.45% increase in respiratory and cardiovascular mortality rates, respectively (Effatpanah et al., 2020). In our study, we investigated ozone-specific mortality among all mortality. In a systematic review and meta-analysis study conducted in China, the pooled relative risk ratio for cardiovascular mortality was found to be 1.0068 (95% CI: 1.0049-1.0086) for every 10 µg/m³ increase in ozone (Guo et al., 2023). Similarly, in our study, every 10 µg/m³ ozone level increase significantly increased mortality and we investigated ozone-specific mortality among all mortalities.

In a study conducted in Ahvaz, Iran, the number of cases of myocardial infarction and cardiovascular mortality attributed to O_3 exposure was found to be 51 and 182 people per year, respectively (Javanmardi et al., 2018). Similarly, the number of annual mortality attributed to ozone was similar in our study. In another study conducted in Ahvaz, Iran, the cumulative number of respiratory and cardiovascular deaths attributed to ground-level ozone was 173 and 43, respectively. The relative risk was 1.004 (95% CI) and 1.008 (95% CI), respectively (Goudarzi et al., 2015). In our study, we investigated all ozone-specific mortality rates and numbers. A study in Guangzhou, a Chinese megacity, found that ozone is a common pollutant and increases mortality rates (Li et al., 2015). Similar to our study, it is seen to increase mortality. In a study on the health effects of surface ozone in Agadir, Morocco, the cumulative incidence of annual mortality due to respiratory disorders was estimated as 419.5 per 100000 people (Bouchriti et al., 2023). Similar to our study, it appears to increase mortality. A study on public health of ozone concentration in the greater Athens region of Greece found that the mortality rate due to ozone exposure was 7.5% in the densely populated urban area of Athinas, compared to 6% in the sparsely populated northern suburb of Thrakomakedones (Ntourou et al., 2023). Similar to our study, it seems to increase mortality. In a global study, it was found that ozone exposure caused 254000 (CI 95%, 97000-422000) deaths in the world. Ozone exposure caused an estimated 8% (95% CI, 3.0-13.3%) of global deaths (Cohen et al., 2017). This global study shows similar results to our study. In a study conducted by Chen et al., it was determined that

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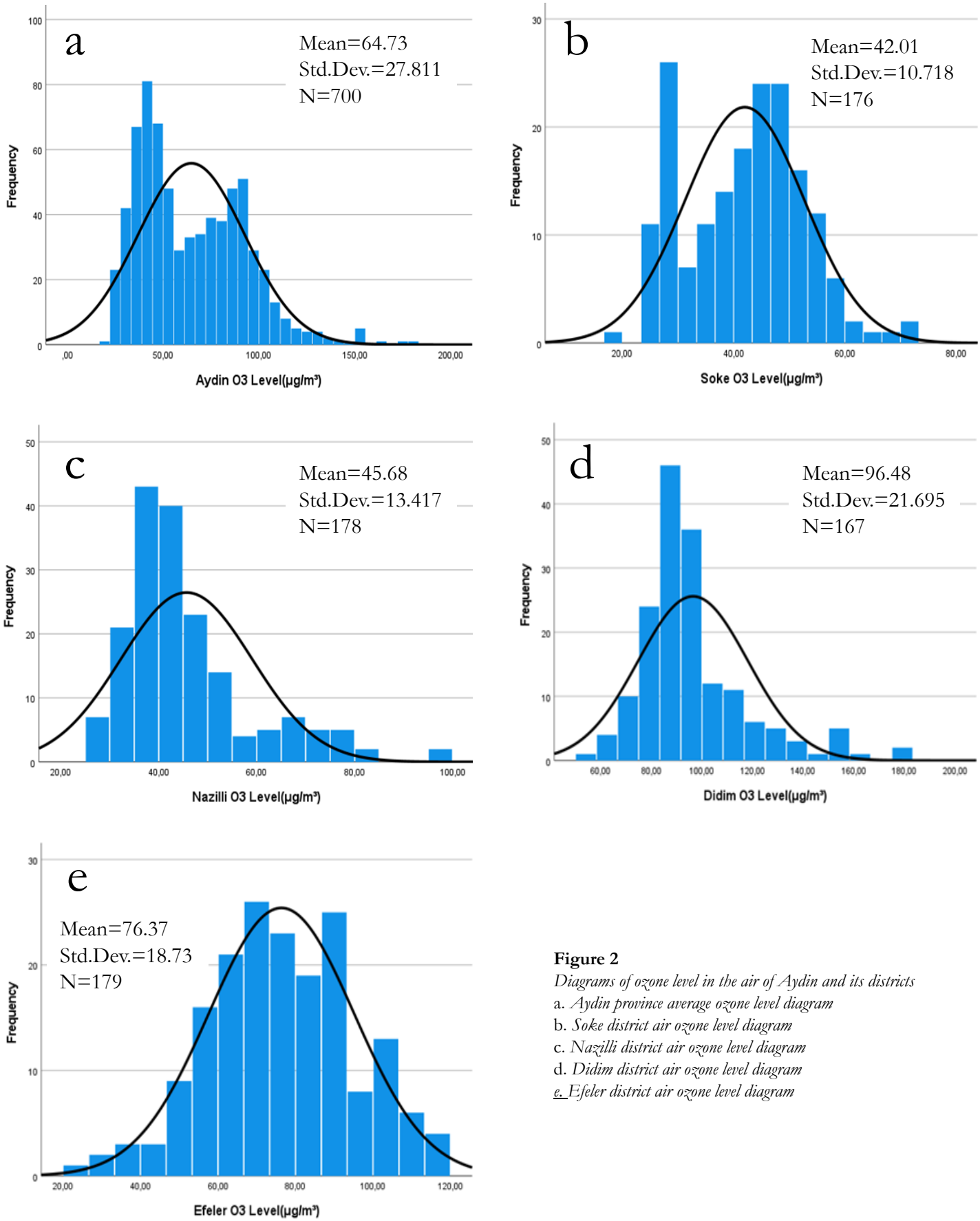

Figure 2
Diagrams of ozone level in the air of Aydin and its districts
a. *Aydin province average ozone level diagram*
b. *Soke district air ozone level diagram*
c. *Nazilli district air ozone level diagram*
d. *Didim district air ozone level diagram*
e. *Efeler district air ozone level diagram*

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ozone exposure may be associated with high oxidative damage that causes asthma development and decreased lung function (Lin et al., 2008). A California study showed that ozone exposure may be associated with increased hospital admissions due to COPD, asthma, pneumonia, acute respiratory infection, and upper respiratory tract inflammation during the hot season (Malig et al., 2016). Another study found that 3 years of ozone exposure was associated with the development of Acute Respiratory Distress Syndrome (ARDS), especially in trauma patients and smokers (Ware et al., 2016). In these three studies, the effect of high ozone levels on respiratory mortality can be seen. Short-term ozone exposure in seven cities in South Korea was associated with 0.40% to 0.48% of respiratory and natural-cause mortality and 0.67% to 0.81% of cardiovascular mortality (Shams et al., 2024). In this study, we can see the reflection of ozone exposure on mortality as a result of both respiratory and cardiovascular effects. In a study by Cohen et al. it was found that ozone exposure caused 254000 deaths worldwide in 2015 and was the 33rd highest risk factor in terms of causes of death (Faridi et al., 2018). In this study, similar to our study, it is seen that the effect of ozone exposure on mortality is undeniable. In addition, for a 10 μg/m³ increase in ozone, the estimated attributable mortality was 1.45% (CI 95%, RR: 0-2.87), the estimated number of attributable deaths was 69 (CI 95%, RR: 0-135) and the estimated number of attributable deaths per 100000 population at risk was 5.94 (CI 95%, RR: 0-11.73). In the light of this information, the increase in ozone significantly increases mortality.

Conclusions

When the results of the data obtained in our study are examined and the above studies on air pollutants are taken into consideration, a parallelism has been found between the results. Ozone levels at ground level cause cardiovascular and respiratory problems and increase hospital admissions. It is a fact that the long-term effect of ozone on mortality is undeniable. In addition, it is seen that the ozone level in the air varies during the day, seasonally, on weekdays and weekends. In our study, only the effect of ozone on mortality has been studied, and the number of studies conducted so far in this context is very low. We believe that our study will inspire other studies in this respect.

Limitations of the research

In our study, we were able to include only one province in Turkey since the number of provinces in which the average ozone level in the air is above 60 μg/m³ , which is the ozone level limit set by the World Health Organization, is very small. In order to obtain better results of ozone-related mortality, multicenter studies between countries are needed. In this sense, inter-institutional cooperation is important.

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Competing interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors Contributions

İbrahim Demir is the first author and corresponding author of the article. Özkan Ayvaz contributed to the literature review and drafting of the article.

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Ethical considerations

The authors fully complied with the ethical guidelines.

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