TRENDS IN AIR QUALITY AND HEALTH IN THE REPUBLIC OF SERBIA

A STATE OF GLOBAL AIR SPECIAL REPORT


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WHAT IS THE STATE OF GLOBAL AIR?

The *State of Global Air* report and interactive website offer a comprehensive analysis of the levels and trends in air quality and health for every country in the world. They are produced annually by the Health Effects Institute and the Institute for Health Metrics and Evaluation’s (IHME’s) Global Burden of Disease (GBD) project and are a source of objective, high-quality, and comparable air quality data and information.

WHO IS IT FOR?

The report and website are designed to give citizens, journalists, policymakers, and scientists access to reliable, meaningful information about air pollution exposure and its health effects. These resources are free and available to the public.

ABOUT THIS REPORT

This report provides an overview of the state of air quality and its impacts on the health of populations in Serbia. We draw on data from the GBD Study 2019 as well as a recent global assessment on sources of air pollution (McDuffie et al. 2021) to discuss trends in air pollution and the associated disease burden.

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INRODUCTION

Globally, air pollution is the leading environmental risk factor for public health, and is associated with significant health, economic, and social costs. The impacts from air pollution are often distributed inequitably across regions and communities. In 2019 alone, exposure to air pollution contributed to 6.67 million deaths (uncertainty interval [UI]: 5.90–7.49), nearly 12% of the total global deaths, a disease burden surpassed only by high blood pressure, tobacco use, and poor diet.

In Serbia, although air pollution concentrations of particulate air pollution and ozone have decreased since 2010, the death rate linked to air pollution in 2019 was among the highest in Europe (HEI 2020). A World Health Organization (WHO) study estimated that the disease burden cost due to air pollution alone represented over 33% of Serbia’s gross domestic product (WHO 2019).

In recent years, public awareness on the topic of air pollution has increased substantially in Serbia. In part, this was due to an increase in independent local, citizen science monitoring networks set up by civic society organizations, data from which are made publicly available. This access to air quality data has led to increasing public awareness and related media coverage, as well as the growth in interest by public health professionals.

Air pollution was the 7th leading risk factor for deaths in Serbia in 2019.

WHAT THIS REPORT ADDS

This report provides an overview of the trends and patterns of air quality and its impacts on health in Serbia using data from the Global Burden of Disease (GBD) Study 2019. It is designed to present the latest data on air pollution exposures, key sources, and the related health impacts, including the burden of disease across age groups, and is one of three reports published by the Health Effects Institute on the topic of air quality and health in Southeast Europe (HEI 2022a, 2022b).

The GBD Study is a unique resource, where high-quality and internally consistent state-of-the-art methods have been applied to estimate current status and annual trends in exposures and burden of disease from 87 risk factors or groups of factors in 204 countries and territories. To learn more, please visit http://www.healthdata.org/gbd/2019. We also draw on a first of its kind, recent global assessment (McDuffie et al. 2021) to discuss the major air pollution sources in Serbia and the related burden of disease from these sources.

For detailed data, figures and factsheets on air quality and health for Serbia and other countries, visit https://www.stateofglobalair.org/.

Air Pollution and Human Health

Air pollution contributed to more than 6.7 million deaths in 2019. It is the 4th leading cause of death globally, accounting for nearly 7 million deaths. The current large body of research has shown conclusively that both short-term (i.e., a few days to weeks) and long-term (i.e., months to years) exposures to air pollution can contribute to serious effects on health, ranging from temporary to chronic, from mild to debilitating, and even fatal conditions. Long-term exposure to particulate matter ≤2.5 μm in aerodynamic diameter (PM_{2.5}) is associated with a variety of health effects, including ischemic heart disease, lung cancer, chronic obstructive pulmonary disease (COPD), lower respiratory infections (such as pneumonia), stroke, type 2 diabetes, and adverse birth outcomes. Household air pollution is also associated with the development of cataracts. Long-term exposure to ground-level ozone is associated with the development of COPD, a progressive and debilitating disease that makes it harder to breathe. Exposure to air pollution also reduces life expectancy around the world.
Legislation Related to National Air Quality

The Law on Public Health ("Official Gazette of Republic of Serbia," No. 15/2016) is the main legal act regulating involvement of the public health sector in environmental health issues. The key role of the network of Institutes of Public Health as determined in Article 8 (Environment and Population Health) is monitoring and analysis of water, air, soil, and noise in populated areas, regarding the impact on health. Thus, health risk assessments should be performed and presented to the local health councils and, where necessary, to the National Council for Public Health. This law is a milestone for the Public Health Strategy in the Republic of Serbia for the period 2018–2026, based on the Sustainable Development Goals of the 2030 SD Agenda ("Official Gazette of Republic of Serbia," No. 61/2018).

Although the Strategy does not specifically address the area of air quality, the preservation of the living and working environment is among the specific objectives of this document. In the Action Plan, environmental impacts on health are recognized through monitoring, evaluation, and improvement of the quality of the environment and health risks assessment.

To harmonize with European Union (EU) legislation, the Republic of Serbia adopted the Law on Air Protection in 2009 and the Ministry of Environmental Protection (MoEP) completed a draft of the first Programme of Air Protection of the Republic of Serbia for the period 2022–2030 with Action Plan (financed by the EU with cooperation from the MoEP). The draft currently awaits approval from the Serbian authorities (EU Projects in Serbia 2021).

Three Pillars of the Draft National Air Protection Program

Pillar I: National Emission Ceiling (NEC)
- Reduce air pollution emissions

Pillar II: Directive 2008/50/EC
- Improve air quality

Pillar III: Programme of Air Protection (PAP) and Action Plan (AP)
- Reduce the impact of air pollution on citizen's health

The Programme will cover the period 2022–2030 and include air pollution mitigation scenarios and cost/benefit analyses, as well as an assessment of health and environmental impacts associated with these scenarios. Developing and implementing such a plan will inevitably pose challenges, as in every other country, for future energy, transport, and industry policy decisions.

As of November 2021, the Programme was in the public consultation process, after which the ministry organized a public debate. Implementation of this Programme would position the Republic of Serbia to be the only country in the Western Balkans with such a Programme focused on air pollution. The Programme will be an important step closer to joining the EU; accession negotiations are ongoing and expected to be completed by the end of 2024.

To address health, the Serbian government adopted the Public Health Strategy of the Republic of Serbia 2018–2026, which calls for reducing the burden from environmental risk factors. In the last 2 years, momentum has built both at the national and municipal levels regarding new developments in the energy sector. Promising measures have been initiated by the Ministry of Energy and the MoEP, including the replacement of heating facilities in public buildings and households. Additionally, regional programs such as the Western Balkans Green Agenda and Economic and Investment Plans, the Sofia Declaration, the Action Plan for the Implementation of the Sofia Declaration on the Green Agenda for the Western Balkans 2021–2030, and broader European programs (e.g., the EU Green Deal) are incentivizing the move toward renewable energy and influencing the push for similar policies in Serbia (see HEI 2022a for details). The area of environmental impacts on health is not covered by a common EU framework, as existing policies and programs pertain to energy and environmental protection.

Additional efforts are underway in Serbia to strengthen linkages across institutions, such as the Institute of Public Health of Serbia, the Energy Ministry, and the MoEP, as well as increase multidisciplinary collaboration. Recent initiatives aimed at increasing renewable energy sources and air quality improvement include a Ministry of Mining and Energy program to provide solar panel subsidies for municipalities and households, as well as the conversion of district heating units from coal to gas and the replacement of solid fuel to cleaner fuel boilers in schools, health centers, and households (in Kragujevac, one of the three cities with the greatest reliance on coal).
EXPOSURE TO AIR POLLUTION

Air pollution is a complex mixture of particles and gases whose sources and composition vary spatially and temporally. Key pollutants of interest include coarse and fine particulate matter (particulate matter that is less than 10 micrometers in diameter [PM10] and particulate matter that is less than 2.5 micrometers in diameter [PM2.5], respectively), nitrogen oxides (nitrogen oxide [NO], and nitrogen dioxide [NO2], referred to as NOx), ozone, carbon monoxide (CO), and sulfur dioxide (SO2). Household air pollution, a mixture of particles and gases resulting from incomplete combustion of fuels in the home, is also of concern due to the proximity of the source to humans and the potential for high exposures; it also contributes substantially to outdoor air pollution. Exposure to these pollutants contributes to the disease burden related to air pollution. As such, knowledge of trends of different pollutants is important in estimating the burden attributable to air pollution in each population and around the world.

In this section, we present an overview of current levels of key air pollutants and their long-term trends in Serbia by using data from the GBD 2019 study.

LEVELS, TRENDS, AND SOURCES

Ambient PM2.5

Ambient fine particle air pollution refers to PM2.5 (i.e., particles measuring less than 2.5 micrometers in aerodynamic diameter — less than a 30th of the diameter of a human hair). These particles are emitted from cars, coal-burning power plants, industrial activities, homes burning coal and wood for heating or cooking, waste burning, and other human activities and natural sources. Fine particles are also formed in the atmosphere from gaseous air pollutants, such as nitrogen or sulfur oxides. Although exposures to smaller and larger airborne particles can both be harmful, studies have shown that among air pollutants, high PM2.5 exposure over several years is the most consistent and robust predictor of mortality and morbidity due to cardiovascular, respiratory, metabolic, and other types of diseases. Such small particles can be suspended in the air for days and be transported by the wind over thousands of kilometers. These particles penetrate deep into the lungs.

The annual average PM2.5 level in Serbia in 2019 was 25.4 μg/m3 (UI: 23.1–27.9 μg/m3), which is among the highest in Southeast Europe where annual average concentrations range from 15.7 to 30.3 μg/m3 (HEI 2022a). The annual average PM2.5 level is about the same as the EU PM2.5 air quality limit value of 25 μg/m3, but more than double the EU-28 (European Union including Great Britain) average PM2.5 level of 11.4 μg/m3 (UI: 11.3–11.6 μg/m3). Notably, Serbia has made progress in reducing ambient PM2.5 levels between 2010 and 2019, and PM2.5 levels declined by 19% from the 2010 level of 31.4 μg/m3 (UI: 28.5–34.5 μg/m3) (Figure 1). However, given the paucity of national monitors in 2010, these trends must be interpreted with some caution (see “Signs of Progress” section below for more details).

These data indicate that all of Serbia’s population lives in areas where PM2.5 levels exceed the annual WHO guideline of 5 μg/m3, although most people (97%) live in areas where levels are below the WHO’s least stringent target (IT-1, 35 μg/m3) (for information on methods, see https://www.stateofglobalair.org/data/estimate-exposure).

Monthly means in 2018–2019 PM2.5 levels across the three largest cities in Serbia — Novi Sad, Belgrade, and Niš — show a distinct seasonal pattern. Concentrations are highest during the winter season in all three cities, where PM2.5 levels start to rise in September with the highest levels typically observed in December/January (Figure 2). The highest PM2.5 levels were seen in Niš, about 1.5 times those of Novi Sad at their peak (Serbian Environmental Protection Agency [SEPA] data, 2018–2019), and during those months the levels exceeded even the least stringent WHO interim target of 35 μg/m3.

More than 50% of Serbia’s population lives in areas where the annual PM2.5 levels exceed the WHO Air Quality Guideline as well as the EU limit value of 25 μg/m3.
FIGURE 1 Trends in population-weighted annual average PM$_{2.5}$ exposure ($\mu$g/m$^3$) in the Republic of Serbia, Southeast Europe, and EU-28, 2010–2019. Visit https://www.stateofglobalair.org/data to explore data.

FIGURE 2 Average monthly means in PM$_{2.5}$ concentrations ($\mu$g/m$^3$) across the three largest cities in the Republic of Serbia based on data collected January 2018 through December 2019 (Source: SEPA).
**Ozone**

Ground-level, or tropospheric, ozone is a highly reactive pollutant that is not released directly into the air but is formed through complex chemical interactions between NOx and volatile organic compounds (VOCs) in the presence of sunlight. NOx and VOCs are both produced by a variety of human activities; nitrogen oxides are emitted from the burning of fossil fuels (oil, gas, and coal) in cars, power plants, industrial boilers, and home heating systems, while VOCs are also emitted by cars, as well as through oil and gas extraction and processing, and other industrial activities. VOCs are also naturally emitted from some species of trees and other plants. Given these emitting sources and the fact that NOX scavenges/titrates ozone, especially along roadways, NOX is typically higher in urban areas, while ozone is found in higher concentrations in suburban and rural areas. The EU target value for short-term ozone (maximum daily 8-hour mean) is 120 μg/m³; the WHO's ozone air quality guideline is 100 μg/m³ for the short-term daily maximum 8-hour mean, and 60 μg/m³ for the long-term as the peak season (6 months) mean of daily maximum 8-hour means.

Over two-thirds of Serbia’s population (67%) lives in areas where ozone levels exceed the current long-term WHO guideline of 60 μg/m³ and nearly half of the population (45%) lives in areas that exceed the second interim target (IT-2) of 70 μg/m³.

In 2019, peak season average ozone exposure in Serbia was 69.8 μg/m³ (UI: 68.2–71.7 μg/m³), among the lowest in Southeast Europe, where ozone exposures range from 65.3 (Romania) to 101 μg/m³ (Slovenia). Unlike exposure to PM_{2.5} and household air pollution, exposure to ozone in Serbia is actually lower than the EU-28 average of 83.5 μg/m³ (UI: 83.3–83.7 μg/m³). Similar to the trends for PM_{2.5}, ozone levels have decreased in the last decade by 19.5% in Serbia, down from 86.6 μg/m³ in 2010 (UI: 84.9–88.4 μg/m³), whereas in many other countries in the region, as well as in EU-28, O₃ levels have increased or remained stable (Figure 3).

Monthly means in ozone levels across three cities — Belgrade (Starigrad), Niš (Sveti Sava), and Novi Sad — display a seasonal pattern (Figure 4). Concentrations are highest during the summer season; in all three cities levels rise beginning in January, peak in August, and decline to a low in December. Throughout the year, concentrations in Novi Sad are higher than those of Belgrade and Niš (SEPA).

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5 All GBD estimates for ozone have been converted (1 ppb = 1.96 μg/m³ for 25°C and 1,013 mb). [https://uk-air.defra.gov.uk/assets/documents/reports/cat06/0502160851_Conversion_Factors_Between_ppb_and.pdf](https://uk-air.defra.gov.uk/assets/documents/reports/cat06/0502160851_Conversion_Factors_Between_ppb_and.pdf)

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**Household Air Pollution from Use of Solid Fuels for Cooking**

Household air pollution results from the combustion of solid fuels (such as coal, lignite, charcoal, wood, agricultural residue, and animal dung, as well as waste) for heating or cooking using open fires or cookstoves with limited ventilation. Burning these fuels produces an array of pollutants that may harm human health, including PM_{2.5}, black carbon, carbon monoxide, polycyclic aromatic hydrocarbons, and other carcinogenic compounds. Of note, GBD only includes the role of burning solid fuels for cooking in its estimates of exposure to household air pollution. These PM_{2.5} exposure estimates are based on the proportion of a country’s population that relies on solid fuel for cooking combined with evidence from household and personal exposure measurement studies.

In Serbia, 24% of the population relies on solid fuels for cooking (UI: 16.2%–32.1%) — comparable with other countries in Southeast Europe — but substantially higher than in EU-28 where only 2.66% (UI: 2.13%–3.34%) of the population uses solid fuels for cooking. However, increasing access to cleaner fuels has resulted in a decrease in use of solid fuels for cooking in Serbia, down from 31.4% in 2010 (Figure 5).

Nevertheless, it is important to note that in Serbia and across the region, burning fuels for residential heating is a greater contributor to air pollution than burning for cooking, and thus the GBD estimate almost certainly underestimates the true contribution of households to air pollution levels. A study on the use of wood fuels for household heating in Serbia for the 2010–2011 heating season indicated that solid fuels, such as wood, coal, and agricultural residues, were the most used fuel type for heating (40.9%), followed by district central heating systems, which run on coal, oil, and gas (23.2%). Oil and gas used independently of the district heating systems contributed 0.1% and 10.6% to residential heating respectively, while electricity contributed 25.3% (Glavonjic 2011). Notably, Serbia has plans to reduce air pollution from residential heating within a new United Nations initiative, complementing already ongoing government efforts (see text box “Legislation Related to National Air Quality”) that aim to reduce air pollution resulting from domestic heating by (1) assessing energy poverty in the country and its link to air pollution and health, (2) developing technical solutions to reduce pollutants, and (3) launching air pollution monitoring and impact assessments in schools in 15 municipalities (UN 2021).

FIGURE 4 Average monthly trends in ozone concentrations (µg/m³) across three major cities in the Republic of Serbia — Niš, Novi Sad, and Belgrade — based on data collected between 2018–2019 (Source: SEPA).
Air quality monitoring is conducted on both local and national levels in the Republic of Serbia. Since 2006, the Serbian Environmental Protection Authority (SEPA) has been responsible for the national system of automatic air quality monitors — with all 40 stations funded by the European Commission under the Instrument for Pre-accession Assistance of 2007–2012, and measuring PM$_{2.5}$, PM$_{10}$, NO$_2$, SO$_2$, ozone, and other pollutants. The full monitoring network was not completed until 2010, thus the air quality data from the earlier years and any trends using those years should be viewed with caution as they are not fully representative given the low number of monitors. The national air quality data are not made readily accessible; however, SEPA is mandated by the Law on Air Protection (2009) to publish an annual report on air quality. In addition to the SEPA stations, municipal government administrations, often in collaboration with the local Institutes of Public Health, conduct local monitoring with up to 95 sampling sites. Twenty local institutes have operational air quality laboratories (Matić and Dejanović 2020, WHO 2019).

Although there are differences in quality between research-grade monitors and low-cost sensors, these citizen-driven air quality monitoring networks may complement the information from the state-run air quality networks and play an important role in raising public awareness on deleterious air quality in Serbia.

To enable the use of air quality data, a simplified, standard methodology is needed to estimate the impact of air pollution exposure on mortality. Previously, there was little knowledge transfer within the government pertaining to estimation of health impacts from air pollution; however, one recent positive development is that 25 networks across the Public Health Institutions in Serbia will receive training to uniformly conduct health impact assessment (from air pollution, as well as chemical contamination) with recognized software (i.e., WHO's AirQ+).

Health Effects of Air Pollution

Understanding the burden of disease that air pollution places on society begins with scientific evidence for its effects on health. An extensive body of scientific evidence has been amassed over several decades, including studies from many countries of the world. Short-term exposures to air pollution can harm health; for example, pollution can trigger asthma symptoms and cause a local spike in hospitalizations or even deaths related to respiratory and cardiovascular diseases. There is broad scientific consensus that long-term exposures to air pollution contribute to increased risk of illness and death from chronic noncommunicable diseases, such as ischemic heart disease, lung cancer, COPD, stroke, and type 2 diabetes, as well as lower respiratory infections (e.g., pneumonia) especially in children under 5 years of age. Exposure to PM$_{2.5}$ also puts mothers at risk of delivering babies too early and smaller than normal. These babies are more susceptible to dying from a range of diseases or are considered to be at increased risk for diseases later in life. There is also emerging evidence on the role of air pollution in cognitive disorders including dementia, as well as impaired cognitive development in children. For example, air pollution was recently acknowledged as a modifiable risk factor by the Lancet Commission on dementia prevention, intervention, and care, and other effects (Livingston et al. 2020). Overall, the public disease burden from long-term exposures is much larger than that from short-term exposures. This large burden of disease reflects the substantial contribution that long-term exposures to air pollution make to chronic noncommunicable diseases and, more specifically, to some of the world’s leading causes of death.

For a summary on health effects of air pollution, please refer to this factsheet and the resources listed at the end of the report. For data on health impacts of air pollution, please visit https://www.stateofglobalair.org/health.
Air pollution and health in Serbia were conducted in the urban area of Niš and found that exposure to black smoke was significantly associated with a higher frequency of respiratory hospital admissions for respiratory diseases, including COPD (Milutinović et al. 2009, Milosević et al. 2010). More recent studies conducted in the Novi Sad found that SO₂ exposure, in mixtures with PM₁₀, as well as exposure to PM₁₀ alone, contributed to COPD-related hospitalizations (Institute of Public Health of Vojvodina 2019). Additionally, PM₁₀ particles, in conjunction with gaseous pollutants, increased asthma exacerbations among women and adults aged 18–64 years in the summer season (Institute of Public Health of Vojvodina 2019). In another study in Novi Sad, investigators found that a mixture of air pollutants (PM₁₀, SO₂, and NO₂) was associated with increased acute respiratory infections (ARI), especially between October and March, with the most effects contributed by NO₂ in combination with PM₁₀ and SO₂ (Bijelović et al. 2012). In Užice, a recent study found allergic asthma exacerbations associated with short-term exposure to black carbon, NO₂, SO₂, and PM₁₀, particularly during the heating season (Kovačević et al. 2020).

Respiratory disease–related exacerbations have also been found to be associated with fine particles and its components, impacting certain population groups disproportionately. In the Novi Sad, increased daily concentrations of PM₂.₅ and equivalent carbonate fractions in PM₂.₅ particles as indicators of fossil fuel combustion were found to be associated with higher hospital admissions for respiratory diseases (in the same day), with stronger effects in women and elderly patients (≥65 years) (Dragić 2019). In Niš, NO₂ had the greatest effect on hospital admissions related to COPD in elderly men and asthma in elderly women, while fine particles had a significant effect on hospital admissions for pneumonia in younger men (Stosić et al. 2021). Additionally, results from a study on nonsmoking women 20–30 years of age in the cities of Niš and Niška Banja—conducted between 1999–2003—suggest that long-term exposure to low concentrations of SO₂ and soot particles was associated with increased prevalence of respiratory symptoms and disease (Stanković et al. 2007). A rare study on indoor air pollution in Niš found that SO₂ and black smoke can present an important risk factor for respiratory symptoms and illnesses among nonsmoking women (Stanković et al. 2011c).

Lung Cancer

An urban study in Novi Sad assessed the concentration of air pollutants (particulate matter, soot, SO₂, and NO₂) for the period 1999–2006 and total average standardized incidence rates of lung cancers for the period 2007–2014. The results showed that particulate pollutants in the ambient air after a decade of exposure, especially soot, are positively correlated with the incidence of the lung cancers among both sexes aged 50–54 and 70–74 years, respectively (Bijelović et al. 2016b). In a large area of Belgrade, another study estimated the effects of PM₁₀ as well as its components (the elements As, Cd, Cr, Mn, Ni, and Pb, as well as benzo[a]pyrene) on lung cancer and found Cr to be the major contributor to carcinogenic health risk (Perišić et al. 2017).

Cardiovascular Disease

Several studies in Serbia also found that air pollution is associated with cardiovascular and cerebrovascular disease. In Niš, short-term black smoke exposure led to increased cardiovascular hospital admissions in adults, including the elderly (Milosević et al. 2010). Another study assessing long-term exposure to black smoke found associations with increased incidence of hypertension (Stanković et al. 2016). Additionally, short-term exposure to black smoke alone or in combination with SO₂ was also associated with cardiovascular-related hospital admissions in people 65 years of age or older in Niš (Stanković et al. 2012), while SO₂ and NO₂ alone were associated with hospitalizations for cardiovascular diseases in Novi Sad (Dragić et al. 2012, Jevtić et al. 2014). In the same city, short-term exposure to NO₂ was also found to increase hospital visits related to cerebrovascular disease (Dragić et al. 2015).

Based on the measurements of PM₂.₅ mass concentration and chemical composition at traffic and background locations in Novi Sad, investigators found that hospital admissions for cardiovascular and cerebrovascular diseases increased after short-term exposure to PM₂.₅, mostly among men and the elderly (≥65 years of age). Additionally, an increase in average daily concentrations of calcium ions in PM₂.₅ particles as indicators for resuspended mineral dust—increased...
the risk of hospitalization due to cardiovascular diseases in women, while sodium in PM$_{2.5}$ particles (in the form of mineral dust) could represent an increased risk factor for exacerbations in acute heart attacks among the people aged 18–64 years (Dragić 2019).

**Maternal and Child Health**

A handful of studies in Serbia have also looked at the association between air pollution exposure and the health of pregnant women and children. Investigators in Niš found that exposure to SO$_2$, black smoke, and lead in sediment could lead to a higher occurrence of anemia and upper respiratory symptoms in pregnant women and that exposure to NO$_2$, SO$_2$, and lead in sediment could have negative effects on red blood cells at pregnancy (Stanković et al. 2011a, 2011d). Additionally, lower birth weight was associated with the mother’s exposure to SO$_2$ and black smoke (Stanković et al. 2011b). In school-aged children, exposure to certain air pollutants (black smoke, NO$_2$, and SO$_2$) was associated with decreased height and weight, especially before the age of 9 years (Nikolić et al. 2014). A retrospective cohort study in children under 5 years of age from Niš and Niška Banja found increased frequency of respiratory symptoms and higher incidence of lower respiratory diseases in more polluted areas when compared to less polluted areas (Nikić et al. 2005). In Niš, short-term exposure to black smoke and SO$_2$ was found associated with an increase in the rate of hospital admission for respiratory diseases in children 0–14 years of age (Nikić et al. 2008). In another more detailed analysis in Novi Sad of PM$_{10}$, SO$_2$, and NO$_2$ adjusted with meteorological data and total ARI number stratified by age in two seasons, the contribution of exposure to SO$_2$ increased frequency of ARIs among the youngest population for all air pollutants studied (Dragić et al. 2016). The results of a study assessing long-term exposure (1990–2000) of children to black smoke, NO$_2$, SO$_2$, and lead in sediment found increased prevalence of anemia, with significant decreases in blood cell count and average hemoglobin blood levels (Nikolić et al. 2008). Another study in Bor showed that ingestion was the primary exposure route for all metals and that lead and arsenic were the main contributors to noncancer health risks in both children and adults (Kurilić et al. 2020).

**Air Pollution–Related Mortality**

A number of studies assessing all-cause mortality (deaths) from air pollution have been conducted in Serbia. One study in Niš found black smoke to be associated with total mortality, as well as cardiovascular mortality, among the elderly (Bogdanović et al. 2006). Another study from Belgrade found PM$_{10}$, SO$_2$, NO$_2$, and soot exposure in both adults (≤65 years) and elderly (>65 years) residents to be associated with increase total mortality, while PM$_{10}$ exposure correlated with a significant increase in the number of daily deaths attributed to circulatory diseases, and SO$_2$ exposure appeared to be more associated with respiratory mortality (Stojić et al. 2016). The same group of investigators found these pollutants were also associated with increased susceptibility to other environment-related deaths, such as temperature-related mortality (Stanišić et al. 2016b). Another study in Novi Sad found that annual concentrations of NO$_2$ and PM$_{10}$ were associated with an increase in respiratory mortality and total mortality in women (Dragić et al. 2018). Also in Novi Sad, PM$_{2.5}$ particle mass concentration, as well as the chemical composition of the particles, were associated with overall mortality in women and more susceptible adults aged ≥65 years (Dragić 2019).

**HEALTH IMPACT ASSESSMENTS**

In addition to the epidemiological health and air pollution research summarized above, quantification of impacts of air pollution on health comes from health impact assessments. On a national level, the first estimates of the WHO, in collaboration with the Institute of Public Health of Serbia, Belgrade, were based on the PM$_{2.5}$ exposure in 2016 and indicated that 3,500 premature deaths in 11 major cities of Serbia could be expected (WHO 2019). Another assessment — based on data from the European Environment Agency (EEA) model that evaluated against regional observations separately — found that 13,600 deaths were attributable to air pollution (PM$_{2.5}$) exposure in Serbia (similar to the EEA estimates of 14,600 deaths attributed to PM$_{2.5}$ in 2018), with the highest number in South Serbia (Belgrade) and lowest in north Serbia (Toplice) (Dragić et al. 2019, EEA 2020). The total number of estimated premature deaths related to PM$_{2.5}$ by WHO in 2016 represents approximately 6.3% of the total annual mortality in Serbia. Of these, 12.6% cases were attributed to the sulfate and nitrate content of PM$_{2.5}$ (Todorović 2020).

**BURDEN OF DISEASE FROM AIR POLLUTION IN THE REPUBLIC OF SERBIA**

According to the GBD estimates, 12,700 deaths (95% UI: 9,946–16,131) were linked to exposure to air pollution in 2019, representing nearly 11% percent of total deaths in Serbia; of these, a majority were linked to exposure to outdoor PM$_{2.5}$ (Figure 7). Overall, while both the total number of deaths attributable to air pollution and the death rate (i.e., deaths/100,000 people) have declined by 20% and 18%, respectively, in the last decade, a rate of 145 deaths per 100,000 people in Serbia represents the 4th highest in the Southeast European region and exceeds the global death rate attributed to air pollution (86.2 deaths/100,000 people) (Figure 8). In comparison, the death rate from smoking in Serbia is nearly double that from air pollution (278 deaths/100,000 people, 95% UI: 224–339).

**Fine Particulate Matter (PM$_{2.5}$)**

In 2019, 10,600 (95% UI: 8,234–13,315) deaths in Serbia were linked to ambient PM$_{2.5}$, a decrease of approximately 16% in the last decade. The burden disproportionally impacts the elderly, as...
FIGURE 7 Percentage of deaths linked to individual air pollutants in the Republic of Serbia.

FIGURE 8 The (age-standardized) rate of deaths per 100,000 people linked to total air pollution, \( PM_{2.5} \), ozone, and household air pollution from solid fuels in the Republic of Serbia in 2019.

FIGURE 9 Trends in death rate linked to \( PM_{2.5} \) in the Republic of Serbia, Southeast Europe, and EU-28, 2010–2019. Visit https://www.stateofglobalair.org/data to explore data.
69% of these PM$_{2.5}$-related deaths befall people 7 years of age and older, whereas 31% of such deaths occur at 40 to 70 years of age. Similarly, the average age-standardized death rate attributable to PM$_{2.5}$ in Serbia decreased from 140 deaths/100,000 people (95% UI: 118–163) in 2010 to 121 deaths/100,000 people in 2019 (Figure 9). This rate is more than twice the respective global death rate (53.5 deaths/100,000 people) and nearly five times higher than that of Western Europe (Figure 8).

Ozone

In Serbia, 112 deaths (95% UI: 42.5–198) were linked to exposure to ozone in 2019, representing approximately 1% of the country’s air pollution-related deaths. Most of the ozone-related deaths occurred at ages 60 and above, and 73% of deaths occurred in people ages 70 and above (Figure 10 shows the distribution of COPD-related deaths linked to air pollution for ages 25 and older because the disease progresses over time). COPD is the only health outcome that is considered for ozone; 3% of the total COPD deaths in Serbia are linked to ozone exposure. Similar to the downward trend of total number of deaths attributable to ozone in the last decade, the ozone-related death rate in Serbia decreased by more than half, from 2.80 deaths/100,000 people (95% UI: 1.23–4.62) in 2010 to 1.28 deaths/100,000 people (95% UI: 0.49–2.26) in 2019.

Household Air Pollution – Cooking

The use of solid fuels for cooking in Serbia resulted in 2,000 deaths (95% UI: 643–4,516) in 2019, representing a decrease of approximately 37% since 2010. This decline in the last decade is in line with the related decrease in household air pollution–related deaths in the region (by 30%). Similarly, household air pollution–attributable age-standardized death rates decreased from 34.8 deaths/100,000 people (95% UI: 15.0–65.2) in 2010 to 22.5 deaths/100,000 people (95% UI: 7.4–51.6) in 2019. This follows the same trend as the rest of the Southeast Europe region (see HEI 2022a for details).

Air Pollution Effects on the Burden on Health from Major Diseases

The burden of disease attributable to air pollution does not fall evenly across age groups. Throughout the world, children and older adults are most acutely affected. Overall, ambient PM$_{2.5}$ and household air pollution are the largest contributors to deaths across age groups globally.

In Serbia, noncommunicable diseases rank among the most frequent causes of death with cardiovascular diseases, digestive diseases, diabetes, and chronic respiratory diseases and infections ranking among the top 10 causes of death. Many of the same diseases are also linked with exposure to air pollution.

Specifically, 23% of all COPD-related deaths are attributed to air pollution (Figure 11), with the largest fractions of those deaths attributable to PM$_{2.5}$ (17%) and ozone (3%) (explore here). Other health outcomes for which air pollution presents a key risk factor in Serbia are type 2 diabetes; trachea, bronchus, and lung cancer; stroke; and ischemic heart disease.

The largest number of air pollution–related deaths in Serbia occur in people 65 years or older (Figure 12); a majority of these (84%) are related to exposure to ambient PM$_{2.5}$ (Figure 6). This peak reflects the contribution of air pollution to major noncommunicable diseases that develop over time — as evidenced by the highest number of deaths impacting Serbs who are between 64–89 years of age for type 2 diabetes (84%), lower respiratory infections (77%), ischemic heart disease (78%), and COPD (82%, see Figure 7), while lung cancer impacts those between 60–74 years of age the most (57%). At the same time, 9% of the deaths among newborns/infants were linked to air pollution (Figure 6).
**FIGURE 10** Distribution of COPD-related deaths in 2019 in the Republic of Serbia linked to air pollution by age [25+ years].

**FIGURE 11** Percentage of deaths (by cause) linked to air pollution in the Republic of Serbia in 2019.

**FIGURE 12** Distribution of deaths linked to air pollution in 2019 in the Republic of Serbia by age (in years, except early neonatal [0 to 6 days] and late neonatal [7 to 27 days]).
Overall, the burning of fossil fuel is the leading source of outdoor PM$_{2.5}$ levels and the single largest contributor to the overall associated burden on health in Serbia (36%, 2,841 deaths/year in 2019) (Figure 13). This is primarily driven by the use of coal across all sectors, which contributed to 1,729 deaths and accounted for 26% of PM$_{2.5}$-related deaths in Serbia in 2019. Coal is used extensively for energy production but also used to a lesser degree in industrial and residential sectors in Serbia (Figure 14). The energy supply sector in Serbia is mainly built upon coal-fired power plants. In 2019, 68% of electricity in Serbia was generated from coal and almost exclusively from low-efficiency power plants burning lignite, a low-quality coal (Republic of Serbia Legal Information System 2020). Although coal use across Southeast Europe is much higher than in the rest of Europe, Serbia reports the highest share of PM$_{2.5}$ and related disease burden from coal among nine Southeast European countries (see details in HEI 2022a). It is also noticeable that the use of solid biofuel, mainly in households, also contributed to a considerable share of PM$_{2.5}$ concentrations and related disease burden (19%, 1,691 deaths/year).

The energy sector in Serbia contributed to the largest share of PM$_{2.5}$ concentrations and the associated burden on health (23%, 2,476 deaths/year), followed by residential combustion (19%, 2,096 deaths/year). As expected, when investigating the fuel types used within these sectors, the majority of PM$_{2.5}$ generated by energy sectors was from burning coal (86%). On the other hand, a large share of PM$_{2.5}$ generated by residential sectors was from burning solid biofuel (85%), such as wood and waste products, for cooking and heating in households (Figure 9). Nearly 10% of Serbia’s households experience energy poverty, that is, a significant proportion of the country's population is unable to afford to heat their homes or lacks access to district central heating systems (EU Eurostat 2021). To reduce the use of fossil fuels and CO$_2$ emissions in Serbia, biomass has been identified as a promising alternative fuel, especially for power and heating supply (Golusin et al. 2010). However, it is noteworthy that while biomass is a renewable fuel, it can also be a large contributor to PM$_{2.5}$. Agriculture and windblown dust are also important sources of PM$_{2.5}$ to consider. In Serbia, similar to other Southeast European countries, agriculture also contributes to a significant share (11%, 1,184 deaths/year of PM$_{2.5}$). An important natural and seasonal source (often in spring and summer) of PM$_{2.5}$ in Serbia is windblown dust, which amounts to 13% of PM$_{2.5}$ concentrations and related disease burden (1,369 deaths/year) (Figure 14).

Although these results were estimated to understand important sources of PM$_{2.5}$ at the national level, the contribution from sources can vary between rural and urban areas (McDuffie et al. 2021). For example, nationally, transportation was estimated to contribute 5% of PM$_{2.5}$ concentrations and the linked disease burden (586 deaths/year), while a study that analyzed PM$_{2.5}$ sources in five Serbian cities reported higher contributions, up to 9.6%, in the city of Subotica (Belis et al. 2019) and another reported 4.5% in Belgrade (McDuffie et al. 2021). Additionally, the major sources of PM$_{2.5}$ also vary in different parts of Serbia. Belis and colleagues (2019) found that energy production was the largest contributor for PM$_{2.5}$ in all five Serbian cities, but the contribution ranged from 26% to 37%. Residential combustion was the second largest contributor of PM$_{2.5}$ in Belgrade, Kragujevac, Niš, and Novi Sad, whereas agriculture was a more important contributor in Subotica (Belis et al. 2019). Other relevant sources including burning of waste or agricultural residues.
How Did We Identify Major Sources of Air Pollution?

We reported major sources of air pollution at the national level for countries in Southeast Europe based on the data from the GBD MAPS Global study (McDuffie et al. 2021). As sources of air pollution often differ between rural and urban areas, we also included some studies conducted in major cities in the region to provide additional insights on local sources of air pollution. The GBD MAPS Global study provided the first contemporary and comprehensive global evaluation of major sources of PM$_{2.5}$ by fuel type and by sector in more than 200 countries using a consistent methodology and global emissions inventories. It utilized updated Community Emissions Data System emissions inventories, satellite data, ground-monitoring data, and advanced air quality modeling (GEOS-Chem model) to estimate the PM$_{2.5}$ exposures from 16 sectors and 4 different fuel types (McDuffie et al. 2021). Unlike regulatory emission data, the GBD MAPS Global study considered both anthropogenic sources (e.g., residential use, industry, and transportation) and natural sources (e.g., windblown dust, open fires, and volcanoes). It also estimated deaths linked to different sources of PM$_{2.5}$ using GBD methodologies. More details about this study can be found here.
Although air quality has improved in Serbia in the last decade, in line with similar improvements observed in other countries in the region and the rest of Europe, air pollution levels and related disease burden remain among the highest in Europe. Energy poverty and lack of access to clean energy remain key issues as energy production continues to rely on old, inefficient coal-fired power plants. As a result, the use of fossil fuels, including coal, oil, and natural gas, as well as the use of solid biofuels by households, are the dominant sources of ambient PM$_{2.5}$ and exact a heavy toll on the health of the young and older adults alike, accounting for 36% of the total PM$_{2.5}$-related deaths. Substantial health benefits can be expected with long-term reductions in air pollution. Increasing access to affordable clean heating sources through investments into an energy sector that moves away from fossil fuels toward renewable energy (solar, wind, etc.) with higher energy efficiency and less pollution is critical in reducing both energy poverty and improving air quality in the Republic of Serbia.

In recent years, visible air pollution episodes in major cities have sparked discussions about air pollution; the discourse has also been bolstered to some extent by the increasingly accessible air pollution data from citizen science monitoring networks. This, in turn, has enabled the public to demand improved air quality and related policy action. However, the national air quality data are not stored in a standardized accessible database, and thereby limit their use in conducting epidemiological research on health effects of air pollution and health impact assessments, and in informing legal frameworks. Thus, access to and transparency of air pollution data are needed.

Just as the COVID-19 crisis has demonstrated the need for multiple strategies to manage the pandemic, solutions to air pollution will require multifaceted ongoing efforts to bring attention to its health threats, to identify the policy changes necessary to control it, and to monitor progress over time. To achieve cleaner air in Serbia, municipal, regional, and national efforts and collaborations are necessary, as well as involvement of all relevant sectors, including health, energy, transport, industry, agriculture, and urban planning. It is important to not only expand and improve access to air quality data and support research on health effects, but also to support collaborations across all relevant stakeholders, sectors, and institutions (i.e., government agencies, legal entities, academia, and nongovernmental organizations).

As coal-fired power plants are the dominant energy source, it is important that economic development plans in Serbia account for health implications of energy choices today and in the future. To maximize the co-benefit to climate and health, strategies to increase shares of renewable energy generated with low PM$_{2.5}$ emissions are crucial. Existing evidence on air pollution emission sources and related burdens on health indicates that implementing emission reduction strategies on the sectors with the highest contributions to ambient air pollution and health impact in the Republic of Serbia, that is, energy production, residential fuel combustion, transportation, and agriculture, would greatly improve air quality and related health, economic, and societal benefits.
WHAT IS THE STATE OF GLOBAL AIR?

The State of Global Air report and interactive website bring into one place a comprehensive analysis of the levels and trends in air quality and health for every country in the world. They are produced annually by the Health Effects Institute and the Institute for Health Metrics and Evaluation’s (IHME’s) Global Burden of Disease (GBD) project and are a source of objective, high-quality, and comparable air quality data and information.

WHO IS IT FOR?

The report and website are designed to give citizens, journalists, policy makers, and scientists access to reliable, meaningful information about air pollution exposure and its health effects. These resources are free and available to the public.

HOW CAN I EXPLORE THE DATA?

This report has a companion interactive website with tools to explore, compare, and download data and graphics reflecting the latest air pollution levels and associated burden of disease. Anyone can use the website to access data for over 200 individual countries, territories, and regions, as well as track trends from 1990 to 2019. Find it at stateofglobalair.org.

Data and figures from this publication may be used for non-commercial purposes. Contents of this report may not be used for any commercial purposes without prior permission from the Health Effects Institute.
**Global Burden of Disease 2019 Methods**

These resources provide background details on the latest GBD methods used to estimate PM$_{2.5}$, ozone, and household air pollution exposures and the deaths reported here.


Explore and download additional information and data on mortality and disease burden for air pollution, as well as other risk factors, at the IHME GBD Compare site https://vizhub.healthdata.org/gbd-compare/.

**Health Effects of Air Pollution**


**Sources of Air Pollution**


**Urban Air Quality**


Dragić N. 2019. Impact of Ambient Suspended Particles PM_{2.5} on Mortality, Cardiovascular and Respiratory Morbidity of Adults in the City of Novi Sad [PhD dissertation]. Novi Sad, Serbia:University of Novi Sad, Faculty of Medicine.


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