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?

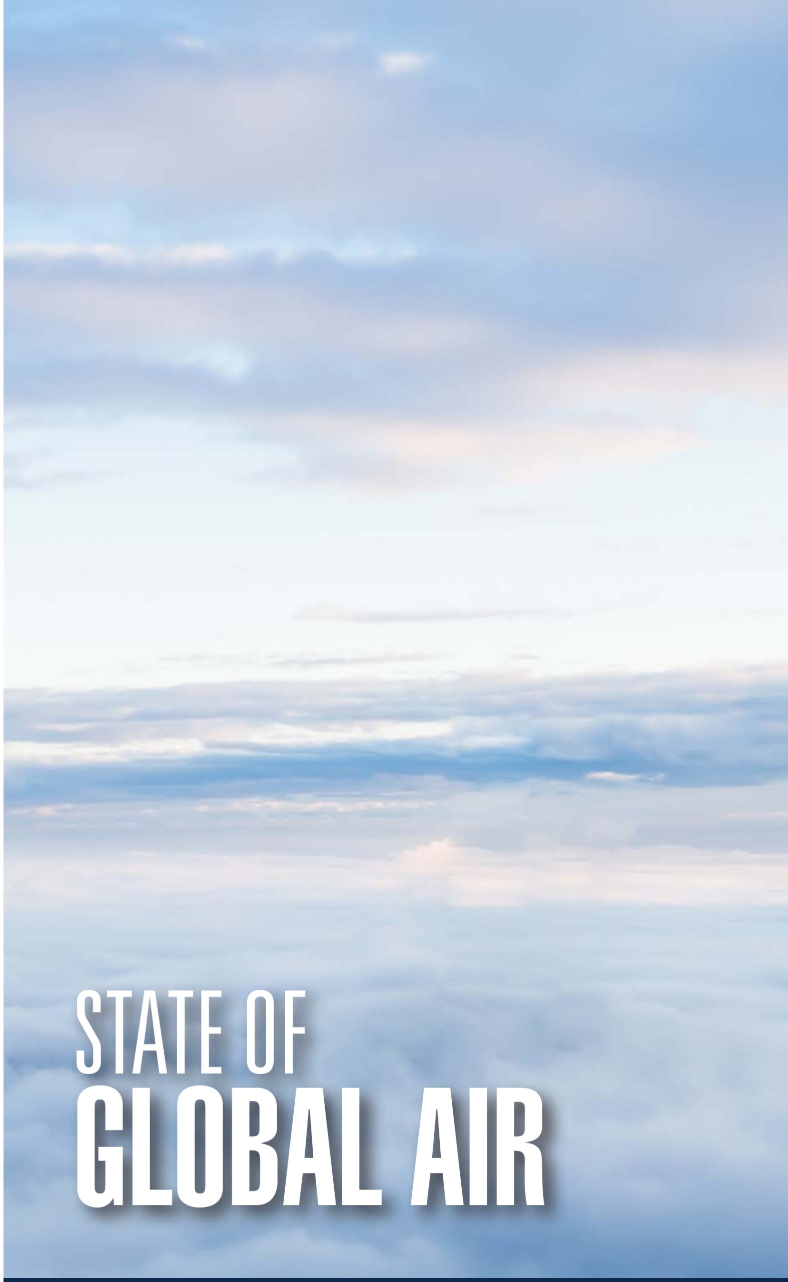
The *State of Global Air* report and interactive website offer a comprehensive analysis of the levels and trends in air quality and health for every country in the world. They are produced annually by the Health Effects Institute and the Institute for Health Metrics and Evaluation's (IHME's) Global Burden 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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INTRODUCTION

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 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.

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/*.

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Belgrade, Serbia

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)	Pillar II: Directive 2008/50/EC	Pillar III: Programme of Air Protection (PAP) and Action Plan (AP)
Reduce air pollution emissions	Improve air quality	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[1], the Action Plan for the Implementation of the Sofia Declaration on the Green Agenda for the Western Balkans 2021–2030[2], 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[3], 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).[4]

[1] *https://www.rcc.int/docs/546/sofia-declaration-on-the-green-agenda-for-the-western-balkans-rn.*

[2] *https://www.rcc.int/docs/596/action-plan-for-the-implementation-of-the-sofia-declaration-on-the-green-agenda-for-the-western-balkans-2021-2030.*

[3] *https://balkangreenenergynews.com/serbia-launches-program-to-subsidize-households-to-install-solar-panels/.*

[4] *https://balkangreenenergynews.com/serbia-starts-coal-phaseout-in-heating-sector-from-2021/.*

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 [PM_{10}] and particulate matter that is less than 2.5 micrometers in diameter [$PM_{2.5}$], respectively), nitrogen oxides (nitrogen oxide [NO], and nitrogen dioxide [NO_2], referred to as NO_x), ozone, carbon monoxide (CO), and sulfur dioxide (SO_2). 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.

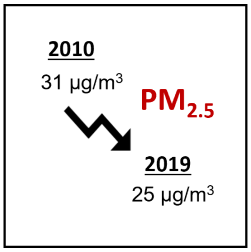
LEVELS, TRENDS, AND SOURCES

Ambient $PM_{2.5}$

Ambient fine particle air pollution refers to $PM_{2.5}$ (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 $PM_{2.5}$ 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.

More than 50% of Serbia's population lives in areas where the annual $PM_{2.5}$ levels exceed the WHO Air Quality Guideline as well as the EU limit value of 25 μg/m³.

The annual average $PM_{2.5}$ level in Serbia in 2019 was 25.4 μg/m³ (UI: 23–27.9 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 $PM_{2.5}$ level is about the same as the EU $PM_{2.5}$ air quality limit value of 25 μg/m³, but more than double the EU-28 (European Union including Great Britain) average $PM_{2.5}$ level of 11.4 μg/m³ (UI: 11.3–11.6 μg/m³). Notably, Serbia has made progress in reducing ambient $PM_{2.5}$ levels between 2010 and 2019, and $PM_{2.5}$ 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 $PM_{2.5}$ 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*).

100% of Serbia's population lives in areas that exceed the WHO Air Quality Guideline

99% of Serbia's population lives in areas that exceed Interim Target 3 (15 μg/m³)

56% of Serbia's population lives in areas that exceed Interim Target 2 (25 μg/m³)

3% of Serbia's population lives in areas that exceed Interim Target 1 (35 μg/m³)

Monthly means in 2018–2019 $PM_{2.5}$ 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 $PM_{2.5}$ levels start to rise in September with the highest levels typically observed in December/January (Figure 2). The highest $PM_{2.5}$ 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.

Exposures to $PM_{2.5}$ are highest in the winter months, as observed in the three largest cities of Serbia: Novi Sad, Belgrade, and Niš.

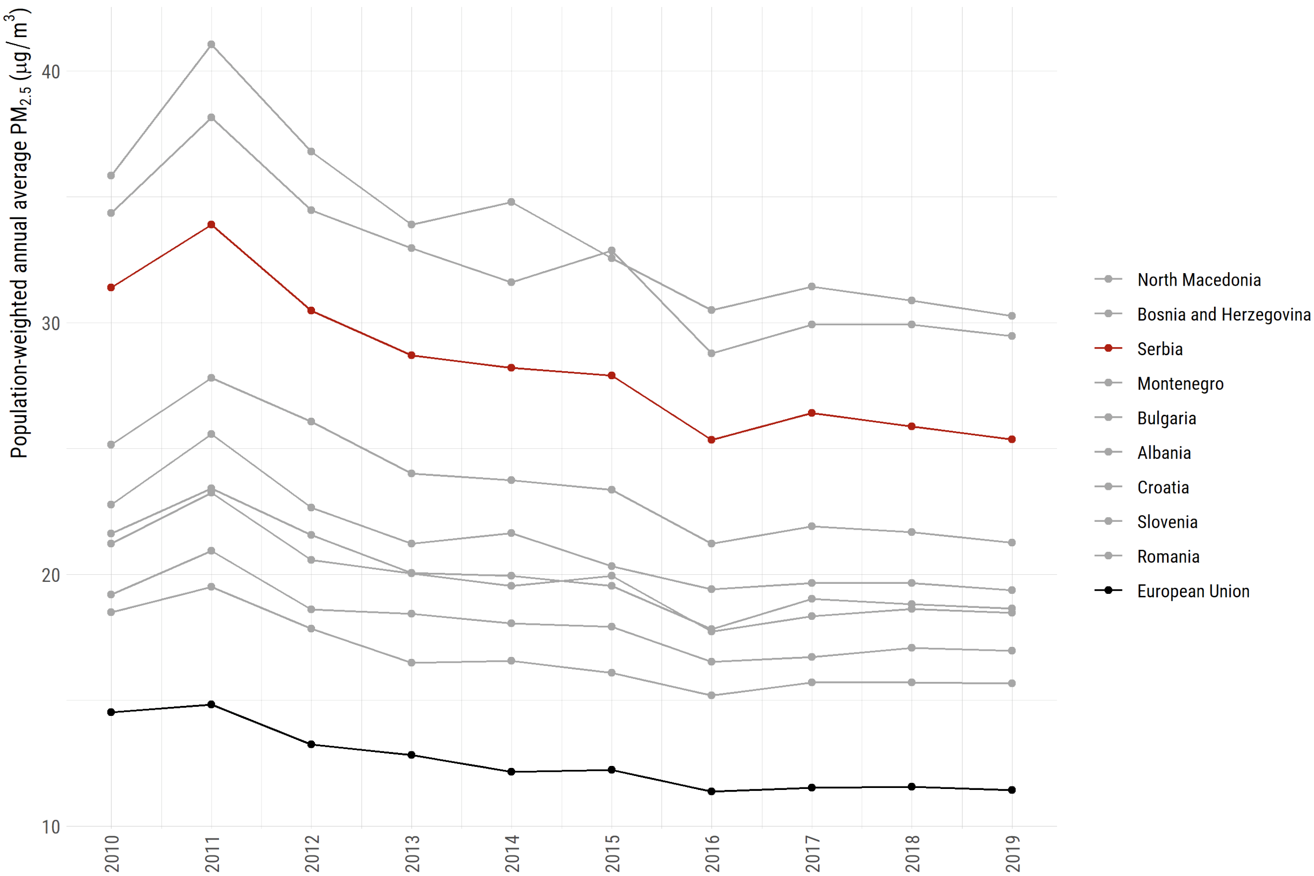


FIGURE 1 Trends in population-weighted annual average $PM_{2.5}$ exposure ($\mu g/m^3$) in the Republic of Serbia, Southeast Europe, and EU-28, 2010–2019. Visit *https://www.stateofglobalair.org/data* to explore data.

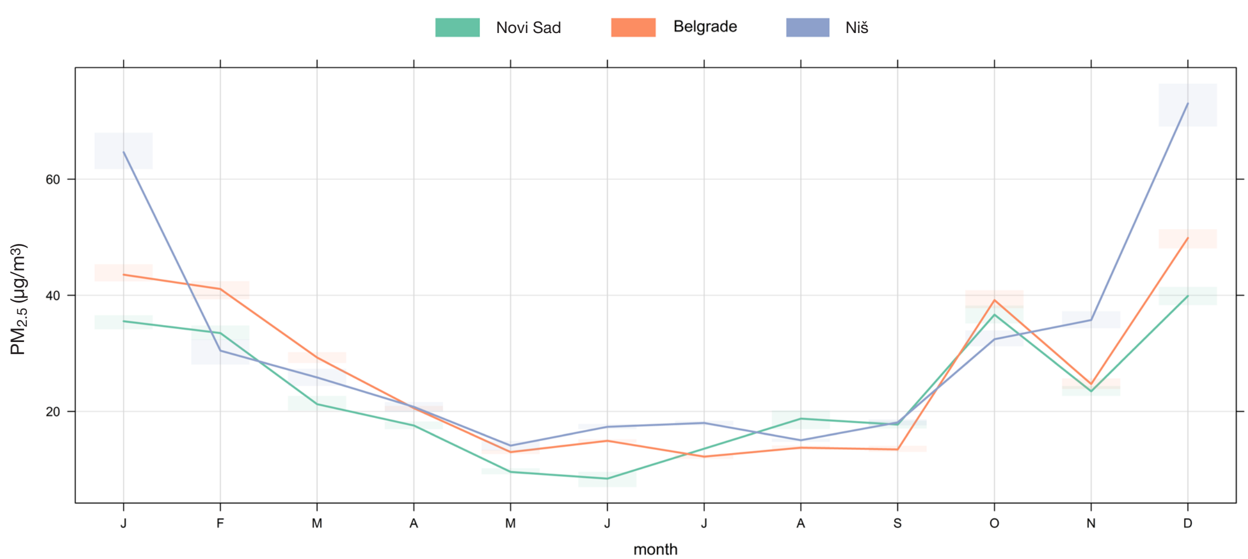


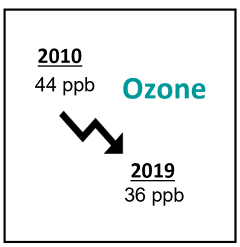
FIGURE 2 Average monthly means in $PM_{2.5}$ concentrations ($\mu g/m^3$) across the three largest cities in the Republic of Serbia based on data collected January 2018 through December 2019 (Source: SEPA).

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 NO_x and volatile organic compounds (VOCs) in the presence of sunlight. NO_x 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 NO_2 scavenges/titrates ozone, especially along roadways, NO_2 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.

More than two-thirds of Serbia's population lives in areas with ozone levels higher than the WHO long-term ozone guideline for healthy air (60 µg/m³).

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, O_3 levels have increased or remained stable (Figure 3).[5]

Monthly means in ozone levels across three cities — Belgrade (Stari grad), 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).

[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*.

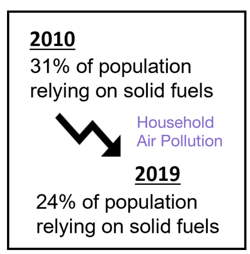
Household Air Pollution from Use of Solid Fuels for Cooking

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).

Although reliance on solid fuels for cooking has decreased in the last decade, 24% of the country's population continues to use them.

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).



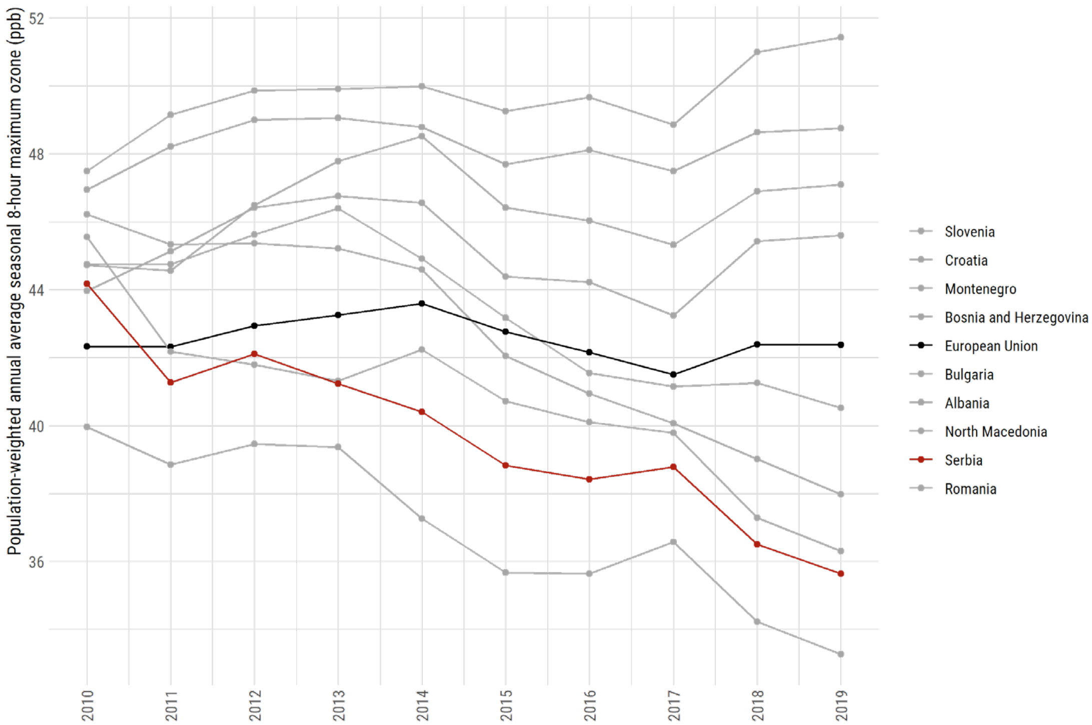


FIGURE 3 Trends in population-weighted annual average seasonal 8-hour daily maximum ozone exposures (ppb) in the Republic of Serbia, Southeast Europe, and EU-28, 2010–2019 (HEI 2020). Visit *https://www.stateofglobalair.org/data* to explore data.

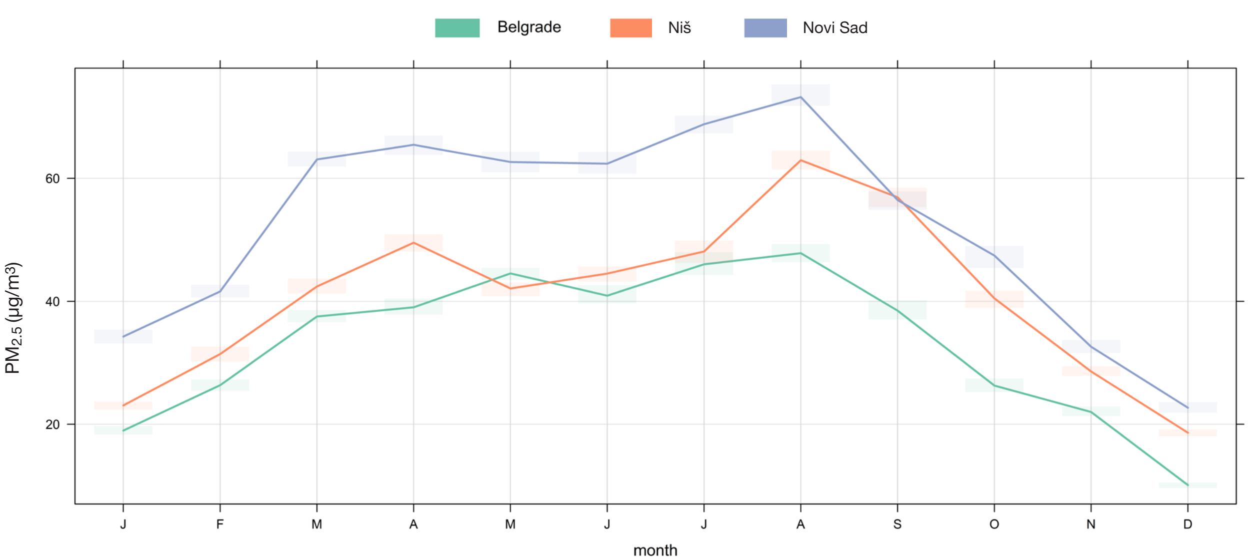


FIGURE 4 Average monthly trends in ozone concentrations (µg/m3) across three major cities in the Republic of Serbia — Niš, Novi Sad, and Belgrade — based on data collected between 2018–2019 (Source: SEPA).

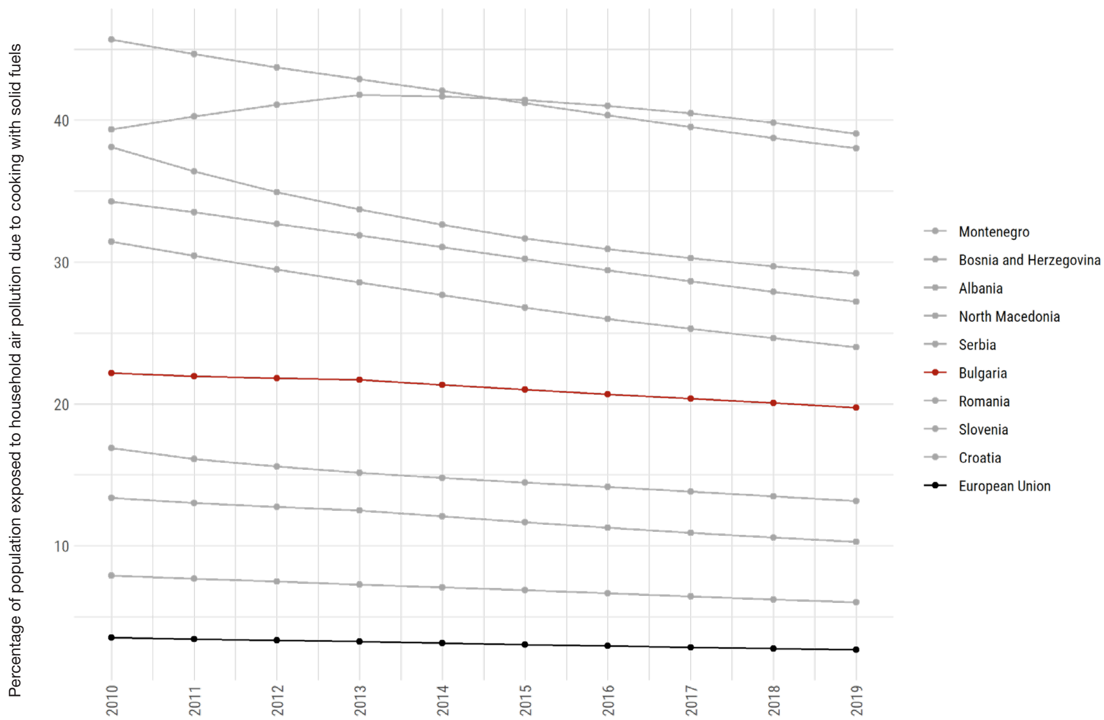


FIGURE 5 Trends in the percentage of population exposed to household air pollution due to cooking with solid fuels in the Republic of Serbia, Southeast Europe, and EU-28, 2010–2019 (HEI 2020). Visit *https://www.stateofglobalair.org/data* to explore data.

AIR QUALITY DATA IMPROVING

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 some signs of progress, data on air quality in Serbia remains limited.

In addition, the air quality monitoring networks and citizen science campaigns implemented by civic organizations are enabling the public to access local air quality data. For example, Belgrade Open School's project "Serbian Air Watch" installed 50 air quality sensors across five cities in Serbia and connected them to the Luftdaten platform to raise awareness on air pollution and support local communities.[6] 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+).

6 *https://www.bos.rs/ekz-eng/implemented-projects/1068/9744/serbian-air-watch.html*.

IMPACTS OF AIR POLLUTION ON HEALTH

Our health is strongly influenced by the air we breathe. Air pollution affects the young and the old, the rich and the poor, and people across the globe. However, the burden of diseases associated with air pollution is not borne equally across regions and countries as variations reflect not only exposures, but also other social, economic, and demographic factors that affect the underlying health and vulnerability of populations to air pollution. Because socioeconomic development can be tied to both air pollution exposures and the availability of health care, changes in a country's level of development can also influence the burden of disease over time. Thus, lower-income households and communities are generally more vulnerable to the health effects from air pollution due to potentially greater exposure and to overall increased susceptibility given possible poor baseline health (for example, exposure to other risk factors, such as smoking), lack of access to health care, and limited ability to afford protective measures or to improve housing quality. Additionally, the burden of disease attributable to air pollution does not fall evenly across age groups. Throughout the world, children and the elderly are those most acutely affected.

This section will explore the patterns and trends in the burden of disease in Serbia from total air pollution, as well as the individual air pollutants that make up total air pollution in GBD estimates (i.e., $PM_{2.5}$, ozone, and household air pollution).

The leading risk factors that account for the most disease burden in Serbia are high blood pressure, dietary risks, tobacco, and high blood sugar (GBD 2020). The main causes of deaths include ischemic heart disease; cerebrovascular disease (stroke and hypertensive heart disease); and trachea, bronchus, and lung cancers; and several noncommunicable diseases that are also linked to air pollution. Air pollution ranks as the 7th leading risk factor for deaths in Serbia in 2019 (Figure 6), and, with 12,700 deaths attributed to air pollution in the country's population of 8.7 million, the national death rate linked to air pollution is among the highest in Europe.

EVIDENCE FROM THE REPUBLIC OF SERBIA

Global evidence on health effects of air pollution, based on thousands of high-quality studies in European countries and others, is relevant for Serbian populations as well. *To date, more than 40 studies of air pollution and health have also been conducted in Serbia, finding a number of effects as described below.* This local research adds to the available global evidence and strengthens conclusions about the risks of air pollution on health of Serbia residents. (Note: National and local studies were identified through searching online literature databases focused on air pollution and health outcomes; although we intended to include as many studies as possible, this report does not encompass an exhaustive literature review. Visit *here* for an interactive literature database featuring studies on air pollution and health in the region, including Serbia).

Although substantial research has been done on short-term respiratory effects from air pollution (i.e., time-series studies), there is a need for conducting studies of effects of long-term exposures on respiratory health in Serbia. Some of the first short-term studies on

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.*

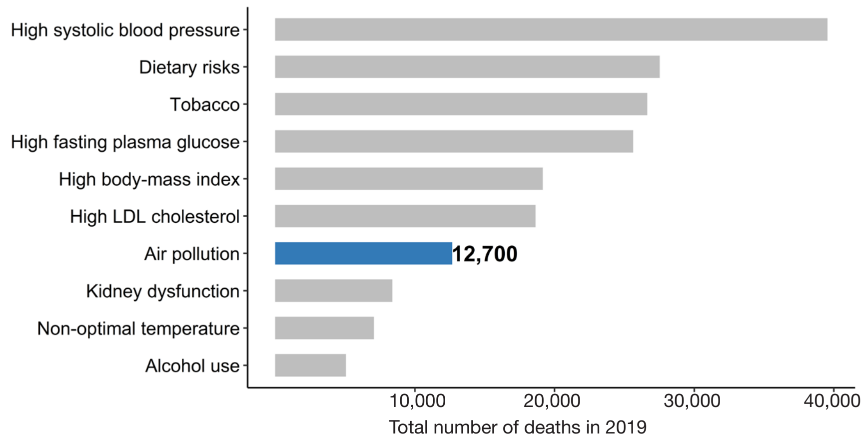


FIGURE 6 Ranking of risk factors by total deaths from all causes in the Republic of Serbia in 2019 (IHME 2019).

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 SO_2 exposure, in mixtures with PM_{10}, as well as exposure to PM_{10} alone, contributed to COPD-related hospitalizations (Institute of Public Health of Vojvodina 2019, Bijelović et al. 2016a). Additionally, PM_{10} 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 (PM_{10}, SO_2, and NO_2) was associated with increased acute respiratory infections (ARIs), especially between October and March, with the most effects contributed by NO_2 in combination with PM_{10} and SO_2 (Bijelović et al. 2012). In Užice, a recent study found allergic asthma exacerbations associated with short-term exposure to black carbon, NO_2, SO_2, and PM_{10}, 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 $PM_{2.5}$ and equivalent carbonate fractions in $PM_{2.5}$ 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, NO_2 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 (Stosic 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 SO_2 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 SO_2 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, SO_2, and NO_2) 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 PM_{10}, 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 SO_2 was also associated with cardiovascular-related hospital admissions in people 65 years of age or older in Niš (Stanković et al. 2012), while SO_2 and NO_2 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 NO_2 was also found to increase hospital visits related to cerebrovascular disease (Dragić et al. 2015)

Based on the measurements of $PM_{2.5}$ 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 $PM_{2.5}$, mostly among men and the elderly (≥65 years of age). Additionally, an increase in average daily concentrations of calcium ions in $PM_{2.5}$ 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

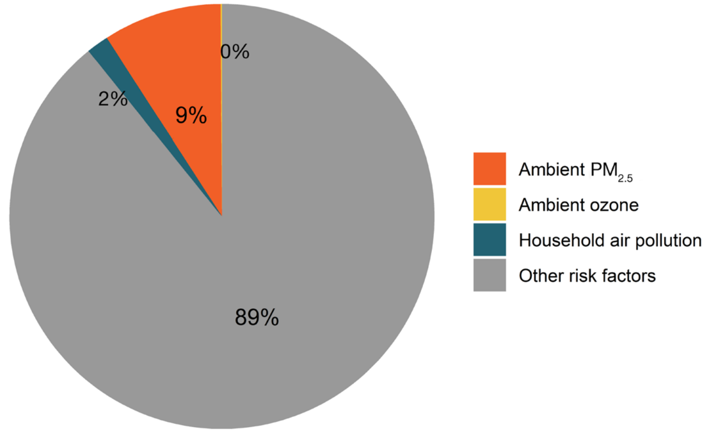
According to the GBD estimates, 12,700 deaths (95% UI: 9,946–16,131) were linked to exposure to air pollution in 2019, representing nearly 11% percent of total deaths in Serbia; of these, a majority were linked to exposure to outdoor $PM_{2.5}$ (Figure 7). Overall, while both the total number of deaths 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).

> Air pollution accounts for 1 in 10 deaths in Serbia.

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 disproportionately impacts the elderly, as

FIGURE 7 Percentage of deaths linked to individual air pollutants in the Republic of Serbia.



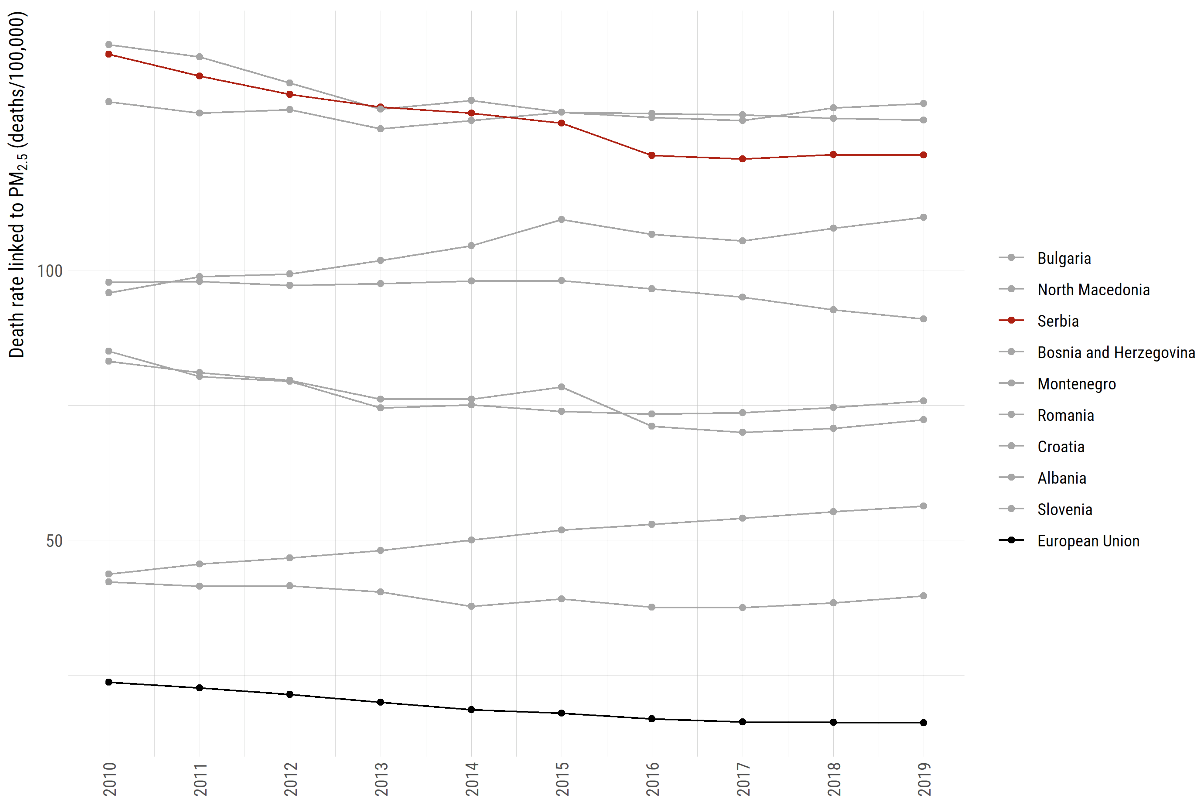


FIGURE 8 The (age-standardized) rate of deaths per 100,000 people linked to total air pollution, $PM_{2.5}$, ozone, and household air pollution from solid fuels in the Republic of Serbia in 2019.

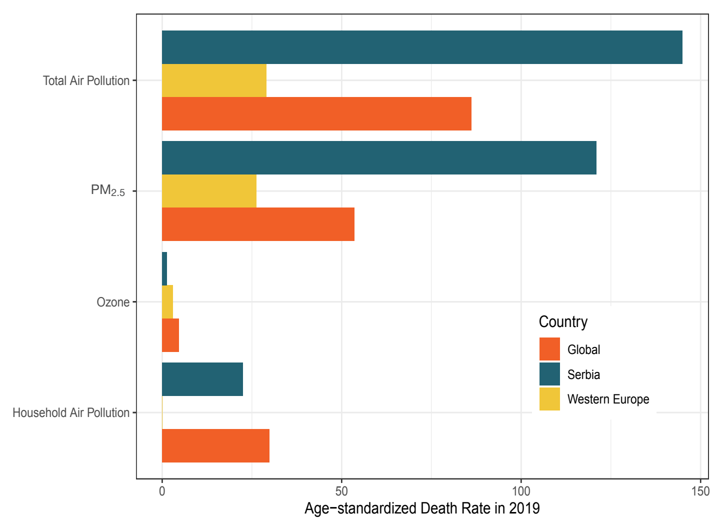


FIGURE 9 Trends in death rate linked to $PM_{2.5}$ in the Republic of Serbia, Southeast Europe, and EU-28, 2010–2019. Visit *https://www.stateofglobalair.org/data* to explore data.

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/100,00 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).

Serbia's burden of disease from outdoor $PM_{2.5}$ is among the highest in Europe.

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.

A majority of deaths linked to ozone exposure occur in adults over the age of 60.

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).

Good news: The burden of disease from household air pollution from cooking has decreased steadily between 2010–2019.

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.

Exposure to air pollution makes a significant contribution to the burden on health from heart disease, chronic lung disease, diabetes, and other noncommunicable diseases, and has the greatest impact on the youngest and the oldest in a population.

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).

82% of all deaths related to air pollution in Serbia were in people over the age of 65.

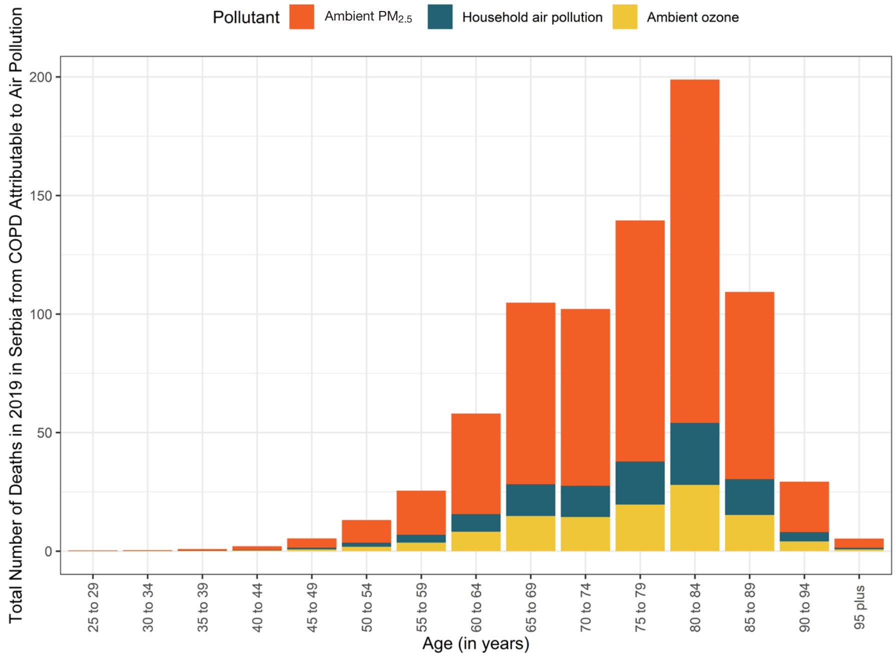


FIGURE 10 Distribution of COPD-related deaths in 2019 in the Republic of Serbia linked to air pollution by age [25+ years].

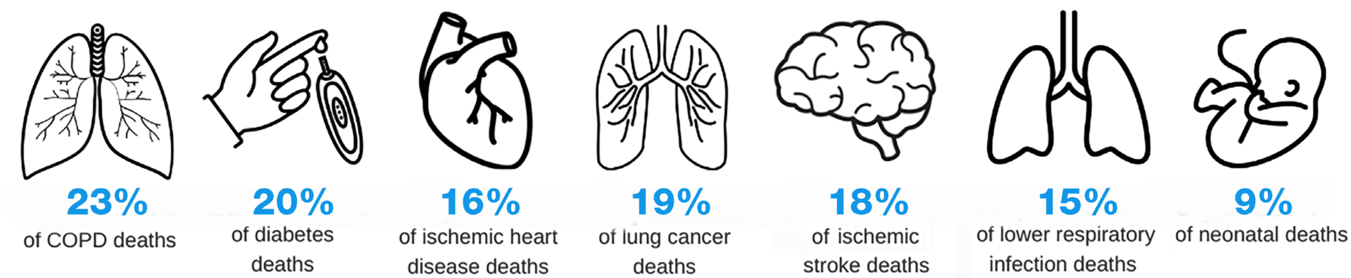


FIGURE 11 Percentage of deaths (by cause) linked to air pollution in the Republic of Serbia in 2019.

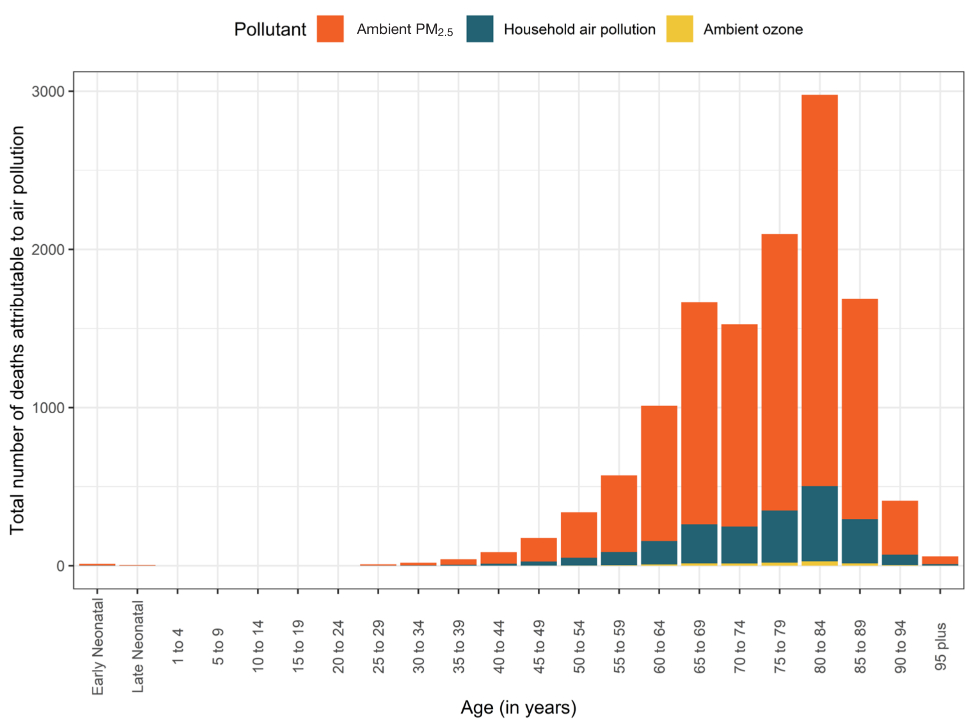


FIGURE 12 Distribution of deaths linked to air pollution in 2019 in the Republic of Serbia by age (in years, except early neonatal [0 to 6 days] and late neonatal [7 to 27 days]).

BURDEN OF DISEASE LINKED TO MAJOR SOURCES OF AIR POLLUTION

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).

Use of fossil fuels (i.e., coal, oil, and natural gas) is associated with 36% of the total $PM_{2.5}$-related deaths in the Republic of Serbia.

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.

Energy production, especially by coal-fired power plants, is the dominant driver of outdoor $PM_{2.5}$ levels and the related burden on health. Coal burning itself contributed to 26% of Serbia's burden on health, the highest contribution among countries in Southeast Europe.

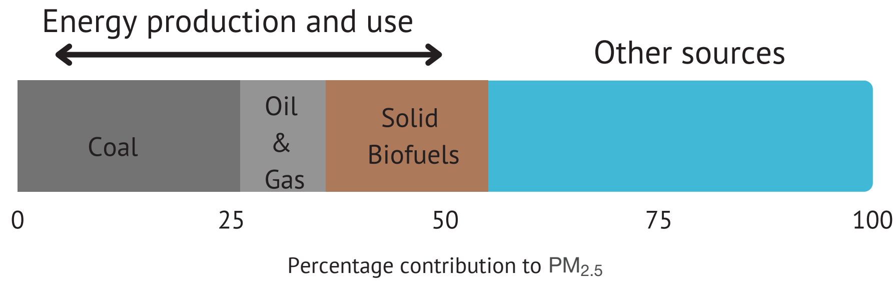


FIGURE 13 Contribution to $PM_{2.5}$ concentrations by fuel type in the Republic of Serbia in 2019 (source: McDuffie et al. 2021).

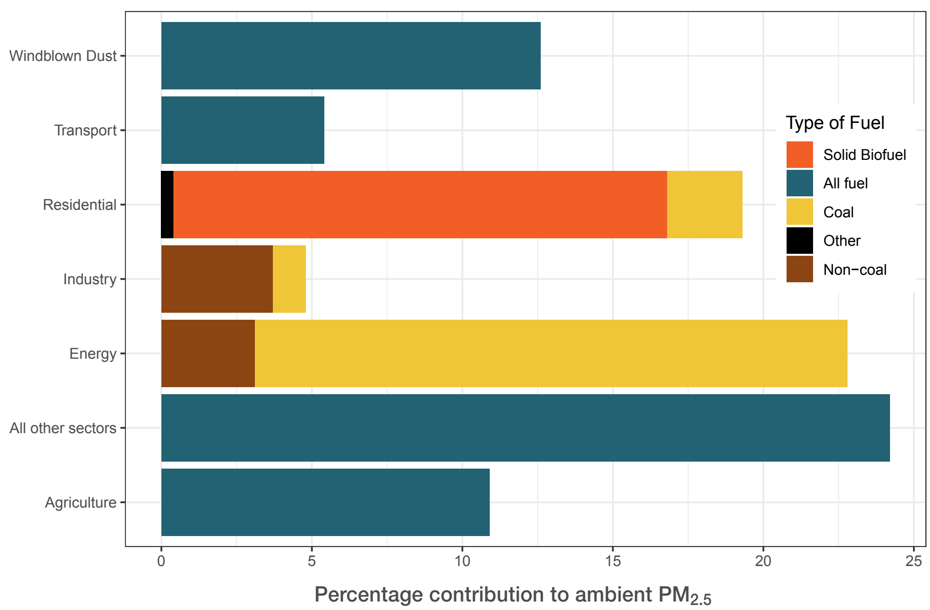


FIGURE 14 Contribution to $PM_{2.5}$ concentrations by sector in the Republic of Serbia (McDuffie et al. 2021).

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*.

CONCLUSIONS

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-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.

Implementing targeted emission reduction strategies for the largest contributors to air pollution in Serbia — energy production, residential fuel combustion, and agriculture — would greatly improve air quality and provide health, economic, and societal benefits

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.

ABBREVIATIONS

AFCID	anthropogenic fugitive, combustion, and industrial dust
ARI	acute respiratory infection
COPD	chronic obstructive pulmonary disease
COVID-19	infectious disease caused by the novel coronavirus SARS-CoV2
EEA	European Environment Agency
EU	European Union
EU-28	European Union including Great Britain
GBD	Global Burden of Disease
HEI	Health Effects Institute
IHME	Institute for Health Metrics and Evaluation
MoEP	Ministry of Environment Protection
NO_2	nitrogen dioxide
NO_x	nitrogen oxide
PAH	polycyclic aromatic hydrocarbon
$PM_{2.5}$	particulate matter ≤2.5 μm in aerodynamic diameter
PM_{10}	particulate matter ≤10 μm in aerodynamic diameter
SEPA	Serbian Environmental Protection Authority
SO_2	sulfur dioxide
SoGA	State of Global Air
UI	uncertainty interval
VOCs	volatile organic compounds
WHO	World Health Organization


Unsplash.com/Nikola Aleksic

Novi Sad, Serbia

KEY RESOURCES

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.

Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, et al. 2017. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: An analysis of data from the Global Burden of Diseases Study 2015. Lancet 389:1907–1918; *doi.org/10.1016/S0140-6736(17)30505-6*.

GBD 2019 Risk Factors Collaborators. 2020. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. Lancet 396:1223–1249; *https://doi.org/10.1016/s0140-6736(20)30752-2*.

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

Boogaard H, Walker K, Cohen A. 2019. Air pollution: The emergence of a major global health risk factor. Int Health 11:417–421; *doi.org/10.1093/inthealth/ihz078*.

Chen J, Hoek G. 2020. Long-term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis. Environ Int 143:105974; *https://doi.org/10.1016/j.envint.2020.105974*.

European Environment Agency (EEA). 2020. Air Quality in Europe — 2020 Report. Available: *https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report*.

European Parliament, Directorate-General for Internal Policies of the Union. 2021. Air pollution and COVID-19: Including elements of air pollution in rural areas, indoor air pollution and vulnerability and resilience aspects of our society against respiratory disease, social inequality stemming from air pollution. Available: *https://www.europarl.europa.eu/RegData/etudes/STUD/2021/658216/IPOL_STU(2021)658216_EN.pdf*.

Health Effects Institute. 2020. State of Global Air 2020. Data Source: Global Burden of Disease Study 2019. IHME, 2020.

Health Effects Institute. 2020. State of Global Air 2020. Explore the Data: Download Maps and Data or Create Custom Plots. Available: *https://www.stateofglobalair.org/data/#/air/plot*.

Health Effects Institute. 2022. Trends in Air Quality and Health in Southeast Europe: A State of Global Air Special Report. Boston, MA:Health Effects Institute.

Huangfu P, Atkinson R. 2020. Long-term exposure to NO_2 and O_3 and all-cause and respiratory mortality: A systematic review and meta-analysis. Environ Int 144:105998; *https://doi.org/10.1016/j.envint.2020.105998*.

World Health Organization (WHO) Regional Office for Europe. 2019. Health impact of ambient air pollution in Serbia: A call to action. Available: *https://apps.who.int/iris/handle/10665/346059*.

Sources of Air Pollution

GBD MAPS Working Group. 2016. Burden of Disease Attributable to Coal-Burning and Other Major Sources of Air Pollution in China. Special Report 20. Boston, MA:Health Effects Institute.

GBD MAPS Working Group. 2018. Burden of Disease Attributable to Major Air Pollution Sources in India. Special Report 21. Boston, MA:Health Effects Institute.

McDuffie E, Martin R, Yin H, Brauer M. 2021. Global Burden of Disease from Major Air Pollution Sources (GBD MAPS): A Global Approach. Research Report 210. Available: *https://www.healtheffects.org/publication/global-burden-disease-major-air-pollution-sources-gbd-maps-global-approach*.

Urban Air Quality

Martin RV, Brauer M, van Donkelaar A, Shaddick G, Narain U, Dey S. 2019. No one knows which city has the highest concentration of fine particulate matter. Atmos Environ 3:100040; *doi.org/10.1016/j.aeaoa.2019.100040*.

OpenAQ. 2020. Open Air Quality Data: The Global State of Play. Available: *openaq.org/assets/files/2020_OpenData_StateofPlay.pdf* [accessed 20 November 2021].

REFERENCES

Belis CA, Pisoni E, Degraeuwe B, Peduzzi E, Thunis P, Monforti-Ferrario F, et al. 2019. Urban pollution in the Danube and Western Balkans regions: The impact of major $PM_{2.5}$ sources. Environ Int 133:105158.

Bijelović S, Dragić N, Arsić M, Popović T. 2016a. Exposure to particulate matter and chronic obstructive pulmonary disease in the City of Novi Sad, Republic of Serbia. In: Proceedings of Abstracts, 10th International Conference on Air Quality – Science and Application, 14–18 March 2016, Milano, Italy. Hertfordshire, UK:University of Hertfordshire.

Bijelović S, Dragić N, Živadinović E, Bobić S, Lukić D, Torović Lj, et al. 2016b. Air pollution in the City of Novi Sad and lung cancer. In: Integrated Symposium with International Participation, 44th Conference "Air Protection 2016"/ 5th Symposium "On Flue Gas Desulphzrization" / 8th Symposium "On Ash, Slag and Waste Landfills in Power Plants and Mines" / 6th Symposium "Remediation 2016", November 2016, Serbia, Kladovo. Belgrade Serbia:Serbian Air Protection Association.

Bijelović S, Dragić N, Živadinović E. 2012. Risk analyses of air pollution due to acute respiratory infections. U: Dikić B, Dikić S, urednici. Edicija Zbornik Radova Petog međunarodnog kongresa "Ekologija, zdravlje, rad, sport"; 6–9 September 2012, Banja Luka, Republika Srpska. Banja Luka:Udruženja Zdravlje za sve.

Bogdanović CD, Nikić SD, Milošević GZ, Stanković MA. 2006. Black smoke air pollution and daily non-accidental mortality in Nis, Serbia. Cent Euro J Med 1:292–297.

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.

Dragić N, Bijelović S, Živadinović E, Bjelanović J, Velicki R, Popović M, et al. 2018. Air quality and urban population moratlity. In: Book of Abstracts, 52nd Days of Preventive Medicine International Congress, 25–28 September 2018, Niš, Serbia. Niš, Serbia:Public Health Institute Niš.

Dragić N, Bijelović S, Zivadinović E, Jovanović M, Jevtić M. 2015. Urban Air Pollution and Cerebrovascular Diseases in Novi Sad. Available: *https://doi.org/10.1093/eurpub/ckv171.009*.

Dragić N, Bijelović S, Zivadinović E, Popović M, Bobić S. 2012. Estimated health effects of air pollution in Novi Sad, Serbia. In: Abstract of Papers (CD-ROM), 14th DKMT Euroregional Conference on Environment and Health, 18–19 May 2012, Szeged, Hungary. Szeged, Hungary:Danube-Kris-Mures-Tisa Regional Cooperation.

Dragić N, Bijelović S, Živadinović E, Ristić M, Bobić S, Torović Lj. 2016. Outdoor air pollution and acute respiratory infection among population of the city of Novi Sad. In: Book of Abstracts, 50th Days of Preventive Medicine International Congress, 27–30 September 2016, Niš, Serbia. Niš, Serbia:Public Health Institute Niš.

Dragić N, Lehtomäki H, Korhonen A, Hänninen O. 2019. Health Effects of Ambient Fine Particulate Matter ($PM_{2.5}$) in Serbia. In: Book of Abstracts, 53rd Days of Preventive Medicine International Congress, 24–27 September 2019, Niš, Serbia. Niš, Serbia:Public Health Institute Niš.

EEA (European Environment Agency). 2020. Air Quality in Europe — 2020 Report. Available: *https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report*.

EU Eurostat. 2021. Inability to Keep Home Adequately Warm — EU-SILC Survey [last update: 19-11-2021]. Available: *https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_mdes01&lang=en*.

EU Projects in Serbia. 2021.Public Invitation for Participation in the Public Debate on the Draft Programme of Air Protection of the Republic of Serbia for the Period from 2022 to 2030 with the Action Plan. Available: *https://www.euzatebe.rs/en/news/public-invitation-for-participation-in-the-public-debate-on-the-draft-programme-of-air-protection-of-the-republic-of-serbia-for-the-period-from-2022-to-2030-with-the-action-plan*.

Glavonjic B. 2011. Consumption of wood fuels in households in Serbia: Present state and possible contribution to the climate change mitigation. Thermal Science; *http://dx.doi.org/10.2298/TSCI1103571G*.

GBD 2019 Risk Factors Collaborators. 2020. Global burden of 87 risk factors in 204 countries and territories, 1990–2019:A systematic analysis for the Global Burden of Disease Study 2019. Lancet; *https://doi.org/10.1016/s0140-6736(20)30752-2*.

Golusin M, Tesic Z, Ostojic A. 2010. The analysis of the renewable energy production sector in Serbia. Renew Sust Energ Rev 14:1477–1483; doi:10.1016/j.rser.2010.01.012. *https://doi.org/10.1016/j.rser.2010.01.012*.

HEI (Health Effects Institute). 2020. State of Global Air 2020. Special Report. Boston, MA:Health Effects Institute.

HEI (Health Effects Institute). 2022a. Trends in Air Quality and Health in Southeast Europe: A State of Global Air Special Report. Boston, MA:Health Effects Institute.

HEI (Health Effects Institute). 2022b. Trends in Air Quality and Health in Bulgaria: A State of Global Air Special Report. Boston, MA:Health Effects Institute.

IHME (Institute for Health Metrics and Evaluation). 2019. GBD Compare. Available: *http://vizhub.healthdata.org/gbd-compare*.

Institute of Public Health of Vojvodina. 2019. Recognition of environmental risk factors important for the prevention of chronic obstructive pulmonary disease among the population of the City of Novi Sad. Project of the City Health Administration, number KSII-51-64-16/2018. Novi Sad, 2019 [Serbian]. Available: *http://izjzv.org.rs/uploads/ddbd4a24-356a-dab0-c031-e3e5b1102a0e/Prilog%20Izvestaju%20Projekta%20zdravstvo%20HOBP%202018.pdf*.

Jevtić M, Dragić N, Bijelović S, Popović M. 2014. Cardiovascular diseases and air pollution in Novi Sad, Serbia. Int J Occup Med Environ Health 27:153–164; doi:10.2478/s13382-014-0239-y. *https://doi.org/10.2478/s13382-014-0239-y*.

Kovačević G, Tomić-Spirić V, Marinković J, Janković S, Æirković A, Milošević Djerić A, et al. 2020. Short-term effects of air pollution on exacerbations of allergic asthma in Užice region, Serbia. Postepy Dermatol Alergol; *https://doi.org/10.5114/ada.2020.96254*.

Kurilić SM, Božilović Z, Abulsba KS, Alhusein M, Ezarzah A. 2020. Contamination and health risk assessment of heavy metals in PM_{10} in mining and smelting basin Bor in Serbia. J Environ Sci Health A Tox Hazard Subst Environ Eng; *https://doi.org/10.1080/10934529.2019.1665946*.

Livingston G, Huntley J, Sommerlad A, Ames D, Ballard C, Banerjee S, et al. 2020. Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. Lancet 396:413–446; doi.10.1016/S0140-6736(20)30367-6. *https://doi.org/10.1016/S0140-6736(20)30367-6*.

Matić B, Dejanović S. 2020. Scope of air quality monitoring within the Network of Public Health Institutes in Republic of Serbia. Tehnika 75:261–265; doi:10.5937/tehnika2002261M. *http://dx.doi.org/10.5937/tehnika2002261M*.

McDuffie E, Martin R, Yin H, Brauer M. 2021. Global Burden of Disease from Major Air Pollution Sources (GBD MAPS): A Global Approach. Research Report 210. Boston, MA:Health Effects Institute.

Milosević Z, Bogdanović D, Jović S, Stanković A, Milutinović S, Rancić N. 2010. Influence of air pollution on hospital admissions for cardiovascular and respiratory diseases in Nis, Serbia. Vojnosanit Pregl; *https://doi.org/10.2298/vsp1006473m*.

Milutinović S, Nikić D, Stosić L, Stanković A, Bogdanović D. 2009. Short-term association between air pollution and emergency room admissions for chronic obstructive pulmonary disease in Nis, Serbia. Cent Eur J Public Health 17:8–13; *https://doi.org/10.21101/cejph.a3508*.

Nikić D, Bogdanović D, Stanković A, Nikolić M, Milosević Z. 2008. Impact of air pollution on the rate of hospital admission of children with respiratory diseases. Vojnosanit Pregl; *https://doi.org/10.2298/vsp0811814n*.

Nikić D, Stojanović D, Nikolić M. 2005. Effects of air pollution on children's health in Nis and Niska Banja. Vojnosanit Pregl; *https://doi.org/10.2298/vsp0508537n*.

Nikolić M, Nikić D, Stanković A. 2008. Effects of air pollution on red blood cells in children. Pol J Environ Stud 17:267–271.

Nikolić M, Stanković A, Jović S, Kocić B, Bogdanović D. 2014. Effects of air pollution on growth in schoolchildren. Coll Antropol. 38:493–497. PMID: 25144978.

Perišić M, Rajšić S, Šoštarić A, Mijić Z. 2017. Levels of PM_{10}-bound species in Belgrade, Serbia: Spatio-temporal distributions and related human health risk estimation. Air Qual Atmos Health 10:93–103. Available: *https://doi.org/10.1007/s11869-016-0411-6*.

Republic of Serbia Legal Information System. 2020. Decision on Determining the Energy Balance of the Republic of Serbia for 2020: 94 / 2019-75. Available: *http://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/vlada/odluka/2019/94/4*.

SEPA (Serbian Environmental Protection Agency). Datasets — Air Quality. Available: *http://data.sepa.gov.rs/en/dataset/kvalitet-vazduha*.

Stanković A, Mitrović V, Zivadinović R. 2011a. Influence of air pollution on pregnant women's health and pregnancy outcomes. Med Preg; *https://doi.org/10.2298/mpns1106279s*.

Stanković A, Mitrović V, Živadinović R. 2011b. Influence of air pollution on birth weight. Srp Arh Celok Lek; *https://doi.org/10.2298/sarh1110651s*.

Stanković A, Nikić D, Nikolić M. 2007. The effects of air pollution on the frequency of respiratory symptoms in the population of Nis and Niska Banja. Med Pregl; *https://doi.org/10.2298/mpns0704173s*.

Stanković A, Nikolić M. 2016. Long-term ambient air pollution exposure and risk of high blood pressure among citizens in Nis, Serbia. Clin Exp Hypertens; *https://doi.org/10.3109/10641963.2015.1060992*.

Stanković A, Nikolić M, Arandjelović M. 2011c. Effects of indoor air pollution on respiratory symptoms of non-smoking women in Niš, Serbia. Multidiscip Respir Med; *doi.org/10.1186/2049-6958-6-6-351*.

Stanković A, Nikolić M, Arandjelović M. 2011d. Effects of air pollution on red blood cells in pregnancy. Healthmed; 5:1664–1669.

Stanković A, Nikolić M, Bogdanović D. 2012. Short-term effects of black smoke on cardiovascular hospitalisation in elderly in Niš, Serbia. Chem Ind Chem Eng Q 18:661–665, 2012. *https://doi.org/10.2298/CICEQ120103107S.*

Stojić SS, Stanišić N, Stojić A, Šoštarić A. 2016. Single and combined effects of air pollutants on circulatory and respiratory system-related mortality in Belgrade, Serbia. J Toxicol Environ Health A; *https://doi.org/10.1080/15287394.2015.1101407*.

Stosic LT, Dragić N, Stojanovic D, Lazarevic K, Bijelovic S, Apostolovic M. 2021. Air pollution and hospital admissions for respiratory diseases in Nis, Serbia. Pol J Environ Stud; *https://doi.org/10.15244/pjoes/132796*.

Todorović M. 2020. Determining the Origin of $PM_{2.5}$ Aerosol Fraction in a Belgrade Urban Boundary Area Using Complemental Statistical Methods [PhD dissertation]. Belgrade, Serbia:University of Belgrade, Faculty for Physical Chemistry.

UN (United Nations) Serbia. 2021. UN Serbia and Partners Launch a New Initiative to Address Air Pollution from Domestic Heating. Available: *https://serbia.un.org/en/143480-un-serbia-and-partners-launch-new-initiative-address-air-pollution-domestic-heating* [accessed 16 November 2021].

WHO (World Health Organization) Regional Office for Europe. 2019. Health impact of ambient air pollution in Serbia: A call to action. Available: *https://apps.who.int/iris/handle/10665/346059*.

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