World Health Organization
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Health impact of ambient air pollution in Serbia

A CALL TO ACTION

Republic of Serbia
MINISTRY OF HEALTH

РЕПУБЛИКА СРБИЈА
Министарство
заштите животне средине

REPUBLIC OF SERBIA
Ministry of
Environmental Protection

INSTITUTE OF PUBLIC HEALTH OF SERBIA
"Dr Milan Jovanovic Batut"

Abstract

This report, on a comprehensive investigation on the impact of air quality on health in Serbia, assesses the effects of air pollution on health in major cities. The results show that long-term exposure to air pollution leads to premature death for a relevant percentage of the population, and short-term exposure to air pollution increases mortality risk. The investigation collected data on air quality, the population and its health in 2010–2015. Levels of pollutants exceeding the values of the WHO air quality guidelines and the limits set by European Union legislation on air quality were recorded in several Serbian cities. The WHO AirQ+ software was used to calculate the proportion of deaths due to air pollution for the main Serbian cities. The analysis of the national data shows that nearly 3600 premature deaths every year are attributable to exposure to fine particulate matter measuring ≤ 2.5 μm ($PM_{2.5}$) in 11 studied cities in Serbia. Simulations of progressive reductions in current $PM_{2.5}$ concentrations point towards major health benefits from improving air quality in the country. The results of this analysis indicate the importance of a reliable monitoring of air quality and the need for interventions to reduce the burden of air pollution in Serbia.

Keywords

AIR POLLUTION
EXPOSURE
HEALTH IMPACTS
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Abbreviations

ALRI	acute lower respiratory infections
CI	confidence interval
COPD	chronic obstructive pulmonary disease
DALY	disability-adjusted life year
IHD	ischaemic heart disease
NO2	nitrogen dioxide
NCD	non-communicable disease
PM	particulate matter
$PM_{2.5}$	fine particulate matter measuring ≤ 2.5 μm
O_3	ozone
SEPA	Serbian Environmental Protection Agency
SO_2	sulfur dioxide
YLL	years of life lost

Acknowledgment

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Foreword

Air pollution from both outdoor and indoor sources represents the single largest environmental risk to health globally. WHO estimated that air pollution was responsible for more than 550 000 premature deaths in the WHO European Region in 2016, almost 6 600 of which were attributed to air pollution in Serbia. This disease burden is preventable, if air quality improves.

Air pollution can affect health in many ways and have both long- and short-term effects. New data have revealed a stronger link between exposure to both indoor and outdoor air pollution and cardiovascular diseases, such as stroke and ischaemic heart disease, and cancer. In addition, air pollution causes respiratory diseases, including acute respiratory infection and chronic obstructive pulmonary disease. Further, the International Agency for Research on Cancer has classified air pollution in general, as well as particulate matter as a separate component of air pollution mixtures, as carcinogenic.

Air pollution affects different groups of people in different ways. The health effects are more severe for people who are already ill. Vulnerable populations – such as children, and people who are elderly or members of households with low incomes and limited access to health care– are more susceptible to the adverse effects.

Assessments of the health impacts of air pollution based on national and subnational data are the starting point for developing or adjusting policies and measures to protect people's health. Sound policy-making requires good-quality data and reliable monitoring and reporting systems for air quality and health. Facing such technical challenges supports policy development and provides a solid basis for measuring the progress expected from improving air quality. It also supports a debate on possible policy options that address the main drivers of air pollution, including energy and transport policies.

Through strong collaboration, countries and WHO can effectively tackle these challenges. The declaration of the Sixth Ministerial Conference on Environment and Health, adopted by all WHO European Member States in June 2017 in Ostrava, Czechia, focuses on improving indoor and outdoor air quality for all. Further, reducing the number of deaths and cases of illness due to poor air quality will contribute to achieving Sustainable Development Goals 3 (on ensuring healthy lives and promoting well-being) and 11 (on making cities inclusive, safe, resilient and sustainable).

Serbia and the WHO European Centre for Environment and Health of the WHO Regional Office for Europe have a long history of collaboration, using WHO tools and methods to quantify both the health effects of air pollution and the benefits of reducing such pollution as a basis for public policy actions in non-health sectors to improve air quality. We at the Regional Office hope that this report will provide useful evidence to support Serbia's efforts to improve air quality and tackle the associated burden on health. The Regional Office will support Serbia in fulfilling its international commitments and achieving its goal of creating healthy, safe, supportive environments for all.

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Executive summary

This report summarizes an extensive analysis of air quality and its impacts on health in Serbia, which was conducted by the WHO European Centre for Environment and Health of the WHO Regional Office for Europe in cooperation with technical experts from Serbia, and concluded in early 2018. The main institutions in Serbia contributing to this work included the Dr Milan Jovanović Batut Institute of Public Health of Serbia, the Statistical Office of the Republic of Serbia, the Serbian Environmental Protection Agency (SEPA), the Institute of Public Health of Belgrade, and the City of Belgrade's Secretariat for Environmental Protection.

The analysis was based on national data and was made using the WHO AirQ+ software. This report provides policy-makers with an overview of air quality and the health impacts of exposure to air pollution in Serbia. The report is intended:

- to present estimates of the impact of air pollution on mortality;
- to describe the methods used to monitor air quality and its impact on health;
- to stimulate debate on the effects of air pollution and of policies on the health of the population of Serbia; and
- to provide evidence to inform policy-makers in devising strategies for disease prevention and health promotion.

Air pollution and its effects on health are a global concern. Exposure to air pollution, especially airborne particulate matter (PM), is associated with increased mortality and morbidity, particularly from cardiovascular and respiratory diseases. WHO estimated that exposure to ambient air pollution accounted for 4.2 million premature deaths globally in 2016, including 0.5 million in the WHO European Region. Of this total, an estimated 6 592 deaths and 131 183 years of life lost (YLL) were due to air pollution in Serbia. Details of these estimates are available on the WHO headquarters website *(1)*. These huge numbers call for policy interventions at the global, regional and national levels.

In Serbia, the state-managed system for monitoring air quality showed that the concentrations of air pollutants, particularly PM, in cities regularly exceeds the levels recommended in the WHO air quality guidelines. The results of this analysis can form the basis of a policy to improve the quality of air to reduce the health impacts of air pollution. This report provides estimates of the magnitude of these effects and simulation scenarios for reducing them by progressive decreases in the concentration of fine PM measuring ≤ 2.5 μm ($PM_{2.5}$) by 5 μg/m^3, 10 μg/m^3 and 20 μg/m^3.

The analysis is based on the concentrations of air pollutants measured in the national network of automatic monitoring stations and national data on mortality. This report describes the health impacts of long-term exposure to PM and calculations of $PM_{2.5}$ levels in 2010–2015, derived from data on PM measuring ≤ 10 μm (PM_{10}) with a conversion factor. A comprehensive (400-page) technical report, to be published later, will document the analysis also provides calculations for other air pollutants, including nitrogen dioxide (NO_2) and ozone (O_3). The main findings of the analysis for 11 Serbian cities are as follows.

- Exposure to $PM_{2.5}$ accounts for 3585 premature deaths per year, including 1796 in Belgrade. Other health outcomes are linked to exposure to NO_2 and O_3, although they are not reported here.
- Over the next 10 years, 150 865 YLL due to air pollution are expected if current levels of air pollution persist. Of these, 75 261 YLL will occur in Belgrade.

- The simulation of progressive reductions in current $PM_{2.5}$ concentrations in different scenarios (by 5, 10 and 20 μg/m^3) indicates that the number of premature deaths due to air pollution would decrease from 3585 to 2737, 1862 and 301, respectively.
- Similarly, progressive reductions in current $PM_{2.5}$ concentrations (by 5, 10 and 20 μg/m^3) would decrease the YLL due to air pollution over 10 years from 150 865 to 114 539, 77 515 and 12 508, respectively.

The overall health impact of air pollution for the whole of the urban areas in Serbia (not just the 11 cities studied in detail) was estimated at 6 394 attributable deaths.

This assessment provides evidence that significant numbers of premature deaths and YLL due to air pollution could be prevented, as well as estimates of the health gains to be made if policies and measures are put in place to reduce air pollution. The case is strong enough to justify calling for urgent action.

One group of possible interventions would directly reduce air pollution and exposure:

1. decreasing the use of solid fuels for household heating and cooking;
2. reducing emissions from industrial sites;
3. changing to more sustainable mobility;
4. improving planning to increase the energy efficiency of buildings and make cities greener and more compact;
5. increasing the use of low-emission fuels and renewable combustion-free power sources;
6. implementing strategies for waste reduction, separation, recycling and reuse; and
7. improving communication and awareness of risks.

These actions should ideally be part of an integrated environmental monitoring framework. Policies for reducing air pollution should be used as an opportunity to take a cross-sectoral approach to air quality management, with shared targets and coordinated interventions across the relevant sectors, such as energy, transport, waste management and agriculture.

Another group of possible actions includes building public health professionals' capacity to introduce contemporary methods for health impact assessment and environmental risk monitoring and to fill gaps in knowledge and epidemiological and air pollution data. Appropriate actions would include: increasing national technical capacity, implementing national strategies for monitoring and mapping environmental risks and their relation to specific health outcomes, and conducting environmental epidemiological surveillance.

Further means of addressing the major public health challenge of air pollution in Serbia include strengthening intersectoral and multistakeholder cooperation. The Declaration of the Sixth Ministerial Conference on Environment and Health *(2)*, held in Ostrava, Czechia in 2017, often called the Ostrava Declaration, provides a framework for designing a national portfolio of actions whose objective is to "[i]mprove outdoor and indoor air quality as one of the most important environmental risk factors in the Region through actions towards meeting the WHO air quality guideline values in a continuous process of improvement". Sustained work to improve the health of the citizens of Serbia by improving air quality will also contribute to achieving the relevant targets in the 2030 Agenda for Sustainable Development *(3)*.

1. Background

1.1 Air pollution as a public health issue, globally and in Europe

Exposure to air pollution, especially airborne PM, is associated with increased mortality and morbidity, particularly from cardiovascular and respiratory diseases. According to the latest published data, ambient (outdoor) air pollution is one of the main environmental health problems. In 2016, exposure to $PM_{2.5}$ caused an estimated 4.2 million premature deaths globally, including some 0.5 million in the WHO European Region *(1)*.

Air pollution is an important risk factor for noncommunicable diseases (NCDs). The United Nations high-level meeting on NCDs, held in September 2018, recognized air pollution as one the five major risk factors, alongside tobacco smoking, the harmful use of alcohol, physical inactivity and unhealthy diets *(4)*.

1.1.1 WHO policy framework for air quality

The WHO policy framework for air quality comprises several important components.

- Adopted by the Sixty-eighth World Health Assembly in 2015, resolution WHA68.8 on health and the environment: addressing the health impact of air pollution *(5)* recognizes clean outdoor and indoor air as a basic right and the urgent need for the health sector's involvement in the response to the effects of air pollution on health. It urges Member States to take action to raise awareness among the public and stakeholders of the health risks posed by air pollution, facilitate research, collect data on air quality and conduct surveillance of diseases related to air pollution.
- The road map for an enhanced global response to the adverse health effects of air pollution in 2016–2019, adopted at the Sixty-ninth World Health Assembly, provides a global framework for the actions of Member States, WHO and other stakeholders, in which the health sector is to take a leading role in raising awareness of both the impacts of air pollution on health and opportunities for public health *(6)*. It sets out the path towards an enhanced global response in four areas: expanding the knowledge base, monitoring and reporting, global leadership and coordination, and strengthening of institutional capacity.
- The targets of the Sustainable Development Goals related to air pollution include target 3.9 (by 2030. substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination), target 7.1 (by 2030, ensure universal access to affordable, reliable, modern energy services) and target 11.6 (reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management) *(3)*.
- Health 2020, the European policy framework, supports action for health and well-being across government and society, including the development of national and subnational health policy, and strategic and technical leadership in governance for health and health equity, particularly on the social determinants of health, gender, human rights and vulnerabilities *(7)*.
- The Ostrava Declaration *(2)* recognizes air quality as one of the priorities for action and encourages Member States in the WHO European Region to improve ambient and indoor air quality to meet the WHO air quality guidelines and other commitments and processes.

1.2 Air quality in Serbia

Air pollution contributes significantly to the overall burden of disease and premature death in Serbia, which has higher estimates of premature death due to air pollution than most countries in the European Union. Assessments of air quality based on data from monitoring stations managed by national authorities indicate that the concentrations of air pollutants, especially PM, regularly exceed the levels that protect human health. The latest WHO estimate of the annual mean $PM_{2.5}$ concentration in the country is 19.4 μg/m^3, with a slightly higher mean in urban than in rural areas: 21.0 μg/m^3 and 19.4 μg/m^3, respectively *(8)*. These figures are much higher than the average annual mean $PM_{2.5}$ concentration calculated by WHO for the European Region as a whole (14.0 μg/m^3).

The main sources of outdoor air pollution in Serbia include the energy sector (thermal power plants, district heating plants and individual household heating), the transport sector (an old vehicle fleet), waste dump sites and industrial activities (oil refineries, the chemical industry, mining and metal processing and the construction industry). The specific documented sources of air pollution include: the petrochemical industry complex in Pančevo and Novi Sad; cement factories in Popovac, Kosjerić and Beočin; chemical plants and metallurgical complexes in Smederevo, Sevojno and Bor; thermal power plants in Obrenovac, Lazarevac and Kostolac; fossil fuel-based individual household heating in periurban and rural towns; and increasing road traffic, especially in large cities such as Belgrade, Novi Sad and Niš.

1.3 Impacts of air quality on health in Serbia

Several international assessments – made by, for example, WHO, the European Environment Agency and the Institute for Health Metrics and Evaluation – estimate the health impact of air pollution in Serbia *(9–12)*. These assessments and analyses use internationally available datasets but base their calculations on different assumptions. Thus, the estimates for Serbia vary somewhat, and an analysis of the impacts of air quality on health based on national and subnational data is a better guide for policy in countries, including in municipalities.

Using data from 2012, WHO estimated the health burden of ambient air pollution in Serbia to be 5 435 premature deaths, 126 637 YLL and 129 313 disability-adjusted life-years (DALYs), although these figures were considered to underestimate the impact of air pollution, "as [they do] not include the separate impacts of health from other air pollutants … and [exclude] health impacts where evidence is still limited (e.g. pre-term birth or low birth weight)" *(8)*. More recent global estimates of the health burden of ambient air pollution were 6 592 premature deaths, 131 183 YLL and 137 609 DALYs. Those for specific causes of death are shown in Table 1. The Institute for Health Metrics and Evaluation ranked household and ambient air pollution as the seventh and eighth leading risk factors, respectively, for most of the disease burden in Serbia *(12)*.

The burden of disease also has an economic impact. A 2015 study by the WHO Regional Office for Europe and the Organisation for Economic Co-operation and Development *(13)* estimated that the cost of premature deaths due to air pollution represented over 33% of Serbia's gross domestic product. Lost working days due to short-term exposure to $PM_{2.5}$ in Serbia and Montenegro (almost 2.5 million days) were equivalent to a loss of € 324 million per year *(14)*.

1.4 Rationale for a new analysis of air quality and health in Serbia

Against this background, the analysis presented here aimed to use national and subnational data to assess air quality in Serbia and to provide evidence of the impact of air pollution on mortality. The analysis used the publicly available WHO software AirQ+ to quantify the health impacts of exposure to air pollution *(15)*.

The data were obtained from the country's air quality monitoring stations, which measure PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2), NO_2 and O_3. Data were collected for the period 2010–2015 from the national network of stations for automatic air quality monitoring operated by SEPA and from the state and local network of the City of Belgrade, managed by the Institute of Public Health of Belgrade. The analysis covered ambient air pollution in the main Serbian cities with air pollution monitoring stations, covering about 30% of the total Serbian population. This summary report focuses on pollution by PM and on its long-term effects on health. The full technical report includes other air pollutants.

Table 1. Serbia: estimates of premature death, YLL and DALYs attributable to ambient air pollution in 2016

Cause of death	Numbers of deaths				YLL				DALYs			
	Total	F	M	CI	Total	F	M	CI	Total	F	M	CI
All	6 592	2 979	3 613	5 473–7 864	131 183	50 696	80 487	112 190–151 661	137 609	53 754	83 855	117 303–158 824
Acute lower respiratory infections (ALRI)	289	128	161	177–411	5 763	2 287	3 477	3 541–8 212	5 840	2 321	3 520	3 588–8 322
Chronic obstructive pulmonary disease (COPD)	813	314	499	437–1274	14 640	5 347	9 293	7 868–22 932	16 799	6 197	10 603	9 029–26 314
Lung cancer	802	216	586	449–1213	21 260	5 764	15 496	11 896–32 123	21 444	5 819	15 625	11 999–32 401
Ischaemic heart disease (IHD)	3 111	1 469	1 641	2 325–3 879	61 387	23 632	37 755	49 277–72 206	62 044	23 922	38 122	49 814–72 993
Stroke	1 577	852	725	1 047–2 400	28 132	13 665	14 467	21 204–37 326	31 481	15 495	15 986	23 807–41 751

Notes. F = females; M = males; CI = 95% confidence interval.

Source: Ambient (AAP) air pollution attributable burden of disease, 2016 (May 2018) *(1)*.

2. Existing knowledge base

This section presents the results of studies by Serbian institutions and experts, which were used as the basis for the assessment described in section 3. Individual studies are not cited; Annex 1 lists the publications consulted, as well as Serbian legislation.

2.1 Investigations of air pollution and its effects on health in Serbia

The rich literature on air pollution and, to a lesser extent, on effects on health in Serbia comprises a large knowledge base, reflects strong interest in the research community and confirms the country's extensive scientific and expert capacity (see Annex 1). Studies address topics ranging from legislative aspects to monitoring, including with bioindicators. Several studies were conducted to characterize air pollutants and their effects on urban populations, and these were used to better frame the overall estimates of the effects of air pollution derived by application of AirQ+. The results for Belgrade and cities with industrial facilities, such as Bor and Niš, are summarized here.

In Belgrade, the research provides evidence of an anthropogenic impact of air pollution, with significant deposition of heavy metals, mainly from intensive vehicular traffic and fossil fuel combustion; road dust is another source of PM in the city. Seasonality and exacerbation of air pollution due to winter heating have been reported. Other studies provide evidence of the production of secondary aerosols and movement of air masses, which affect local pollution, such as the contribution of the power plant in Obrenovac, with air masses from the south-west. The effects of transboundary air pollution from eastern and western Europe were also estimated. Epidemiological studies of the association between air pollution and health indicate a risk related to exposure to carcinogens such as chromium and arsenic, especially in areas with coal mining and coal combustion. Another study described the impact of long-term exposure to PM_{10}, NO_2, SO_2 and soot on mortality rates.

High levels of SO_2 and metals or metalloids, such as arsenic, lead and cadmium, were found in Bor, where copper is mined and smelted, in 2004–2015. Pollution was also found in soil and lake water. One study found a statistically significant association between the number of days on which the statutory $PM_{2.5}$ level in ambient air was exceeded and the number of cases of moderate exacerbation of respiratory symptoms in subgroups of adults (with asthma or COPD) registered in a secondary care hospital.

Several studies addressed the correlation between exposure to air pollution in Niš and anaemia, allergy and skin symptoms, as well as effects on the respiratory system.

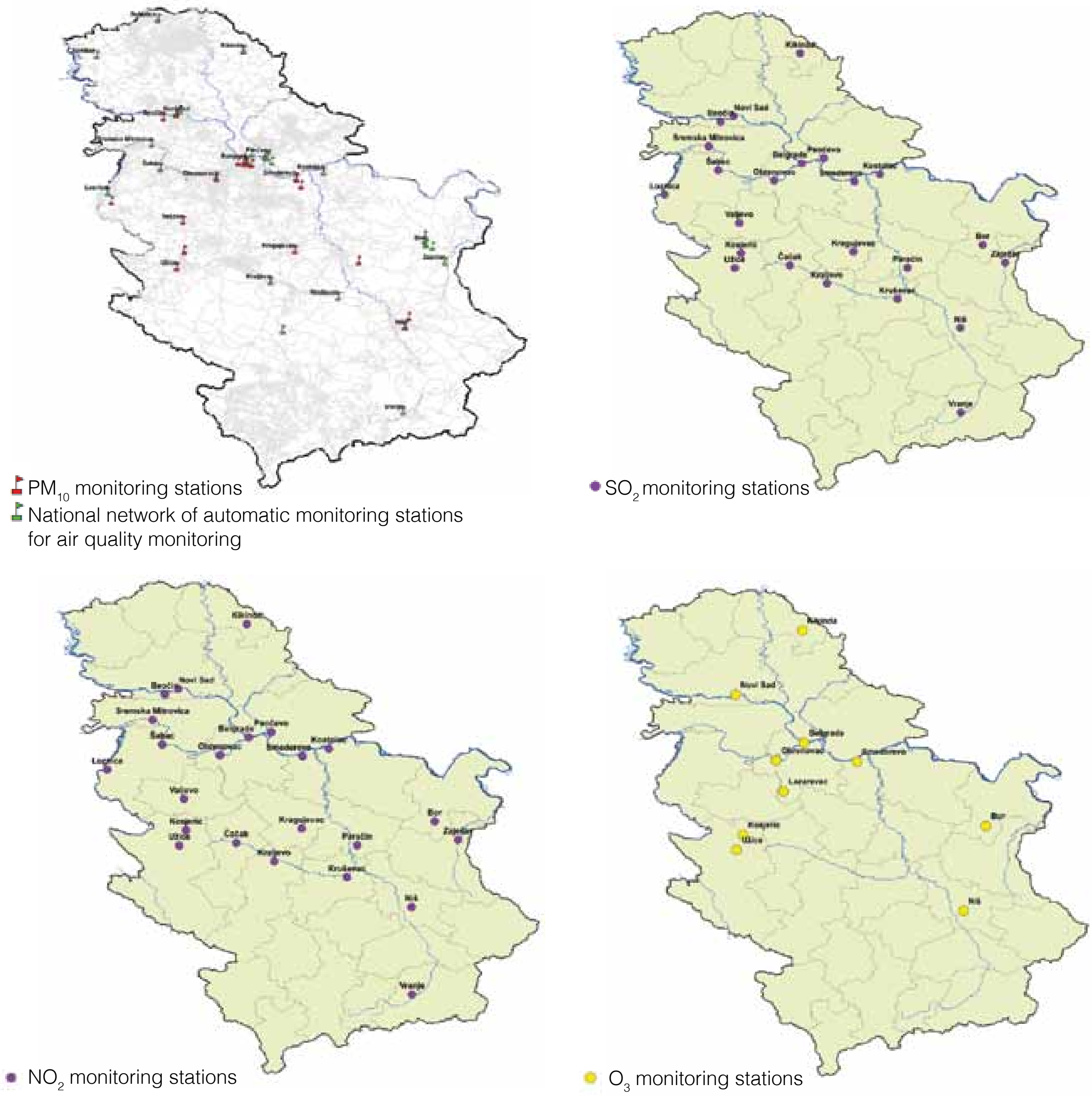
Overall, studies on air quality are more numerous than those on the association between air pollution and health; this was one of the reasons for performing the study described here. Nevertheless, there is a recognized need for further research to estimate the size of the population affected by air pollution and the health impacts of different sources of pollution, such as industry, traffic and heating.

2.2 National network of stations for automatic air quality monitoring

Since 2006, SEPA has been responsible for the establishment and operational functioning of a national system for automatic air quality monitoring. SEPA is mandated by law to use the national network to monitor and to publish an annual report on air quality in Serbia (articles 13 and 67, respectively, of the Law on Air Protection). The first automatic monitoring stations were set up in Smederevo and Bor. The European Commission supplied monitoring equipment within the programme for Community Assistance for Reconstruction, Development and Stabilisation. After completion of the programme in 2011, the European Union introduced the Instrument for Pre-accession Assistance in 2012, which supported the establishment of an integrated environmental monitoring system for air and water quality and included the supply of information and communication technology, and equipment and software for air quality monitoring. The aim was to support the collection, updating and processing of data from automatic air quality monitoring by the national network, for reporting at the national and European Union levels.

The national network comprises 47 stations, 33 in the national SEPA network and 14 in local networks. The monitoring stations collect measurements of PM, NO_2, SO_2, O_3 and other pollutants such as carbon monoxide, and the results are publicly available in real time. Fig. 1 shows the locations of the stations in the national network according to the pollutants measured. Serbia participates in t*he European Monitoring and Evaluation Programme under the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution* and regularly reports the results. The country also reports annually on air quality monitoring to the European Environment Agency.

Fig. 1. Coverage of the national network of automatic monitoring stations



Data from air quality monitoring can only be used to assess health effects if the monitoring is regular and continuous. Table 2 shows the continuity and discontinuity of monitoring by monitoring stations. As air pollution depends on the characteristics of a region or city, the investigators prepared a descriptive form for each city with its main features, such as topography, climate, traffic dynamics, urban structure, industry and heating system. The term the city of Belgrade means the metropolitan area of the city, while the term Belgrade refers to the municipal area only. The city of Belgrade comprises six municipalities (Novi Beograd, Savski Venac, Stari Grad, Rakovica, Vračar and Zvezdara) and parts of the territories of another four municipalities (Voždovac, Zemun, Palilula and Čukarica). The metropolitan area of Belgrade is divided into 17 municipalities, 10 urban (Čukarica, Novi Beograd, Palilula, Rakovica, Savski Venac, Stari Grad, Surčin, Voždovac, Vračar, Zemun and Zvezdara) and seven suburban (Barajevo, Grocka, Lazarevac, Mladenovac, Obrenovac and Sopot).

Table 2. Continuity and discontinuity of PM_{10} monitoring at SEPA monitoring stations, 2010–2015

Measurement site	Continuity (Yes) and discontinuity (No)					
	2010	2011	2012	2013	2014	2015
Beočin, centre	No	No	No	Yes	Yes	No
Belgrade						
Novi Beograd	Yes	Yes	Yes	Yes	Yes	No
Stari Grad	Yes	Yes	Yes	Yes	No	No
“Mostar“	Yes	Yes	Yes	Yes	Yes	No
Zeleno Brdo	No	Yes	Yes	Yes	No	Yes
Vračar	No	No	Yes	Yes	Yes	Yes
Kosjerić	No	Yes	Yes	Yes	Yes	No
Kragujevac	No	No	No	No	Yes	Yes
Niš						
Kamenički Vis–EMEP	No	No	Yes	Yes	Yes	Yes
IZJZ Niš	Yes	Yes	Yes	Yes	Yes	No
Novi Sad						
SPENS	No	No	No	Yes	Yes	Yes
Dnevnik	Yes	Yes	Yes	No	No	No
Obrenovac, centre	No	Yes	Yes	Yes	No	No
Popovac, Holcim	No	No	Yes	Yes	No	No
Smederevo						
Centre	No	No	No	Yes	No	No
Radinac	Yes	Yes	No	No	No	No
Ralja	No	Yes	Yes	No	No	No
Užice	No	No	No	Yes	Yes	Yes
Valjevo	No	No	Yes	Yes	Yes	Yes
Zajača	No	No	Yes	Yes	Yes	Yes

Fig. 2 shows the locations of the 11 cities assessed for PM_{10} concentrations, and Fig. 3, the administrative structure of the city of Belgrade. Belgrade has an extended network of 24 air quality monitoring stations, run by different agencies.

Fig. 2. Cities in which PM_{10} concentrations were analysed

Fig. 3. City of Belgrade

Note. The terms New Belgrade and Old Belgrade were devised to distinguish the older and newer parts of the whole of urban Belgrade, which have different climate zones, wind rates and types of buildings. The areas covered are different from the municipalities of Novi Beograd and Stari Grad.

2.3 Data from the automatic monitoring stations

Operating monitoring stations produce daily data on the concentrations of pollutants. Table 3, Fig. 4 and Table 4 show examples of the information derived from the data: levels of PM_{10} during 2010–2015, the period for which the latest national data on mortality by age were available.

The impacts of long-term exposure to fine PM on mortality rates were estimated for $PM_{2.5}$ from values for PM_{10} according to a ratio of $PM_{2.5}$:PM_{10}, obtained from data recorded at monitoring stations that measure both. In 2015, this ratio was 0.81 in Belgrade, 0.79 in Lazarevac and 0.85 in Obrenovac.

Table 3 indicates that, in several years, the average concentrations of PM_{10} were higher than the WHO interim target 2 (50 μg/m³) set in the air quality guidelines for human health protection *(17)*. For PM_{10}, WHO interim target 1 is 70 μg/m³; interim target 2 is 50 μg/m³; interim target 3 is 30 μg/m³, and the air quality guideline is 20 μg/m³. For example, values ≥ 50 μg/m³ were found in Smederevo in all years in which monitoring was conducted (2010–2013). Fig. 4 and Table 4 shows the numbers of days on which the level of 50 μg/m³ was exceeded.

Table 3. Annual levels of PM_{10} and average levels of PM_{10} and $PM_{2.5}$ for 2010–2015 in 11 cities and towns in Serbia, by city, 2010–2015

City/Town	PM_{10} (μg/m³)							$PM_{2.5}$ (μg/m³)
	2010	2011	2012	2013	2014	2015	Average, 2010–2015	Average, 2010–2015
Belgrade	39.0	54.2	46.4	41.2	40.7	47.6	44.9	29.19
Obrenovac	37.5	68.1	56.4	41.2	41.0	50.6	49.1	31.92
Lazarevac	52.2	69.8	46.6	48.8	94.9*	45.4	52.6	34.19
Novi Sad	35.8	44.5	35.4	32.6	21.3	40.7	35.1	22.82
Beočin	NA	NA	NA	38.1	30.2	NA	34.2	22.23
Smederevo	60.7	77.0	50.2	54.2	NA	NA	60.5	39.33
Kragujevac	NA	NA	NA	NA	42.2	51.8	47.0	30.55
Užice	NA	NA	NA	61.5	67.2	76.1	68.3	44.39
Kosjerić	NA	63.2	52.6	40.2	35.3	NA	47.8	31.07
Niš	50.9	67.0	37.9	30.8	38.3	NA	45.0	29.25
Valjevo	NA	NA	62.8	63.1	76.0	72.5	68.6	44.59

Note. NA means that measurements were made on fewer than 180 days in a year.

Fig. 4. Numbers of days per year with PM_{10} concentrations over 50 μg/m³ in Serbian cities, 2010–2015

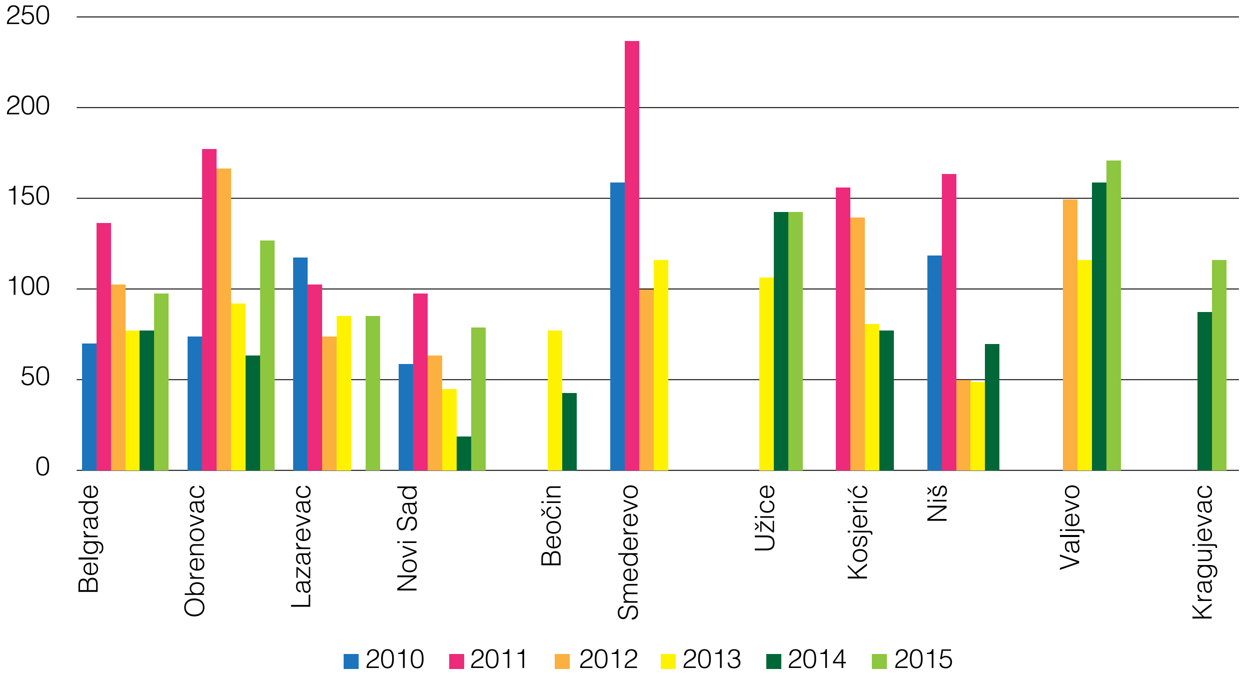


Table 4. Numbers of days per year with PM_{10} concentrations over 50 μg/m³ in Serbian cities, 2010–2015

City/Town	Days					
	2010	2011	2012	2013	2014	2015
Belgrade	72	140	106	80	81	101
Obrenovac	77	180	170	95	66	130
Lazarevac	120	107	76	88		89
Novi Sad	61	102	66	47	21	82
Beočin	–	–	–	80	45	–
Smederevo	161	240	102	119	–	–
Užice	–	–	–	110	146	146
Kosjerić	–	159	142	83	80	–
Niš	121	–	52	52	73	–
Valjevo	–	–	153	118	162	174
Kragujevac	–	–	–	–	90	120

The information given above is also available for other pollutants. To illustrate, Table 5 presents the annual average concentrations of NO_2 at Serbian monitoring stations.

Table 5. Annual average concentrations of NO_2 (μg/m³) and average for 2010–2015, by city

City/Town	2010	2011	2012	2013	2014	2015	Average, 2010–2015
Belgrade	33.2	40.8	43.0	31.5	29.2	34.3	35.3
Obrenovac	NA	16.4	25.8	NA	NA	22.5	21.6
Novi Sad	69.3	61.7	19.0	18.8	NA	NA	42.2
Beočin	NA	NA	NA	24.4	19.1	NA	21.8
Smederevo	16.4	18.8	16.8	13.8	26.6	15.3	18.0
Kragujevac	29.1	53.7	21.5	26.9	NA	29.8	32.2
Užice	44.9	NA	50.6	48.7	32.2	38.4	43.0
Kosjerić	NA	16.4	18.8	12.9	NA	NA	16.0
Niš	36.4	23.2	33.3	25.9	21.8	26.0	27.8
Valjevo	30.9	18.9	28.3	34.2	21.7	20.7	25.8

3. Estimates of the health impact of PM pollution

This section gives the methods and results of the assessment of the effects of PM on health. The most recent data (from 2015) on health and mortality attributable to different causes were retrieved from the Statistical Office of the Republic of Serbia *(18)*. The causes of death considered were: lung cancer, COPD, IHD, stroke, respiratory diseases, cardiovascular diseases and acute lower respiratory tract disease (for children aged 0–4 years).

The analysis also used the most recent data (2015) for the population. Serbia had a population of 7 095 383, comprising 3 640 048 females and 3 455 335 males; Belgrade had 1 364 453 inhabitants. Population ageing is significant, with 17.4% of the population aged ≥ 65 years in 2011, which has implications for the overall burden of disease related to exposure to external factors, including air pollution.

Further, the assessment used data on populations at risk, which were calculated for the age groups aged ≥ 30 years and ≥ 25 years, depending on the health outcome assessed and the availability of relative risks. The at-risk population of adults aged ≥ 30 years was estimated to be 4 842 068, equivalent to 68.24% of the total Serbian population. The population of adults aged ≥ 25 years was estimated to be 5 295 163, equivalent to 74.63% of the Serbian population.

3.1 Methods

The AirQ+ software, developed by the WHO Regional Office for Europe and available online for downloading, allows estimation of ambient and household air pollution *(15)*. The investigators assessed only ambient air pollution and the long-term effects of exposure to PM, the most significant component of air pollution, as it is strongly correlated with other air pollutants and a variety of adverse health outcomes. $PM_{2.5}$ is considered to be a greater threat to health than PM_{10}, as smaller particles are more likely to be deposited deep in the lung and throughout the body. The long-term effects of $PM_{2.5}$ therefore provide a good picture of the health consequences of air pollution.

The method is based on the recent WHO recommendations for concentration–response functions developed in the Health Risks of Air Pollution in Europe project *(18)*. The calculations of cause-specific effects on mortality are based on the burden-of-disease method calculation for 2012 and include relative risks for five diseases: acute lower respiratory tract disease in children, and COPD, lung cancer, IHD and stroke in adults. They are also based on average concentrations. The average annual concentration of ambient particles is usually recognized as a primary exposure measure.

Two options to reduce the health impact were considered:

- comparison of actual $PM_{2.5}$ levels with a hypothetical scenario of compliance with the WHO air quality guidelines *(17)*, which would require a reduction of $PM_{2.5}$ levels to 10 μg/m^3; and
- progressive decreases in existing $PM_{2.5}$ concentrations by 5, 10 and 20 μg/m^3 over time.

3.2 Results

3.2.1 Results for 11 Serbian cities

Table 6 summarizes the estimated premature mortality attributable to levels of $PM_{2.5}$ exceeding the WHO air quality guideline of 10 μg/m³. In total, 3 585 premature deaths in the 11 cities were attributable to exposure to such levels of $PM_{2.5}$. The estimated proportion of all deaths attributable to $PM_{2.5}$ ranged from 7.1% in Beočin to 18.8% in Valjevo.

Table 6. Total long-term mortality due to $PM_{2.5}$ (cut-off = 10 μg/m³) in 11 Serbian cities

City	Mean concentration (μg/m³)	Total population	Population aged ≥ 30 years	Estimated attributable deaths		Estimated attributable proportion	
				No.	CI	%	% (95% CI)
Beočin	22.2	15 304	10 183	14	9–18	7.1	4.68–9.29
Belgrade	29.2	1 364 453	937 461	1 796	1 194–2 337	10.9	7.25–14.19
Old Belgrade	29.4	932 813	640 819	1 259	838–1639	11.0	7.34–14.37
New Belgrade	28.7	431 640	296 642	539	358–702	10.7	7.08–13.87
Kosjerić	31.1	11 341	8 234	25	17–33	11.9	7.93–15.46
Kragujevac	30.5	178 610	122 020	250	166–324	11.6	7.74–15.11
Lazarevac	34.2	57 735	37 999	104	69–135	13.5	9.05–17.54
Niš	29.2	257 883	176 513	354	236–461	10.9	7.27–14.23
Novi Sad	22.8	350 930	231 604	280	185–367	7.4	4.90–9.72
Obrenovac	31.9	72 323	48 594	117	78–152	12.3	8.24–16.04
Smederevo	39.3	105 774	70 221	223	150–287	16.2	10.87–20.85
Užice	44.4	75 805	52 856	180	121–231	18.7	12.62–23.98
Valjevo	44.6	87 944	61 802	242	164–311	18.8	12.69–24.1
All		2 578 102	2 694 948	3 585			

Note. $PM_{2.5}$ values were converted from PM_{10} values with a coefficient of 0.65.

Table 7 presents the rates of mortality attributable to $PM_{2.5}$ in terms of total deaths and YLL among adults aged ≥ 30 years. To inform policy-making, three different scenarios indicate the health benefits that could be gained through policy actions to achieve different cut-off concentrations of $PM_{2.5}$. For example, Table 7 shows that reducing the concentration of $PM_{2.5}$ could substantially decrease the number of deaths attributable to it in the 11 Serbian cities analysed. Thus, the three scenarios (reductions by 5, 10 and 20 μg/m³) would reduce the numbers of deaths from 3585 to 2737, 1862 and 301, respectively. In Belgrade, a reduction by 20 μg/m³ would drastically reduce mortality due to air pollution, theoretically to zero deaths. The number of YLL due to $PM_{2.5}$ air pollution calculated over 10 years would be 150 865 in the 11 Serbian cities analysed, including 75 261 in Belgrade. The three scenarios would decrease the number of YLL to 114 539, 77 515 and 12 508, respectively.

Table 7. Mortality attributable to $PM_{2.5}$ in 11 Serbian cities: mean concentrations, estimated numbers of attributable deaths and YLL over 10 years from all (natural) causes, adults aged ≥ 30 years

City	Current situation			Reduction by 5 μg/m³			Reduction by 10 μg/m³			Reduction by 20 μg/m³		
	Mean (μg/m³)	Estimated deaths (cut-off = 10 μg/m³)	YLL	Mean (μg/m³)	Estimated deaths	YLL	Mean (μg/m³)	Estimated deaths	YLL	Mean (μg/m³)	Estimated deaths	YLL
Beočin	22.2	14	623	17.2	8	372	12.2	3	116	2.2	0	0
Belgrade	29.2	1 796	75 261	24.2	1 348	56 183	19.2	886	36 740	9.2	0	0
Kosjerić	31.1	25	928	26.1	20	713	21.1	14	495	11.1	1	49
Kragujevac	30.5	250	10 701	25.5	192	8 175	20.5	132	5 599	10.5	7	297
Lazarevac	34.2	104	4 237	29.2	84	3 392	24.2	63	2 531	14.2	19	761
Niš	29.2	354	14 865	24.2	266	11 106	19.2	175	7 275	9.2	0	0
Novi Sad	22.8	280	11 849	17.8	174	7 296	12.8	64	2 656	2.8	0	0
Obrenovac	31.9	117	4 975	26.9	92	3 876	21.9	66	2 757	11.9	11	452
Smederevo	39.3	223	9 593	34.3	187	8 036	29.3	151	6 447	19.3	75	3 173
Užice	44.4	180	7 757	39.4	156	6 692	34.4	131	5 606	24.4	80	3 370
Valjevo	44.6	242	10 076	39.6	210	8 698	34.6	177	7 294	24.6	108	4 406
Total	32.7	3 585	150 865	27.7	2 737	114 539	22.7	1 862	77 515	12.7	301	12 508

Note. Concentrations are rounded to one decimal point; $PM_{2.5}$ values were converted from PM_{10} with a coefficient of 0.65.

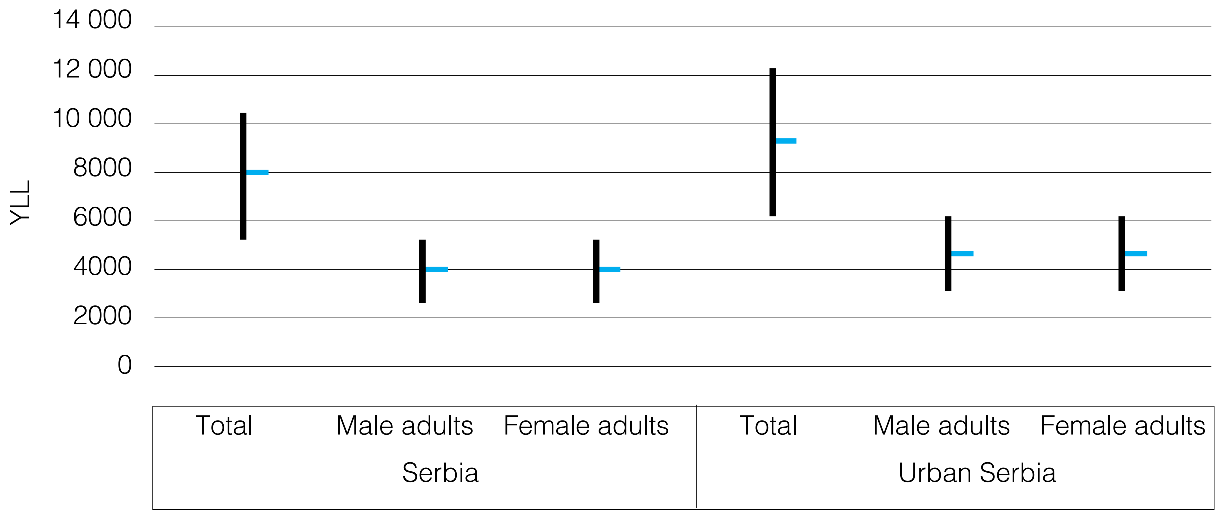
Air pollution has by far the highest impact in absolute terms in Belgrade. When estimates per 100 000 of the population at risk are presented, as in Fig. 5, the mortality rates for the 11 cities and three scenarios appear to be comparable; the existing concentration of $PM_{2.5}$ (dark-red line) appears to be associated with the highest relative health impacts of air pollution in Valjevo and Užice. Fig. 5 shows that interventions for pollution abatement would reduce premature mortality in all 11 cities.

Fig. 5. Mortality attributable to $PM_{2.5}$ in 11 Serbian cities: estimated numbers of premature deaths per 100 000

3.2.2 Results for Serbia as a whole

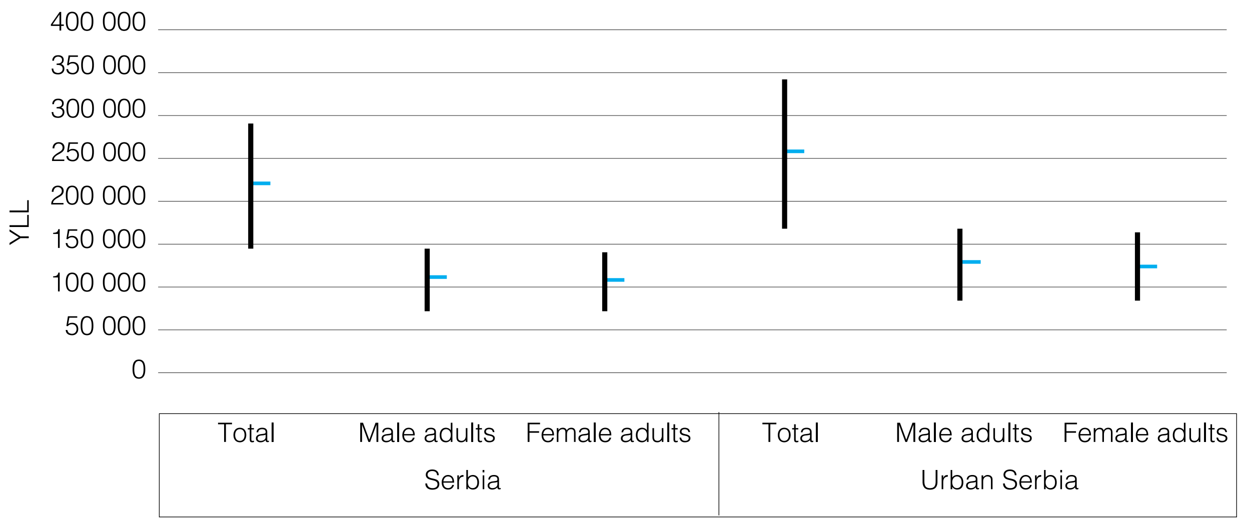
Data from urban, rural and traffic monitoring stations in Serbia were used to estimate the burden of disease at the national level on the basis of an average $PM_{2.5}$ concentration of 19.4 μg/m^3 for urban and rural areas in 2016, based on exposure in 2010–2015. Urban exposure was higher than the national average, which produces a high burden for cities when considered in isolation. Exposure to high $PM_{2.5}$ concentrations accounted for 8033 YLL (Fig. 6): slightly more for women (4040) than men (3991). The total number of YLL calculated over 10 years was 221 626 (Fig. 7): fewer for women (108 986) than men (112 076).

Fig. 6. YLL attributable to $PM_{2.5}$ in 2016 for adults aged ≥ 30 years, in urban and rural areas and per 100 000 population in urban Serbia



Note. The vertical lines show the 95% CIs.

Fig. 7. YLL attributable to $PM_{2.5}$ over 10 years among adults aged ≥ 30 years, in urban and rural areas and per 100 000 population in urban Serbia



Note. The vertical lines show the 95% CIs.

Table 8, Fig. 8 and Table 9 summarize the health effects of air pollution when considering the whole of the urban areas in Serbia, not just the 11 cities studied. The YLL can be interpreted as years of life gained by the population if there is a significant reduction in air pollution (Fig. 8 and Table 9).

Table 8. Estimated annual mortality attributable to $PM_{2.5}$ in urban areas in Serbia, adults aged ≥ 30 years

Attributable deaths	Estimate	Range
Proportion of the total (%)	6.4	4.2–8.4
Number	6 394	4 217–8 386
Number per 100 000 population at risk	132	87–173

Note. The proportions are rounded to one decimal point, and the numbers of attributable deaths are rounded.

Fig. 8. YLL due to $PM_{2.5}$ under three scenarios: annual decreases in the mean concentration by 5 μg/m³, 10 μg/m³ and 20 μg/m³

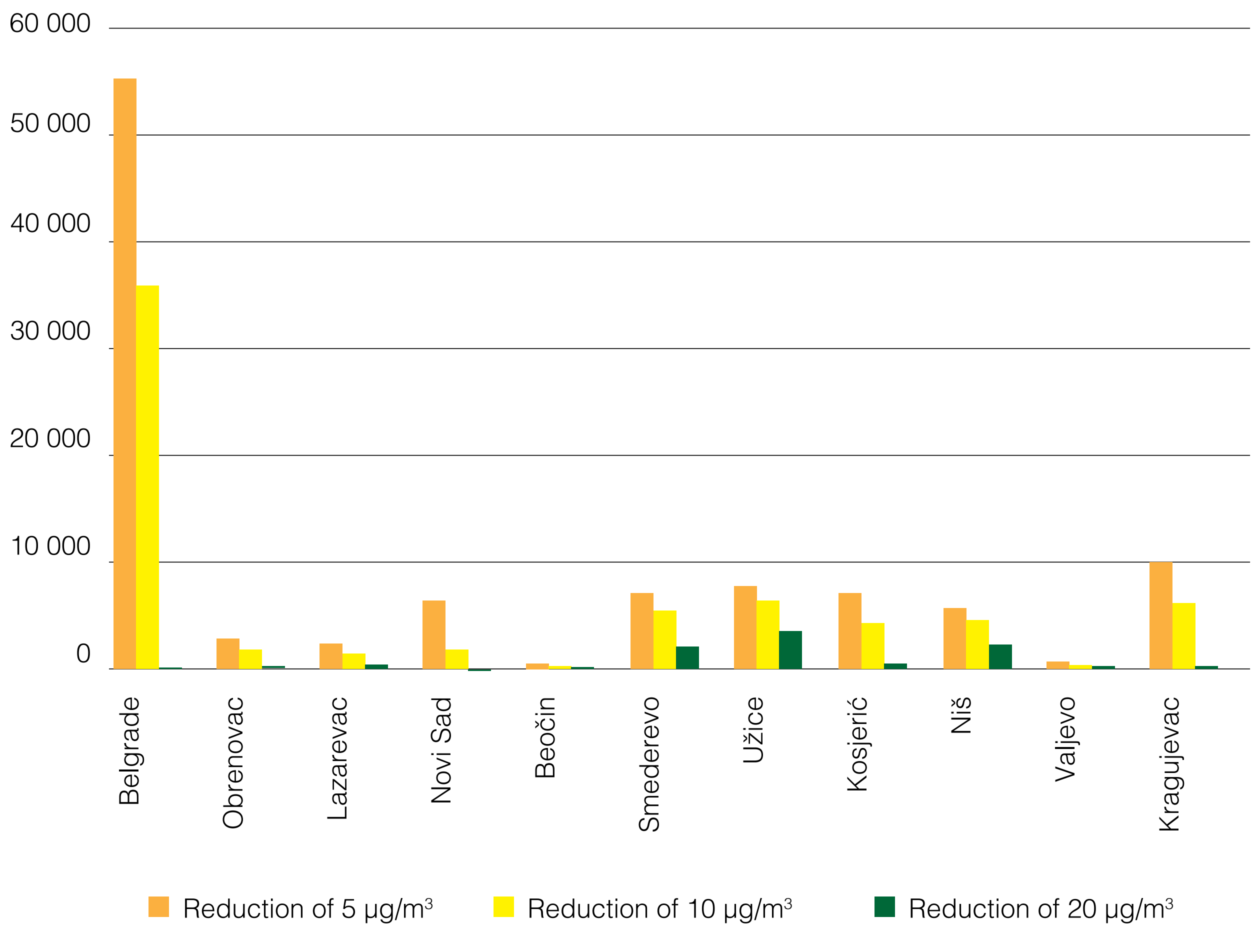


Table 9. YLL due to $PM_{2.5}$ under three scenarios: annual decreases in the mean concentration by 5 μg/m³, 10 μg/m³ and 20 μg/m³

City	YLL with annual reductions of:		
	5 μg/m³	10 μg/m³	20 μg/m³
Belgrade	56 183	36 740	0
Obrenovac	3 876	2 757	452
Lazarevac	3 392	2 531	761
Novi Sad	7 296	2 656	0
Beočin	372	116	0
Smederevo	8 036	6 447	3 173
Valjevo	8 698	7 294	4 406
Kragujevac	8 175	5 599	297
Užice	6 692	5 606	3 370
Kosjerić	713	495	49
Niš	11 106	7275	0

3.3 Data limitations and gaps

The results of this analysis should be considered approximate and be used with care. One of the main reasons is that studies of mortality and air pollution show no evidence of a threshold for concentrations of air pollutants, below which adverse effects on health would not occur. Assessments only of PM are therefore commonly considered to provide conservative or underestimates. Further, estimates of mortality among adults aged ≥ 30 years do not include deaths occurring in the group aged 25–30, which are less likely but do occur.

Other important aspects to be considered for improving knowledge and monitoring of air quality and its impacts relate to the local collection, quantity and quality of data. After the end of the European Commission's support for the establishment and operation of the national network of automatic monitoring stations, these were no longer regularly maintained, affecting both data quantity and quality. PM_{10} is measured at a limited number of automatic monitoring stations, and only three SEPA stations in the national network measured $PM_{2.5}$ in 2016: two in Belgrade and one in Novi Sad. Such measurements would ideally be made throughout the country.

The continuity of measurement is another important issue; without data continuity, health impact assessments are likely to be biased. For example, a very high PM value was recorded in 2014 in Lazarevac, following prolonged discontinuity in the operation of the monitoring station (see Table 2). This value was considered unreliable and thus excluded from the calculations.

The Serbian Institute of Public Health provides national data on morbidity, but some data that are required to assess the health impact of air quality are not sufficiently comprehensive, and the quality of existing morbidity data could be improved by increasing both human and technical resources. One way to upgrade capacity would be to establish new disease registers, with links to various environmental risks. A framework for such a programme could be found in the indicators for achievement of the Sustainable Development Goals *(3)* and the provisions of the Ostrava Declaration *(2)*. The alignment of national indicators with those for achieving the Sustainable Development Goals is recommended.

4. Conclusions and possible action

The analysis presented in this report provides evidence that a significant number of premature deaths and YLL due to air pollution could be prevented if the levels of the main pollutants were reduced to comply with the values given in the WHO air quality guidelines *(17)*. As such reductions cannot be made immediately, the report presents several scenarios that provide a solid basis for urgent action. Although the cost of air pollution to human health is externalized, and is transferred from the polluting sectors to the health sector and health insurance, the overall negative economic effect is seen in lower productivity due to disease and the costs of sick leave, medical treatment, and years of life lived with disability. Improvements in air quality and the prevention of adverse effects on health would therefore have economic benefits for the whole of society.

A number of policies in various sectors could reduce air pollution. Examples include:

- in industry, introducing clean technologies to reduce smokestack emissions and improving waste management, including capturing methane gas emitted from waste sites;
- in energy, ensuring access to affordable clean energy for cooking, heating and lighting in households;
- in transport, changing to clean modes of power generation; prioritizing public transport in urban areas, walking and cycling networks and interurban rail travel; and changing to cleaner heavy-duty diesel vehicles and low-emission vehicles and fuels;
- in urban planning, improving the energy efficiency of buildings; making cities greener, more compact and thus energy efficient; and carefully planning institutions such as schools, play schools and hospitals;
- in power generation, increasing the use of low-emission fuels and renewable combustion-free power sources, such as solar, wind and hydropower; co-generating heat and power; and increasing distributed energy generation (through, for example, minigrids and rooftop solar power generation); and
- in municipal and agricultural waste management, introducing strategies for waste reduction, separation, recycling and reuse or reprocessing; improving methods of biological waste management; and, in case of incineration, using the best available technologies, with strict emission controls.

These actions should ideally be part of an integrated environmental monitoring framework.

Policies and actions to reduce air pollution should represent an opportunity for a cross-sectoral approach to air quality management, with shared targets and coordinated interventions in sectors such as transport, energy, waste and agriculture. Involving stakeholders and raising awareness and strengthening capacity in the health and other sectors are also important. A broad perspective should be taken of agendas for air quality and climate change policy, to identify synergies and maximize the health benefits.

Further, a range of interventions is available to improve knowledge production and management, from capacity building to strategic planning. They include:

- institutional capacity building and training of human resources in contemporary methods of health impact assessment and environmental risk monitoring, especially in the network of institutes of public health;

- better planning of collaboration and coordination among researchers working on the health effects of air pollution;
- better quantification of the chronic effects of pollution by identifying the determinants of differences in cities and populations' responses to exposure to air pollution and quantification of the impact of air pollution on the disease burden;
- support for comparisons of the health effects of air pollution with those in other cities and countries;
- support for regular registration of data on health and air pollution;
- the promotion of studies on the economic impact of air pollution on health;
- the monitoring and mapping of environmental risks and their relation to specific health outcomes, including environmental justice, such as the proximity of vulnerable groups to sources of pollution; and
- a programme of epidemiological surveillance.

References[1]

1. Ambient (AAP) air pollution attributable burden of disease, 2016 (May 2018). Geneva: World Health Organization; 2018 (http://www.who.int/airpollution/data/aap_bod_may2018_v0.xlsx?ua=1).
2. Declaration of the Sixth Ministerial Conference on Environment and Health. Copenhagen: WHO Regional Office for Europe; 2017 (http://www.euro.who.int/en/media-centre/events/events/2017/06/sixth-ministerial-conference-on-environment-and-health/documentation/declaration-of-the-sixth-ministerial-conference-on-environment-and-health).
3. Transforming our world: the 2030 Agenda for Sustainable Development. In: Sustainable Development Goals Knowledge Platform [website]. New York: United Nations; 2019 (https://sustainabledevelopment.un.org/post2015/transformingourworld).
4. Time to deliver: Third High-Level Meeting on Non-communicable Diseases. New York; United Nations; 2018 (http://www.who.int/ncds/governance/third-un-meeting/brochure.pdf?ua=1).
5. World Health Assembly resolution WHA68.8 on health and the environment: addressing the health impact of air pollution. In: Sixty-eighth World Health Assembly. Geneva, 18–26 May 2015. Resolutions and decisions. Annexes. Geneva: World Health Organization; 2016:20–25 (http://apps.who.int/gb/ebwha/pdf_files/WHA68-REC1/A68_R1_REC1-en.pdf#page=27).
6. Health and the environment. Draft road map for an enhanced global response to the adverse health effects of air pollution. Geneva: World Health Organization; 2016 (http://apps.who.int/gb/ebwha/pdf_files/WHA69/A69_18-en.pdf).
7. Health 2020: the European policy for health and well-being. In: World Health Organization Regional Office for Europe [website]. Copenhagen: WHO Regional Office for Europe; 2018 (http://www.euro.who.int/en/health-topics/health-policy/health-2020-the-european-policy-for-health-and-well-being).
8. Ambient air pollution: a global assessment of exposure and burden of disease. Geneva: World Health Organization; 2016 (https://www.who.int/phe/publications/air-pollution-global-assessment/en).
9. Air quality in Europe – 2015 report. Luxembourg; European Environment Agency; 2015 (EEA Report No. 5; https://www.eea.europa.eu/publications/air-quality-in-europe-2015).
10. Air quality in Europe – 2016 report. Luxembourg; European Environment Agency; 2016 (EEA Report No. 28; https://www.eea.europa.eu//publications/air-quality-in-europe-2016).
11. Air quality in Europe – 2017 report. Luxembourg; European Environment Agency; 2017 (EEA Report No. 13; https://www.eea.europa.eu//publications/air-quality-in-europe-2017).
12. Serbia. Seattle: Institute for Health Metrics and Evaluation; 2019 (http://www.healthdata.org/serbia).
13. WHO Regional Office for Europe, OECD. Economic cost of the health impact of air pollution in Europe: clean air, health and wealth. Copenhagen: WHO Regional Office for Europe; 2015 (http://www.euro.who.int/en/media-centre/events/events/2015/04/ehp-mid-term-review/publications/economic-cost-of-the-health-impact-of-air-pollution-in-europe).

[1] All electronic references were accessed on 11 January 2019.

14. Holland M (2014). Cost-benefit analysis of final policy scenarios for the EU clean air package. Version 2. Corresponding to IIASA TSAP report #11, version 1. Laxenburg: International Institute for Applied Systems Analysis (http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/TSAP_CBA_corresponding_to_IIASA11_v2.pdf).

15. AirQ+: software tool for health risk assessment of air pollution. In: World Health Organization Regional Office for Europe [website]. Copenhagen: WHO Regional Office for Europe; 2019 (http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/airq-software-tool-for-health-risk-assessment-of-air-pollution).

16. Republic of Serbia. Ministry of Environmental Protection. Environmental Protection Agency [website]. Belgrade: Serbian Environmental Protection Agency; 2019 (http://www.sepa.gov.rs) (in Serbian).

17. Air quality guidelines. Global update 2005. Particulate matter, ozone, nitrogen dioxide, and sulfur dioxide. Copenhagen: WHO Regional Office for Europe; 2006 (http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/pre2009/air-quality-guidelines.-global-update-2005.-particulate-matter,-ozone,-nitrogen-dioxide-and-sulfur-dioxide).

18. Statistical Office of the Republic of Serbia [website]. Belgrade: Statistical Office of the Republic of Serbia; 2019 (http://www.stat.gov.rs/en-us).

19. Health risks of air pollution in Europe – HRAPIE project. Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide. Copenhagen: WHO Regional Office for Europe; 2013 (http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2013/health-risks-of-air-pollution-in-europe-hrapie-project.-recommendations-for-concentrationresponse-functions-for-costbenefit-analysis-of-particulate-matter,-ozone-and-nitrogen-dioxide).

Annex 1. Publications and legislation on air pollution and health in Serbia

Publications[2]

Air quality in Republic of Serbia in 2015. Belgrade: Serbian Environmental Protection Agency; 2015 (http://www.sepa.gov.rs/download/VAZDUH2015.pdf ISSN 2334–8763).

Aničić M, Frontasyeva MV, Tomašević M, Popović A. Assessment of atmospheric deposition of heavy metals and other elements in Belgrade using the moss biomonitoring technique and neutron activation analysis. Environ Monit Assess. 2007;129(1–3):207–19.

Austin KF, Mejia MT. Household air pollution as a silent killer: women's status and solid fuel use in developing nations. Popul Environ. 2017;39:1–25.

Belojević GA, Jakovljević BD, Stojanov VJ, Belojević GA, Jakovljević BD, Stojanov VJ et al. Nighttime road-traffic noise and arterial hypertension in an urban population. Hypertens Res. 2008;31(4):775–81.

Cvetković A, Jovašević-Stojanović M, Ađanski-Spasić L, Matić-Besarabic S, Marković DA. Seasonal trends of benzo(a)pyrene in urban suspended particulate matter of Belgrade City, Serbia. Chem Ind Chem Engineer Q. 2010;16(3):259–68.

Đekić T. Analyze of the air quality in Belgrade city during the period September 2010–September 2011. J Geograph Inst Jovan Cvijic. 2013;63(2):11–19.

Grzetic I. Traffic pollution in the streets of Belgrade. J Environ Prot Ecol. 2003;4:761–6.

Holland M. Cost–benefit analysis of final policy scenarios for the EU clean air package. Brussels: European Commission; 2014 (http://ec.europa.eu/environment/air/pdf/TSAP%20 CBA.pdf).

Janković S, Vlajinac H, Bjegović V, Marinković J, Šipetić-Grujičić S, Marković-Denić L, et al. The burden of disease and injury in Serbia. Eur J Public Health. 2007;17(1):80–5.

Jevtić M, Dragić N, Bijelović S, Popović M. Cardiovascular diseases and air pollution in Novi Sad, Serbia. Int J Occup Med Environ Health. 2014;27(2):153–64.

Joksić J, Radenković M, Cvetković A, Matić-Besarabić S, Jovašević-Stojanović M, Bartonova A et al. Variations of PM_{10} mass concentrations and correlations with other pollutants in Belgrade urban area. Chem Ind Chem Eng Q. 2010;16(3):251–8.

Joksić JD, Jovašević-Stojanović M, Bartonova A, Radenković MB, Yttri KE, Matić-Besarabić S et al. Physical and chemical characterization of the particulate matter suspended in aerosols from the urban area of Belgrade. J Serb Chem Soc. 2009;74(11):1319–33.

Jovašević-Stojanović M, Bartonova A. Current state of particulate matter research and management in Serbia. Chem Ind Chem Eng Q. 2010;16(3):207–12.

Jovašević-Stojanović M, Matić-Besarabić S. Comparison of EU framework and daughter directives and current Serbian legislation on air pollution monitoring. Chem Ind Chem Eng Q. 2008;14(1):5–10.

Jović J, Đorić V. Traffic and environmental street network modelling: Belgrade case study. Transport. 2010;25(2):155–62.

[2] All electronic references were accessed on 11 January 2019.

Kalinovic TS, Serbula SM, Kalinovic JV, Radojevic AA, Petrovic JV, Steharnik MM, et al. Suitability of linden and elder in the assessment of environmental pollution of Brestovac spa and Bor lake (Serbia). Environ Earth Sci. 2017;76(4):178.

Lazić L, Urošević MA, Mijić Z, Vuković G, Ilić L. Traffic contribution to air pollution in urban street canyons: integrated application of the OSPM, moss biomonitoring and spectral analysis. Atmos Environ. 2016;141:347–60.

Marković DM, Marković DA, Jovanović A, Lazić L, Mijić Z. Determination of O_3, NO_2, SO_2, CO and PM_{10} measured in Belgrade urban area. Environ Monit Assess. 2008;145(1–3):349–59.

Matić BI, Rakić UD, Dejanović SM, Jovanović VS, Jevtić MR, Đonović NŽ. Industrially contaminated areas in Serbia as a potential public health threat to the exposed population. Tehnika. 2017;72(3):441–7.

Matić-Besarabić S, Ađanski L, Jovanović A. Air pollution monitoring network in Belgrade – Evaluation of air pollution measurement sites. Belgrade: Public Health Institute of Belgrade; 2017 (http://www.vin.bg.ac.rs/webiopatr/1st-workshop/abstracts/80–84.pdf).

Mijić Z, Stojić A, Perišić M, Rajšić S, Tasić M, Radenković M, et al. Seasonal variability and source apportionment of metals in the atmospheric deposition in Belgrade. Atmos Environ 2010;44(30):3630–7.

Milijić V. Report on wood pellet production and market structure in Serbia. Belgrade: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; 2014 (http://www.bioenergy-serbia.rs/images/documents/studies/WOOD_PELLET_PRODUCTION_AND_MARKET_STRUCTURE_IN_SERBIA.pdf).

Milosević Z, Bogdanović D, Jović S, Stanković A, Milutinović S, Rancić N. Influence of air pollution on hospital admissions for cardiovascular and respiratory diseases in Niš, Serbia. Vojnosanit. Pregl. 2010;67(6):473–9.

Milutinović S, Nikic D, Stosic L, Stankovic A, Bogdanovic D. Short-term association between air pollution and emergency room admissions for chronic obstructive pulmonary disease in Niš, Serbia. Central Eur J Public Health. 2009;17(1):8.

Ministry of Agriculture and Environmental Protection. First biennial update report of the Republic of Serbia under the United Nations Framework Convention on Climate Change. Belgrade; Ministry of Agriculture and Environmental Protection; 2016.

Nikić D, Bogdanovic D, Nikolic M, Stankovic A, Zivkovic N, Djordjevic A. Air quality monitoring in Niš (Serbia) and health impact assessment. Environ Monit Assess. 2009;158(1):499–506.

Nikić D, Bogdanović D, Stanković A, Nikolić M, Milošević Z. Impact of air pollution on the rate of hospital admission of children with respiratory diseases. Vojnosanit Pregl. 2008;65(11):814–9.

Nikolić D, Milošević N, Mihajlović I, Živković Ž, Tasić V, Kovačević R, et al. Multi-criteria analysis of air pollution with SO_2 and PM_{10} in urban area around the copper smelter in Bor, Serbia. Water Air Soil Pollut. 2010;206(1–4):369–83.

Perišić M, Rajšić S, Šoštarić A, Mijić Z, Stojić A. Levels of PM_{10}-bound species in Belgrade, Serbia: spatio-temporal distributions and related human health risk estimation. Air Q Atmos Health. 2017;10(1):93–103.

Petrović J, Ivković I, Vujačić I, Žeželj S. Possibilities of buses on alternative fuel in public urban transport in Belgrade. Technol Econ Dev Econ. 2009;15(1):78–89.

Popović Z, Lazarević L, Vukićević M, Vilotijević M, Mirković N. The modal shift to sustainable railway transport in Serbia. MATEC Web Conf. 2017;106:05001.

Rajšić SF, Tasić MD, Novaković VT, Tomašević MN. First assessment of the PM_{10} and $PM_{2.5}$ particulate level in the ambient air of Belgrade city. Environ Sci Pollut Res. 2004;11(3):158–64.

Ristić SS, Kosanić MM, Ranković BR, Stamenković SS. Lichens as biological indicators of air quality in the urban area of Kuršumlija (Southern Serbia). Kragujevac J Sci. 2017;39:165–75.

Sawidis T, Breuste J, Mitrovic M, Pavlovic P, Tsigaridas K. Trees as bioindicator of heavy metal pollution in three European cities. Environ Pollut. 2011;159(12):3560–70.

Serbula SM, Miljkovic DD, Kovacevic RM, Ilic AA. Assessment of airborne heavy metal pollution using plant parts and topsoil. Ecotoxicol Environ Saf. 2012;76:209–14.

Serbula SM, Milosavljevic JS, Radojevic AA, Kalinovic JV, Kalinovic TS. Extreme air pollution with contaminants originating from the mining–metallurgical processes. Sci Total Environ. 2017;586:1066–75.

Sevo G, Davidovic M, Erceg P, Despotovic N, Milosevic DP, Tasic M. On aging and aged care in Serbia. J Cross-Cultural Gerontol. 2015;30(2):217–31.

Stanković A, Nikić D, Nikolić M, Bogdanović D. Short-term effects of air pollution on cardiovascular mortality in elderly in Niš, Serbia. Central Eur J Public Health. 2007;15(3):95–8.

Stanković A, Nikolić M, Aranđelović M. Analysis of the impact of long-term exposure to air pollution on women’s health in Niš (Serbia). Facta Univ Ser Working Living Environ Protect. 2016;13(1);13–9.

Stevanović I, Jovašević-Stojanović M, Stošić JJ. Association between ambient air pollution, meteorological conditions and exacerbations of asthma and chronic obstructive pulmonary disease in adult citizens of the town of Smederevo. Vojnosanit Pregl. 2016;73(2):152–8.

Stevanović S, Stanković A. Air pollution as a risk factor for pneumonia. Facta Univ Ser Working Living Environ Protect. 2016;13:245–51.

Stojić SS, Stanišić N, Stojić A, Šoštarić A. Single and combined effects of air pollutants on circulatory and respiratory system-related mortality in Belgrade, Serbia. J Toxicol Environ Health Part A. 2016;79(1):17–27.

Tasic M, Rajsic S, Novakovic V, Mijic Z. An assessment of air quality in Belgrade urban area: PM_{10}, $PM_{2.5}$ and trace metals. J Physics Conf Ser. 2007;71(1):012016.

Tasić V, Kovačević R, Maluckov B. The content of As and heavy metals in TSP and PM_{10} near copper smelter in Bor, Serbia. Water Air Soil Pollut. 2017;228(6):230.

Todorovic MN, Perisic MD, Kuzmanoski MM, Stojic AM, Sostarić AI, Mijic ZR, et al. Assessment of PM_{10} pollution level and required source emission reduction in Belgrade area. J Environ Sci Health Part A. 2015;50(13):1351–9.

Vojinović S, Savić D, Lukić S, Savić L, Vojinović J. Disease relapses in multiple sclerosis can be influenced by air pollution and climate seasonal conditions. Vojnosanit Pregl. 2015;72(1):44–9.

Vuković G, Urošević MA, Škrivanj S. The first survey of airborne trace elements at airport using moss bag technique. Environ Sci Pollut Res. 2017;24(17):1–9.

Vuković G, Uroševic MA, Pergal M, Janković M, Goryainova Z, Tomašević M et al. Residential heating contribution to level of air pollutants (PAHs, major, trace, and rare earth elements): a moss bag case study. Environ Sci Pollut Res. 2015;22(23):18956–66.

Vuković G, Urošević MA, Razumenić I, Goryainova Z, Frontasyeva M, Tomašević M et al. Active moss biomonitoring of small-scale spatial distribution of airborne major and trace elements in the Belgrade urban area. Environ Sci Pollut Res. 2013;20(8):5461–70.

Vuković G, Urošević MA, Škrivanj S, Milićević T, Dimitrijević D, Tomašević M et al. Moss bag biomonitoring of airborne toxic element decrease on a small scale: a street study in Belgrade, Serbia. Sci Total Environ. 2016;542:394–403.

Živanović S. Annex to the analysis of Belgrade environmental endangerment by nitrogen oxides from the engines in road transport. Facta Univ Ser Working Living Environ Protect. 2009;6(1):73–82.

Žujić AM, Radak BB, Marković DA. The characteristics of the air pollution of a transition economy city: the example of Belgrade. J Serb Chem Soc. 2007;72(8–9):889–99.

Legislation

Main law and accompanying regulations

Law on Air Protection. Official Gazette of the Republic of Serbia, No. 36/09 of 15.05.2009 and 10/13 of 30.01.2013.

Regulation on Monitoring Conditions and Air Quality Requirements. Official Gazette of the Republic of Serbia, No. 11/10 of 05.03.2010, 75/10 of 20.10.2010 and 63/13 of 19.07.2013.

Regulation on Criteria and Manner of Approving Programmes and Projects Implemented within the Clean Development Mechanism. Official Gazette of the Republic of Serbia, No.44/10 of 30.06.2010.

Regulation on the Methodology for Data Collection for the National Inventory of Unintentional Emissions of Persistent Organic Pollutants. Official Gazette of the Republic of Serbia, No. 76/10 of 22.10.2010.

Published bylaws based on the law

Regulation on the Methodology for Data Collection for the National Greenhouse Gases Inventory. Official Gazette of the Republic of Serbia, No. 81/10 of 05.11.2010.

Regulation on Determining Zones and Agglomerations. Official Gazette of the Republic of Serbia, No. 58/11 of 05.08.2011.

Regulation Amending Regulation on Determining Zones and Agglomerations. Official Gazette of the Republic of Serbia, No. 98/12 of 12.09.2012.

Regulation on Determining the Air Quality Control Programme within the State Network. Official Gazette of the Republic of Serbia, No. 58/11 of 05.08.2011.

Regulation on the List of Installations and Activities, in Which Volatile Organic Compound (VOC) Emissions Shall Be Controlled, on VOC Emission Values at Certain Consumption of Solvents and Total Allowed Emissions, and Schemes to Reduce VOC Emission. Official Gazette of the Republic of Serbia, No. 100/11 of 29.12.2011.

Regulation on Determining the List of Air Quality Categories by Zones and Agglomerations in the Territory of the Republic of Serbia for 2011. Official Gazette of the Republic of Serbia, No. 124/12 of 29.12.2012.

Regulation Amending Regulation on Air Quality Monitoring and Requirements Related to Air Quality. Official Gazette of the Republic of Serbia, No. 63/13 of 19.07.2013.

Regulation on Handling Substances That Deplete the Ozone Layer, and Conditions for Issuing Import and Export Permits for These Substances. Official Gazette of the Republic of Serbia, No. 114/13 of 23.12.2013.

Regulation on Handling Fluorinated Greenhouse Gases, and Conditions for Issuing Import and Export Permits for These Gases. Official Gazette of the Republic of Serbia, No. 120/13.

Regulation on Determining the List of Air Quality Categories by Zones and Agglomerations in the Territory of the Republic of Serbia for 2012. Official Gazette of the Republic of Serbia, No. 17/14 of 14.02.2014.

Regulation on Determining the List of Air Quality Categories by Zones and Agglomerations in the Territory of the Republic of Serbia for 2013. Official Gazette of the Republic of Serbia, No. 105/15 of 18.12.2015.

Regulation on Determining the List of Air Quality Categories by Zones and Agglomerations in the Territory of the Republic of Serbia for 2014. Official Gazette of the Republic of Serbia, No. 105/15 of 18.12.2015.

Regulation on Limit Values of Air Pollutant Emissions from Stationary Sources of Pollution, except from Combustion Installations. Official Gazette of the Republic of Serbia, No. 111/15 of 29.12.2015.

Regulation on the Methodology for the Development of Air Pollutant Emissions and Projections Inventory. Official Gazette of the Republic of Serbia, No. 03/16 of 15.01.2016.

Regulation on Measurements of Air Pollutant Emissions from Stationary Sources of Pollution. Official Gazette of the Republic of Serbia, No. 05/16 of 25.01.2016.

Regulation on Limit Values of Air Pollutant Emissions from Combustion Installations. Official Gazette of the Republic of Serbia, No. 06/16 of 28.01.2016.

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