PREDICTION OF MORTALITY ATTRIBUTED TO NO_2 AIR POLLUTANT IN SAKARYA BY USING AIRQ+ SOFTWARE FOR 2018 AND 2019

Sakarya'da 2018 ve 2019 yıllarında AirQ+ yazılımı kullanılarak NO_2 hava kirleticisine atfedilen mortalitenin tahmini

Kadir ULUTAŞ[1]

Abstract

Air pollution is one of the biggest environmental problems that threaten human health today. The aim of this study is to investigate the effect of nitrogen dioxide (NO_2) air pollutant on mortality in Sakarya. Air pollutant data were obtained from the Ministry of Environment, Urbanisation and Climate Change (MEUCC), and population and death data were obtained from the Turkish Statistical Institute (TUIK) database. For the population aged 30 and over, estimated attributable proportion (EAP), estimated number of attributable cases (ENAC), and estimated number of attributable cases per 100,000 (ENAC/100,000) population at risk group were calculated with AirQ+ software in 2018 and 2019 for cut-off values (COV) of 20, and 10 µg/m^3. In Sakarya for 2018 and 2019, the mean concentrations of NO_2 were determined as 28.12 and 31.50 µg/m^3, respectively. Due to the increase in 2018 and 2019 annual NO_2 concentration, was increased from 3.21% to 4.52% and from 7.02% to 8.28% for COV of 20 and 10 µg/m^3, respectively. It has been observed that the World Health Organization (WHO) devreasing the air quality gualideline level for NO_2 resulted in an increase in death rates attributable to this pollutant, as expected in the cut-off value recommended by for NO_2, as expected, causes an increase in mortality that can be attributed to this pollutant.

Keywords: Mortality, NO_2, air pollution, AIRQ+.

Özet

Hava kirliliği günümüzde insan sağlığını tehdit eden en büyük çevre sorunlarından biridir. Bu çalışmanın amacı, Sakarya'da azot dioksit (NO_2) hava kirleticisinin mortaliteye olan etkisini araştırmaktır. Hava kirletici verileri Çevre, Şehircilik ve İklim Değişikliği Bakanlığı'ndan, nüfus ve ölüm verileri Türkiye İstatistik Kurumu (TÜİK) veri tabanından elde edilmiştir. 30 yaş ve üzeri nüfus için 2018 ve 2019 yıllarında AirQ+ yazılımı ile tahmini atfedilebilir oran (EAP), tahmini atfedilebilir vaka sayısı (ENAC) ve risk grubundaki 100.000 nüfus başına tahmini atfedilebilir vaka sayısı (ENAC/100.000) 20 ve 10 µg/m^3 eşik değerleri (COV) için hesaplanmıştır. Sakarya'da 2018 ve 2019 yıllarında ortalama NO_2 konsantrasyonları sırasıyla 28,12 ve 31,50 µg/m^3 olarak belirlendi. 2018 ve 2019 yıllık NO_2 konsantrasyonundaki artış nedeniyle, EAP 20 ve 10 µg/m^3 COV için sırasıyla %3,21'den %4,52'ye ve %7,02'den %8,28'e yükseldi. Dünya Sağlık Örgütü'nün (WHO) NO_2 için hava kalitesi kılavut seviyesini düşürmesinin beklendiği gibi bu kirleticiye atfedilebilecek mortalitede artışa neden olduğu gözlemlenmiştir.

Anahtar kelimeler: Mortalite, NO_2, hava kirliliği, AIRQ+.

1- Karabük University Faculty of Engineering, Karabük, Turkey

Sorumlu Yazar / Corresponding Author: Assist. Prof. Kadir ULUTAŞ
e-posta / e-mail: kadirulutas@karabuk.edu.tr
Geliş Tarihi / Received: 21.01.2022, **Kabul Tarihi / Accepted:** 25.03.2022

ORCID: Kadir ULUTAŞ: 0000-0002-2931-3559

Nasıl Atıf Yaparım / How to Cite: *Ulutas K. Prediction of mortality attributed to NO_2 air pollutant in Sakarya by using AirQ+ software for 2018 and 2019. ESTUDAM Public Health Journal. 2022;7(2):315-25.*

Introduction

Air pollution is one of the biggest environmental problems that threatens human health today. The increase in average age and changing lifestyles lead to the rising of noncommunicable diseases that cause death and disability globally. In addition, increases in morbidity and mortality from cardiovascular and respiratory diseases and lung cancer have been observed because of air pollution. There is also substantial evidence that air pollution has serious effects on other organ systems (1). Approximately 7 million premature deaths occur annually due to air pollution and its economic cost is over US$2.9 trillion (2, 3).

Particulate matter, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead are six common air pollutants identified by United States Environmental Protection Agency (EPA) as criteria air pollutants (4). As a result of increasing industrialization and urbanization, industrial activities, factories, domestic heating, transportation and power plants beceme the most important sources of air pollution (5, 6). NO_2 is one of the air pollutants in the group of gases with highly reactive properties known as nitrogen oxides. NO_2 is mainly released into the atmosphere because of fuel combustion. Therefore, NO_2 is considered as an indicator to describe the impact of pollutants from traffic. Cars, trucks and buses, power plants and off-road equipment are among the most important emission sources of NO_2 (7).

The health effects of urban air pollution are generally greater in megacities where atmospheric air pollutants are in higher concentrations. (8). The airways in the human respiratory system can be irritated by breathing in ambient air containing high concentrations of NO_2. Exposure to air contaminated by NO_2 for a short period can increase the severity of respiratory diseases, particularly asthma, and cause severe lung damage. It can also lead to hospitalizations and emergency room visits due to respiratory symptoms such as coughing, wheezing and difficult breathing. Prolonged exposure to air containing high NO_2 concentrations can lead to the progression of asthma and potentially increased susceptibility to respiratory infections. People in sensitive group, including children and the elderly, as well as people with asthma, are generally more at risk than others for the health effects of NO_2. It is an active reagent for particulate matter and ozone, which have harmful effects on the respiratory system. NO_2 has negative effects not only on human health but also on the environment. NO_2 and other NOXs contribute to the formation of acid rain as a result of their interaction with water, oxygen and other chemicals in the atmosphere (7).

Limit concentration values for NO_2 are determined by the European Union (EU) as 200 μg/m^3 for one hour and 40 μg/m^3 for one calendar year (9). Turkey has adopted the European Union air quality (NO_2) limit values according to the Regulation of Air Quality Assessment and Management (RAQAM, 2008) to protect human health. The annual NO_2 limit concentration values for the adaptation duration in Turkey were 44 μg/m^3 in 2018 and 40 μg/m^3 in 2019 (10). The report states that there is consensus for a quantitative recommendation for NO_2 below the current annual guideline value of 40μg/m^3 based on the quantity and quality of new studies and evidence (11). It has also been argued that the current annual value for the EU and the United Kingdom is not sufficient to protect public health (12). 20 μ g/m^3 has already been imposed for the NO_2 COV used in AirQ+ software developed by the WHO Regional Office for Europe (13). However, the annual NO_2 guideline value was determined as 10 μg/m^3 in 2021 to protect public health (1).

Since 1987, WHO has established air quality guidelines for public health to help reduce the negative effects of air pollution. These are not legal regulations but are presented as a helpful tool to legislators for WHO member states (1). AirQ+ is a software tool developed by the WHO Regional Office for Europe to estimate the effect of air pollution on public health (14, 15). AirQ+ software can be used to evaluate the effects of air pollutant parameters such as PM_{10}, $PM_{2.5}$, black carbon, NO_2, O_3, in terms of morbidity and mortality in the long-term and short-term. Consequently, health outcomes from estimates are an important resource for assessing mortality and morbidity for both acute and chronic conditions (16).

In this study, AirQ+ software was used to obtain information about the mortality rates caused by the NO_2 air pollutant parameter for the population aged 30 and over in 2018 and 2019 in Sakarya for COV of 20 and 10 $\mu g/m^3$.

Material-Method

Sakarya, which is one of the metropolitan cities of Turkey, is located in the northeast of the Marmara Region in Turkey, on the main transportation link connecting Anatolia to other regions. For this reason, the passage of the Istanbul-Ankara highway through Sakarya was provided ease of transportation. The natural vegetation of Sakarya, which has a surface area of 4,821 km^2, is generally forest. Sakarya, which has the characteristics of the Marmara climate, has a rainy, humid air and a temperate climate. In recent years, there have been great developments especially in the automotive, textile and food industries. The total area of organized industrial zones is spread over an area of 772 hectares (17, 18).

NO_2 air pollutant concentrations were obtained from the air quality monitoring stations of MEUCC (19). Monitoring efficiency (ME) was determined before annual mean pollutant concentrations were calculated (20) by equation 1, and stations with ME values above 90% were used to calculate annual means (21).

$$\text{ME}=\frac{\text{number of valid 24 hours avg. data}}{\text{total number of days in the year}} \quad (1)$$

The annual concentrations were calculated according to the arithmetic mean of 4 stations namely Hendek, Merkez, Ozanlar and Sakarya (HNDK, MRKZ, ZNLR and SKRY) in Sakarya. In this study, data from 4 air quality monitoring stations in Sakarya were used. However, while data valid for 2018 could not be reached at one station (SKRY), valid data for 2019 were available for all stations.

In this study, which is an ecological study, death and population data were obtained from TUIK. Population data according to provinces and age groups were obtained from the TUIK database, and population data of 30 years and over, living in each province was determined from these data. The total number of deaths by provinces and age groups was obtained from the TUIK death statistics database, and the number of deaths over the age of 30 was determined from this data. After subtracting the deaths due to external causes of injury and poisonings from the total number of deaths in the year and province of the study, the valid death numbers used in the AirQ+ software were determined (22).

AirQ+ is software developed to estimate the effects of exposure to air pollutants on the health of certain population living in a given period and region (23-25). The calculations are based on methodologies and concentration-response functions created as a result of epidemiological studies (21). For each different air pollutant parameter, EAP, ENAC, and ENAC/100,000 population at risk group can be calculated with AirQ+ software. The input data required by the AirQ+ software in the calculation to obtain the estimated mortality information from the air pollution in the study area are explained in Table 1 (20).

Table 1: Input data and descriptions for AirQ+.

Concentration data of air pollutants	The software requires the average annual or daily air pollutant concentration for long-term or short-term exposure effects, respectively.
Population data	In the software, population information is needed for a certain period and region. In addition, if the study will be carried out for people over the age of 30, population information is requested.
Mortality data	Natural death information is required, excluding deaths from external injuries, and poisoning from the number of deaths in the years indicated. Also, if a study is conducted for people over 30 years of age, death information should be used accordingly.
COV	This value is chosen according to the legal limit or imposing concentration of the air pollutant parameter for the long-term or short-term periods in the study.

In order to protect public health, the COV value, which was used as 20 μg/m^3 in previous years, was 10 μg/m^3. For this reason, in this study, AirQ+ software was updated to used for COVs of 20 and 10 μ g/m^3 to evaluate the health impact of NO_2 for the population aged 30 and over in 2018 and 2019 in Sakarya. Ethics committee approval was not obtained because the study did not include an application for individuals.

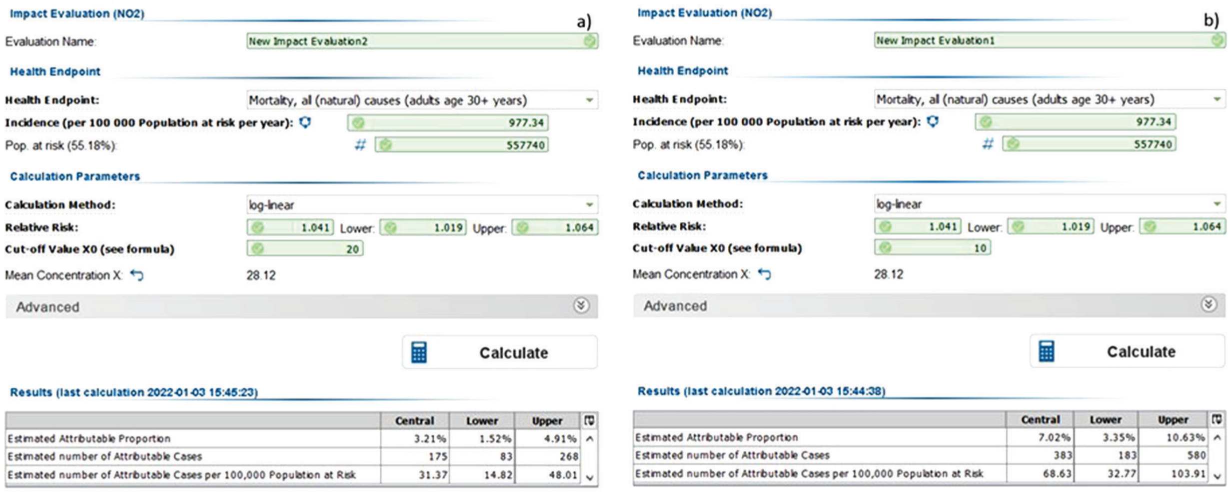
Results

The mean concentration of NO_2 for HNDK, MRKZ, ZNLR and SKRY air quality monitoring stations in Sakarya were found to be as 32.43±9.11, 26.65±11.32, 25.43±10.83 and 37.95±8.49 μg/m^3 for 2018, respectively. The mean concentration of NO_2 for these air quality monitoring stations in 2019 were 35.62±10.05, 34.17±10.28, 20.69±10.08 and 34.86±11.92 μg/m^3, respectively. Except for SKRY air quality monitoring station (18.90%), ME was over 90% at all stations (92.88%, 98.36% and 94.52% for HNDK, MRKZ and ZNLR air quality monitoring stations, respectively) in 2018. ME was over 90% at all stations (92.33%, 97.26%, 90.41% and 100.00% for HNDK, MRKZ, ZNLR and SKRY air quality monitoring stations, respectively) in 2019. The current annual mean limit concentration of NO_2 of 40 μg/m^3 for Turkish and European Union Regulations was not exceeded by any station however the guideline imposed by the WHO as 10 μ g/m^3 was always exceeded. While the annual mean concentration of NO_2 for HNDK and MRKZ air quality monitoring stations increased by 3.19 and 7.52 μg/m^3, respectively, the annual mean concentration of NO_2 for ZNLR and SKRY air quality monitoring stations decreased by 4.74 and 3.09 μg/m^3, respectively. Statistical definitions for NO_2 concentration were given Table 2.

Table 2: Statistical definitions for NO_2 concentrations.

Statistical Definitions	2018				2019			
	HNDK	MRKZ	ZNLR	SKRY	HNDK	MRKZ	ZNLR	SKRY
Mean	32.43	26.65	25.43	37.95	35.62	34.17	20.69	34.86
S. Deviation	9.11	11.32	10.83	8.49	10.05	10.28	10.08	11.92
Min	10.61	5.51	5.23	19.03	8.29	7.92	5.81	12.38
Max	57.64	85.43	55.19	68.44	76.07	78.31	52.73	79.57
Valid Data	339	359	345	69	337	355	330	365
Days in The Year	365	365	365	365	365	365	365	365
Monitoring Efficiency (%)	92.88	98.36	94.52	18.90	92.33	97.26	90.41	100

The annual mean concentrations of NO_2 to represent the whole stations of Sakarya for the years 2018 and 2019 was used in AirQ+ software to determine the effects of air pollution caused by NO_2 pollution on mortality. By taking the annual mean concentration of NO_2 of all stations with a percentage of available data above 90%, the mean concentration of NO_2 in 2018 and 2019 were calculated as 28.12 and 31.50 µg/m^3, respectively. Considering the COV of 20 µg/m^3, recommended by WHO in its guideline, with the 95% confidence interval (95% CI) EAP to air pollution from NO_2 was 3.21% in 2018 and 4.52% in 2019. However, WHO has revised the annual guide values of NO_2 as 10 µg/m^3 (1). For the COV of 10 µg/m^3, EAP to air pollution from NO_2, was found as 7.02% and 8.28% in 2018 and 2019, respectively. In 2018 and 2019, considering the 20 µg/m^3 COV, ENAC to air pollution from NO_2 was 175 and 263, while it was found as 383 and 482 for the 10 µg/m^3 COV, respectively. In addition, in 2018 and 2019, (ENAC) per 100,000 population at risk was 31.37 and 46.07 for the 20 µg/m^3 COV, while it was found as 68.63 and 84.44 for the 10 µg/m^3 COV, respectively. In the AirQ+ interface image, the input data, calculation parameter and results to introduce the software are shown in the Figure 1 (a-d) according to the study periods and COVs. In addition, the results are visualized with a graph (Figure 2) to easily understand the difference between years (2018-2019) and COVs (10 and 20 µg/m^3).



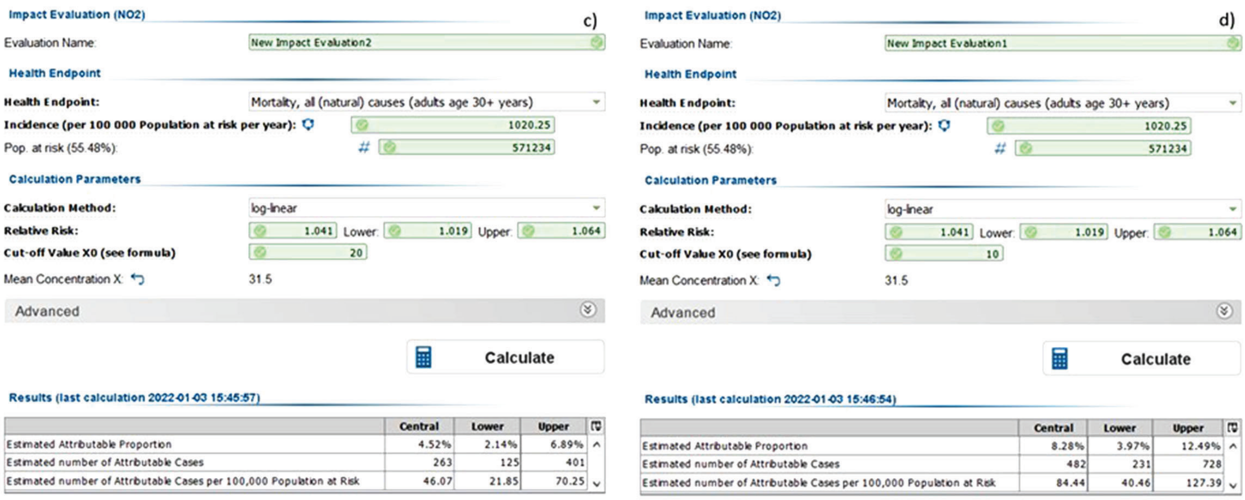


Figure 1: Deaths attributable to air pollution from NO_2 in 2018 a) for COV 20 µg/m³, b) COV 10 µg/m³ and in 2019 c) for COV 20 µg/m³, d) COV 10 µg/m³ (AIRQ+ programme).

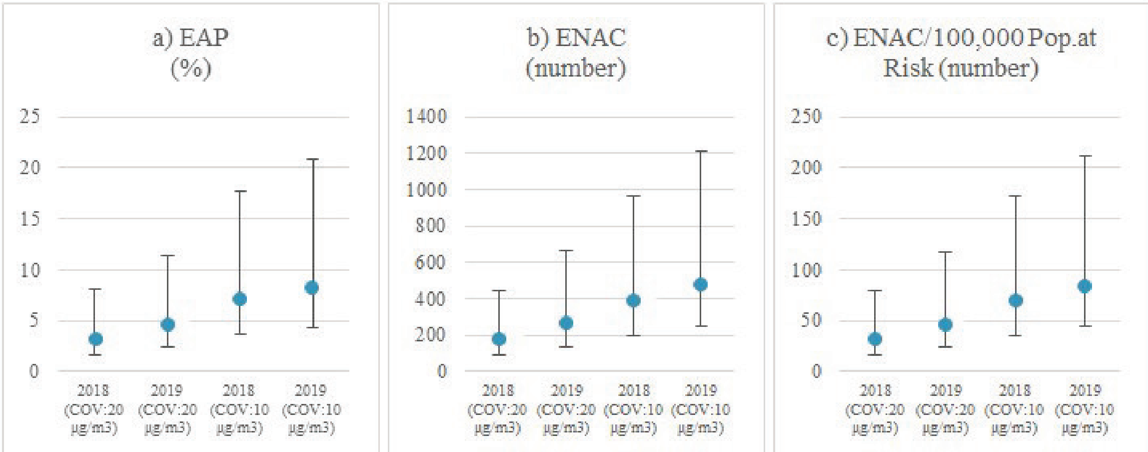


Figure 2: a) EAP, b) ENAC and c) ENAC/100,000 population at risk attributable to air pollution from NO_2 for 2018 and 2019 (for COV 10 and 20 µg/m³) (●: central value, ⊥: lower value, ┬: upper value).

Discussion

NO_2 is one of six common air pollutants identified as "criteria air pollutants" by the EPA. In particular, emphasis is placed on harmful effects on health, the environment and property. For this reason, considering the characterizations of the latest scientific studies on the effects of these pollutants on health and comfort, criteria have been set for them by the EPA (4). In addition, exposure to NO_2 as an ambient air pollutant is known to have an epidemiological effect on mortality (21). Thus, RAQAM and EU determined hourly and annual limit values of NO_2 for the protection of human health as 200 and 40 µg/m³, respectively. However, WHO has revised the guide values of substances causing air pollution (1) and NO_2 value has been reduced to 10 µg/m³ annually. In this study, the effect of NO_2 air pollutant on mortality was evaluated according to the 20 µ g/m³ COVs previously recommended by the WHO Europe office for 2018 and 2019. The COV was also evaluated as 10 μ g/m^3 due to the update. Finally, the results obtained according to years and COVs were compared.

According to Sakarya Environmental Status Reports, the highest NO_2 values were observed in March and January in 2018 and in November 2019 (18,19). In 2007, SO_2 and PM concentrations in the center of Adapazarı were higher than in all other districts of Sakarya, as expected (6). In a study, it was emphasized that some environmental problems, although little known, could cause serious health problems and it was concluded that there was a need to inform the public (26). In a study covering the Marmara region, higher PM_{10} concentration values were obtained in the provinces of Sakarya and Bursa. In addition, Sakarya was among the provinces with the highest NO_2 concentration, excluding Istanbul (27). In another study, it was stated that the significant decrease in NO_2 concentration and the decrease in PM_{10} and $PM_{2.5}$ concentrations also affected the decrease in the EAP (20). In a study conducted for Balıkesir, Bursa, İstanbul, Kocaeli, Sakarya and Tekirdağ in 2016-2019, the mortality rate attributed to $PM_{2.5}$ air pollution was determined for the population over the age of 30. For Sakarya in the years of 2016-2019, the mean EAP values were determined as 16.06, 16.80, 15.99 and 10.85%, respectively. The mean ENAC values were determined as 858, 917, 897 and 624, and the mean ENAC/100,000 population at risk values were determined as 161.55, 169.03, 160.84 and 109.19, respectively (28). In another study conducted in Erzurum between 2016 and 2019, mortality rates attributed to NO_2 air pollution were determined. In the years of 2016, 2017 and 2018, the mean EAP values were determined as 10.61, 12.82 and 8.54% respectively. The mean ENAC values were determined as 442, 516 and 336, and the mean ENAC/100,000 population at risk values were determined as 58.01, 67.79 and 43.71, respectively. According to the 20 μ g/m^3 COV, the EAP value of Sakarya was approximately 2.5 times higher than Erzurum in 2018. However, according to the 10 μg/m^3 COV, it can be said that the EAP values of both provinces were close to each other (21). In addition, all EAP values obtained for Sakarya were in the range of mortality (2.61-8.94%) attributed to NO_2 air pollution in 2018 for the total population of the provinces in the Marmara Region in Turkey (29).

In the study, it was shown that the percentage of all natural-cause deaths attributable to NO_2 concentrations decreased from 10% in 2010 to 4% in 2018 (20). The study examined the impact of air pollution on the health of people living in a highly industrialized, densely populated area of Northern Italy. While the maximum NO_2 concentration was determined as 76 μg/m^3 in winter months, the EAP value for NO_2 was calculated as 2.4% (1.7–3.0) (23). Another study highlighted that the legal maximum annual mean NO_2 concentration (40 μg/m^3) may not provide sufficient protection for long-term to protect public health in the European Union and the United Kingdom. The research found that up to 15.9% (95% CI 9.4%-21.9%) of mortality in the area studied could be attributed to long-term exposure to NO_2 levels in 2016 (12). Therefore, the researchers suggested that a lower value may be required.

According to the Turkey Environmental Problems and Priorities Report (MEUCC 2020), air pollution is not among the priority problems for Sakarya. However, considering that NO_2 values are at the maximum level especially in cold months, it can be concluded that sustainability of air quality should be improved (30). In addition, in another report it was stated that Sakarya is above the WHO limit values in terms of PM_{10} pollution. In the same report, it was determined that NO_2 levels, mostly originating from fossil fuels used in transportation, decreased in 2020, as in other pollutants. However, in order for the improvement in air quality to turn into decreasing health risks; it is thought that measures should be taken to improve long-term air quality in the post-corona pandemic period (22).

Conclusions

In this study, for the population aged 30 and over, EAP, ENAC, ENAC/100,000 people at risk population group were calculated caused by NO_2 air pollutant with AirQ+ software developed by WHO Regional Office for Europe in 2018 and 2019 for cut-off values of 20 and 10 µg/m^3. The results and recommendations obtained from this research can be listed as follows:

• The ZNLR station has the lowest annual mean NO_2 concentration for both 2018 and 2019. SKRY and HNDK stations have the highest annual mean NO_2 concentrations in 2018 and 2019, respectively.

• It was determined that the annual mean NO_2 concentration in 2019 was higher than in 2018.

• In this study, the mean concentration of NO_2 were below the Turkey and EU legal limit values (40 µg/m^3), but above the cut-off value (20 µg/m^3) determined by the WHO for the AIRQ+ software in 2018 and 2019.

• The effect of NO_2 air pollutant, which is expressed as EAP, ENAC and ENAC/100,000 population at risk, on human health generally shows an increasing trend by years and COVs.

• Due to the increase in annual NO_2 concentration, EAP to air pollution increased from 3.21% to 4.52% and from 7.02% to 8.28% for COVs of 20 and 10 µg/m^3, respectively.

• The threatening effect of air pollution caused by NO_2 air pollutant on mortality in Sakarya was more clearly seen when the COV was reduced by WHO. However, the current results for 2020 and 2021 could not be calculated because the death statistics data set could not be reached, and the study was limited to 2018 and 2019.

• The results obtained with the AirQ+ software can be used to control the NO_2 concentration and set the cut-off value. In addition, environmental and health assessments can be used as source data for city managers and policy makers to develop future projects.

• With the addition of new air quality monitoring stations throughout the province, the pollution profile can be revealed more clearly

• In order to reduce NO_2 pollution, pollutant sources should be kept under control, plans that facilitate traffic especially in big cities with heavy traffic should be developed, and the use of more environmentally friendly private and public transportation vehicles should be encouraged.

References

1. World Health Organization. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. 2021 [cited 2022 January 2]. Available from: https://apps.who.int/iris/bitstream/handle/10665/345329/9789240034228-eng.pdf?sequence=1&isAllowed=y.
2. IQAir. World air quality report: region and city PM2.5. 2020 [cited 2022 January 2]. Available from: https://www.iqair.com/world-air-quality-report.
3. World Health Organization. How air pollution is destroying our health. 2018 [cited 2022 January 2]. Available from:https://www.who.int/news-room/spotlight/how-air-pollution-is-destroying-our-health.
4. EPA. Criteria ait pollutants. 2021 [cited 2022 January 2]. Available from: https://www.epa.gov/criteria-air-pollutants.
5. Ghorani-Azam A, Riahi-Zanjani B, Balali-Mood M. Effects of air pollution on human health and practical measures for prevention in Iran. J Res Med Sci. 2016;21:65. doi:10.4103/1735-1995.189646.
6. Gümrükçüoğlu M. Urban air pollution monitoring by using geographic information systems: a case study from Sakarya, Turkey. Carpathian journal of Earth and environmental sciences. 2011 [cited 2022 January 2];6(2):73-84. Available from:https://www.researchgate.net/publication/260350178_Urban_Air_Pollution_Monitoring_By_Using_Geographic_Information_Systems_A_Case_Study_From_Sakarya_Turkey
7. EPA. Basic information about NO_2. 2021 [cited 2022 January 2]. Available from: https://www.epa.gov/no2-pollution/basic-information-about-no2.
8. Brook RD, Newby DE, Rajagopalan S. The global threat of outdoor ambient air pollution to cardiovascular health: time for intervention. JAMA Cardiology. 2017;2(4):353-4. doi:10.1001/jamacardio.2017.0032.
9. EU. Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. Official Journal of the European Communities 2008 [cited 2022 January 2];152:1-43. Available from: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF.
10. Regulation of Air Quality Assessment and Management. 2008 [cited 2022 January 2]. Available from: https://www.mevzuat.gov.tr/File/GeneratePdf?mevzuatNo=12188&mevzuatTur=KurumVeKurulusYonetmeligi&mevzuatTertip=5.
11. World Health Organization. WHO Expert Consultation: Available evidence for the future update of the WHO Global Air Quality Guidelines (AQGs). 2015 [cited 2022 January 2]. Available from: https://www.euro.who.int/__data/assets/pdf_file/0013/301720/Evidence-future-update-AQGs-mtg-report-Bonn-sept-oct-15.pdf.
12. Lyons R, Doherty R, Reay D, Shackley S. Legal but lethal: Lessons from NO2 related mortality in a city compliant with EU limit value. Atmospheric Pollution Research. 2020;11(6):43-50. doi:10.10160/j.apr.2020.02.016.
13. World Health Organization. Regional Office for Europe. Health risks of air pollution in Europe–HRAPIE project Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide. Copenhagen: WHO Regional Office for Europe; 2013 [cited 2022 January 2]:10. Available from: https://www.euro.who.int/__data/assets/pdf_file/0006/238956/Health_risks_air_pollution_HRAPIE_project.pdf.
14. World Health Organization. Health

impact assessment of air pollution: AirQ+ life table manual, December 2020 (No. WHO/EURO: 2020-1559-41310-56212). World Health Organization. Regional Office for Europe. 2020. [cited 2022 January 2] Available from: https://apps.who.int/iris/bitstream/handle/10665/337683/WHO-EURO-2020-1559-41310-56212-eng.pdf?sequence=1&isAllowed=y.
15. World Health Organization. European centre for environment and health AirQ+: software tool for health risk assessment of air pollution. Bonn (Germany): WHO Regional Office for Europe. 2019 [cited 2022 January 2]. Available from: http://www.euro.who.int/en/health-topics/environment-and-health/air-qualityactivities/airq-software-tool-for-health-risk-assessment-of-air-pollution.
16. Mudu P, Gapp C, Dunbar M. AirQ+: example of calculations (No. WHO/EURO: 2018-2965-42723-59596). World Health Organization.Regional Office for Europe. 2018 [cited 2022 January 2]. Available from: https://www.euro.who.int/__data/assets/pdf_file/0004/371551/AirQ-Examples-of-calculations_ENG.pdf.
17. Sakarya Governorship. Sakarya İli 2018 Yili Çevre Durum Raporu. 2019 [cited 2022 January 2]. Available from: https://webdosya.csb.gov.tr/db/ced/icerikler/sakarya_-cdr2018-20191003171221.pdf.
18. Sakarya Governorship. Sakarya İli 2019 Yili Çevre Durum Raporu. 2020 [cited 2022 January 2]. Available from: https://webdosya.csb.gov.tr/db/ced/icerikler/sakarya_-cdr2019-20201207205637.pdf.
19. Ministery of Environment, Urbanisation and Climate Change. National Air Qualıty Monitoring Network. 2022 [cited 2021 Dec 1]. Available from: https://sim.csb.gov.tr/.
20. Toscano D, Murena F. The historical trend of air pollution and ıts ımpact on human health in Campania Region (Italy). Atmosphere. 2021;12(5):553. doi:10.3390/atmos12050553.
21. Kavuncuoğlu D, Yilmaz S, Koşan Z. Erzurum'da 2016-2018 yillarinda NO_2 düzeylerinin mortalite üzerine etkisi. ESTÜDAM Halk Sağlığı Dergisi. 2021;6(2):114-22. doi:10.35232/estudamhsd.855684.
22. Right to Clean Air Platform. Dark repot. 2020 [cited 2022 January 2]. Available from: https://www.temizhavahakki.com/wp-content/uploads/2020/09/Dark-Report-2020Vfinal.pdf.
23. Fattore E, Paiano V, Borgini A, Tittarelli A, Bertoldi M, Crosignani P, Fanelli R. Human health risk in relation to air quality in two municipalities in an industrialized area of Northern Italy. Environmental Research. 2021;111(8):1321-7. doi:10.1016/j.envres.2011.06.012.
24. Rovira J, Domingo JL, Schuhmacher M. Air quality, health impacts and burden of disease due to air pollution (PM10, PM2.5, NO_2 and O_3): Application of AirQ+ model to the Camp de Tarragona County (Catalonia, Spain). Science of The Total Environment. 2020;703:135538. doi:10.1016/j.scitotenv.2019.135538.
25. Mirzaei A, Tahriri H, Khorsandi B. Comparison between AirQ+ and BenMAP-CE in estimating the health benefits of PM 2.5 reduction. Air Quality, Atmosphere and Health. 2021;14(6):807-15. doi:10.1007/s11869-021-00980-5.
26. Nursan C, Muge AT, Cemile D, Pinar T, Sevin A. Parent's knowledge and perceptions of the health effects of environmental hazards in Sakarya, Turkey. J Pak Med Assoc. 2014 [cited 2022 January 2];64(1):38-41. Available from: https://www.jpma.org.pk/PdfDownload/5738
27. Arslan O, Akyürek Ö. Spatial modelling of air pollution from PM10 and SO_2 concentrations during winter season in Marmara Region (2013-2014). International Journal of Environment and

Geoinformatics. 2018 [cited 2022 January 2];5(1):1-16. Available from: https://dergipark.org.tr/tr/download/article-file/452620

28. Kahraman AC, Sivri N. Comparison of metropolitan cities for mortality rates attributed to ambient air pollution within the context of SDGS using the AirQ model. 2021. doi:10.21203/rs.3.rs-838069/v1.
29. Önal AE, Palanbek S, Pacci SN, Çağlayan Ç. Marmara bölgesi NO_2 değerlerinin mortalite üzerine etkisi. In 3. International 21. National Public Health Congress. 2019 [cited 2022 January 2]. Available from: https://uhsk.org/2019/images/KONGRE2019.pdf
30. Ministery of Environment, Urbanisation and Climate Change. Turkey environmental problems and priorities evaluation report. ISBN: 978-625-7076-11-1, Publication No:47, 2020 [cited 2022 January 2]. Available from: https://webdosya.csb.gov.tr/db/ced/icerikler/tu-rk-yecevresorunlariveoncel-kler-_2020-20210401124420.pdf