Air Pollution and Human Health: The Case of the Western Balkans

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Acknowledgements

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Executive summary

At the third session of the United Nations Environment Assembly (UNEA 3), held in Nairobi, Kenya, from 4-6 December 2017, delegates from around the world unanimously agreed that air pollution is the single greatest environmental threat to health, and one of the main avoidable causes of death and disease globally. Following the consensus reached on the resolution on *Preventing and Reducing Air Pollution to Improve Air Quality Globally*[1], proposed at the UNEA 3, UN Environment has actively supported governments in preventing and reducing air pollution. Every year, around 6.5 million people across the globe die prematurely from exposure to outdoor and indoor air pollution. Nine out of ten people breathe outdoor air that is polluted beyond levels deemed acceptable under the World Health Organization's Guidelines. Air pollution is considered a global public health emergency, and has an equivalent effect to tobacco use, putting everyone from unborn babies, to children walking to school, to women cooking over open fires at risk (UNEP, 2017). In 2015, the World Health Assembly adopted the resolution 'Health and the environment: addressing the health impact of air pollution'. The air quality in many cities does not meet national or European Union (EU) air quality standards, or the World Health Organization's (WHO) Air Quality Guidelines (AQG).

The major sources of outdoor air pollution are fossil fuel emissions from coal burning for electricity and heat, transport, industrial furnaces, brick kilns, agriculture, domestic solid fuel heating and the unregulated burning of waste materials such as plastics and batteries in open pits and incinerators (Morman, 2013). Particulate matter ($PM_{2.5}$ and PM_{10}) affects people's health more than any other air pollutant; levels of $PM_{2.5}$ have remained largely constant despite efforts to reduce them (Sacks, 2011).

The population of the Western Balkans region[2] is exposed to some of the highest concentrations of air pollution in Europe. They are up to five times higher than the national and EU guideline levels, let alone the WHOS's AQG.

The health effects of air pollution are well documented in global toxicological, clinical and epidemiological research studies. The WHO's AQG (Air Quality Guidelines, 2005) review the evidence about the health effects of particle pollution, ozone and nitrogen dioxide, and set limits for concentrations of pollutants in the air to reduce the harmful health effects of exposure. Recent WHO reviews confirm the Guidelines' validity amid mounting evidence supporting the recommendations' relevance over the last decade (WHO R. , 2013). Epidemiological studies and meta-analyses provide data on functional relationships between concentrations of air pollutants and increased health risks associated with exposure (WHO H. , 2013). Widely used health risk assessment methods provide assessments of the health impacts of pollution in populations for which pollution exposure estimates as well as national background health data are available (Health risk assessment of air pollution, 2016).

The assessment report '*Air Pollution and Human Health: The Case of the Western Balkans*', produced by the United Nations Environment Programme with support from the Government of Norway, provides an overview of air quality in the Western Balkans as well as an estimate of the health impacts of air pollution in the region, to elaborate a conceptual framework for the development of appropriate instruments to alleviate energy poverty, a major cause of air pollution in the region. The assessment report covers the following countries: Albania, Bosnia and Herzegovina, North Macedonia,

[1] 1 UNEP/EA.3/Res.8.

[2] The Western Balkans is a political neologism that evolved in the early 1990s and refers to Albania and the territory of the former Yugoslavia (with the exclusion of Slovenia). The region of the Western Balkans, a designation used exclusively in Europe, roughly corresponds to the Dinaric Alps territory.

Montenegro and Serbia. When available, data from Kosovo[3] was also analysed in this study. The focus is on populations of cities[4] for which data from national air quality monitoring systems and health data and statistics are available. In addition, country-wide estimates based on a global analysis conducted by the WHO are presented.

The annual concentrations of particulate matter ($PM_{2.5}$) in all of the selected Western Balkan cities (with the exception of Vlorë, Albania) exceed the WHO's AQG value of 10 μg/m³ (WHO, 2005). **The majority of these cities (approx. 75 per cent) even exceed the less stringent European Union limit values of 25 μg/m³** (Air Quality Standards, n.d.). The average exposure indicator calculated by the European Environmental Agency (EEA) (EEA, 2018) denotes that **out of 37 reporting European countries, only eight (five of which are countries in the Western Balkans region) exceed the recommended level of exposure to $PM_{2.5}$ concentrations, which is set at 20 μg/m³.** The **daily limit value of PM_{10} is exceeded between 120-180 days per year** in Western Balkan cities, although national and EU legislation **limit the number of exceedances to 35 days per year**. These exceedances usually occur during the winter months.

The main sources of particulate matter emissions are electricity generation from thermal power plants (mostly lignite-fired) and household heating. Only 12 per cent of the buildings in the Western Balkans are connected to district heating systems. Solid fuels (coal and firewood) are used for domestic heating by over 60 per cent of the population (Framework, 2017). The share of energy in the annual household consumption expenditure is substantial. **The Western Balkans region suffers from high levels of energy poverty**, preventing a smooth transition to more sustainable and more eco-friendly heating systems (Sandra Esser, 2018).

The Western Balkans region included in this study have transposed EU legislation limiting the concentrations of air pollutants. The air quality is monitored in accordance with EU legislation and the collected data is reported to the European Environment Information and Observation Network (EIONET). The lack of financing to operate and maintain the air quality stations results in inconsistencies in monitoring and in data gaps[5]. To analyse the health impact of air pollution in the Western Balkans region, **only air quality data collected on minimum 274 days per year were used[6]** to reduce the sampling bias when estimating the annual mean. [1]

Air pollution contributes between 4 per cent and 19 per cent of total premature mortality in the selected cities and reduces life expectancy by between 0.4 and 1.3 years. On average, 20 per cent of years of life lost due to exposure result in premature deaths of persons under the age of 65 years. **It is estimated that exposure to fine particulate matter ($PM_{2.5}$) is responsible for 75 per cent of all deaths associated with the exposure**. Proportion of total mortality from natural causes attributable to all considered air pollutants (attributable proportion – APs) in cities varied from 4 per cent in Bar and Tivat to 19 per cent in Tetovo. For the 18 cities for which baseline mortality data were available, the attributable proportion was used to calculate the annual number of deaths attributable to air pollution. **The sum of all deaths directly attributable to air pollution in the Western Balkan cities covered by this study is nearly 5,000 per year,** with the highest number of deaths registered in the region's largest city, Belgrade (1 004 deaths per year are attributable to air pollution). In the absence of $PM_{2.5}$ data for Belgrade, however, this estimate is based on the total number of deaths attributable to NO_2 exposure only. **Estimates of mortality attributable to $PM_{2.5}$ exposure exceeding the WHO's AQG level in Bosnia and Herzegovina, Montenegro, North Macedonia and Serbia, are higher than for most EU Member States.**

[3] This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence

[4] Banja Luka, Brod, Prijedor, Tuzla, Zenica, Bar, Niksic, Pljevlja, Podgorica, Tivat, Bitola, Skopje, Tetovo, Beograd, Pancevo, Uzice, Valjevo

[5] Annual country reports on air pollution (see references).

[6] Applicable to cities with more than 274 valid daily values per calendar year to reduce sampling bias (errors) when estimating the annual mean.

Based on the available data in these countries, an in-depth analysis of the burden of disease associated with air pollution as well as of the expected health benefits of reductions in air pollution in the selected cities was conducted. Unfortunately, an analysis of $PM_{2.5}$ impacts was not possible for the largest city of the region (Belgrade) and for cities in Albania, as no necessary $PM_{2.5}$ data for these cities was incomplete.

Air quality improvement by alleviating energy poverty is crucial to reduce the number of deaths and diseases associated with air pollution in the Western Balkans. This can be achieved by increasing access to modern energy services, by promoting the use of renewable energy, reducing the environmental impact of cities, and through environmentally sound management of chemicals and waste. Western Balkan governments need assistance in the implementation of policies to create a cleaner, healthier environment for their populations. The necessary policy measures should include improved air quality monitoring, the introduction of subsidies for electric vehicles, restrictions on fossil fuel power stations and bans on the most polluting vehicles. Businesses must also join the fight against pollution by fostering innovation, reducing their own emissions and responding to citizens' demands for smarter, cleaner products.

Abbreviations

AP	Attributable proportion
APV-PAN	Provincial network of automatic stations Pancevo
AQ	Air quality
AQG	Air Quality Guidelines
AQM	Air quality monitoring
B&H	Bosnia and Herzegovina
BOR TIR	Provincial network of automatic stations Bor
CETI	Center for ecotoxicological investigations in Montenegro
COPD	Chronic obstructive pulmonary diseases
DIMAC	Data integration model for air quality
EEA	European Environment Agency
EIONET	Environmental Information and Observation Network
EMEP	European Monitoring and Evaluation Programme
EU	European Union
FB&H	Federation of Bosnia and Herzegovina
FHMI	Federal Hydro-meteorological Institute of Bosnia and Herzegovina
IHD	Ischaemic heart disease
IHMK	Institute for Hydrometeorology of Kosovo under UNSCR 1244/99
HMI RS	Hydro-meteorological Institute of Republika Srpska, B&H
IPHA	Institute for Public Health of Albania
JRC/EC	Joint Research Centre/European Commission
KEPA	Kosovo under UNSCR 1244/99 Environmental Protection Agency
LCA	Cancer of trachea, bronchus and lung
LE	Life expectancy
MEIC	Macedonian Environmental Information Center
MEPS	Ministry of Environmental Protection Serbia
MESPK	Ministry of Environment and Spatial Planning of Kosovo under UNSCR 1244/99
MoEPPM	Ministry of Environment and Physical Planning of North Macedonia
MoFTER	Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina
MoSDTM	Ministry of Sustainable Development and Tourism of Montenegro
NEAA	National Environmental Agency Albania
NEPAM	Nature and Environment Protection Agency of Montenegro
North Macedonia	North Macedonia
PM	Particulate matter
PS-APV	Provincial network of automatic stations Vojvodina
RS	Republika Srpska
SEPA	Serbian Environmental Protection Agency
SIHM	State Institute for Hydrometeorology of Montenegro
TPP	Thermal power plant
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
WHO	World Health Organization
WMO	World Meteorological Organization
YLL	Years of life lost

1 Air quality in the Western Balkans

The Western Balkans region face a number of challenges to the development of economy, society and environment. The biggest challenge for Albania, Bosnia and Herzegovina, Kosovo[7], Montenegro, North Macedonia and Serbia is the pace of their integration in the European Union. The region's economic and industrial structures have been upgraded; now, the air pollution control policies must be significantly improved. International and EU policies on air pollution will have a strong influence on national air quality and environmental standards in the Western Balkans region. The choice of the path to be taken will determine the region's environmental future.

1.1 Air quality monitoring network in the Western Balkans

All Western Balkans region monitors the air quality in accordance with EU regulations, and report data to the European Environment Information and Observation Network (EIONET). The main problems of the air quality monitoring systems in the Western Balkans include inconsistent data due to the shortage of financial resources for maintenance of the stations, the lack of certified calibration laboratories and the absence of air quality modelling[8]. The Western Balkans region covered in this study has adopted new legislation and transposed the legally binding limits for concentrations of air pollutants set by the EU (Table 1).

Table 1 Limit values for main air pollutants in the Western Balkans region[9]

Parameter	Mean	WHO[10] (µg/m³)	EU[11]	B&H		Serbia	Kosovo [12]	North Macedonia	Albania	Montenegro
				FB&H[13]	RS[14]					
SO_2	1 h	500	350	350	350	-	350	350	350	350
	24 h	20	125	125	125	125	125	125	125	125
NO_2	1 h	200	200	200	150	150	200	200	200	200
	1 year	40	40	40	40	40	40	40	40	40
	24 h	-	-	-	85	-	-	-	-	-
PM_{10}	24 h	50	50[15]	50	50	50	50	50	50	50
	1 year	20	40	40	40	40	40	40	40	40
$PM_{2.5}$	24 h	25	-	-	-	25	25	25	25	25
	1 year	10	25	-	-	-	20	20	20	20
Ozone O_3	8h	100	120	120	120	120	-	120	120	120

Over the last decade, the Western Balkans region has established a significant number of air quality monitoring stations (Figure 1). Many cities have multiple stations (depending on city size and source

[7] This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

[8] Annual country reports on air pollution.

[9] In B&H, NO_2 limit values are even stricter than in the EU, while the 24h limit value is only regulated in the B&H entity Republika Srpska. The target value for concentrations of ground level ozone is not regulated in Kosovo under UNSCR 1244/99. $PM_{2.5}$ annual and 24h limit values are not regulated in B&H at all, while they are stricter than in the EU in some of the region's other countries. In Serbia, only the daily limit values of $PM_{2.5}$ are regulated.

[10] http://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health and http://apps.who.int/iris/bitstream/handle/10665/69477/WHO_SDE_PHE_OEH_06.02_eng.pdf;jsessionid=1E1A00F47340C8FF1A5EE85CACC1DDDF?sequence=1

[11] http://ec.europa.eu/environment/air/quality/standards.htm

[12] Kovoso - This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

[13] http://mpz.ks.gov.ba/sites/mpz.ks.gov.ba/files/Pravilnik_112_1.pdf

[14] https://rhmzrs.com/wp-content/uploads/2019/01/uredba-o-vrijednostima-kvalitete-zraka.pdf

[15] Not to be exceeded more than 35 times per year.

of pollution). Despite the high number of stations in the region, their location and the lack of financing to operate and maintain them affect data quality. To determine the health impact of air pollution in the Western Balkans region, only air quality data collected on minimum 274 days per year were used to reduce the sampling bias when estimating the annual mean. A summary of the air quality monitoring networks in the Western Balkan countries is provided below.

Albania: the country's air quality monitoring network consists of seven automatic stations located in **Tirana** (two stations), **Elbasan, Durrës, Shkodër, Vlorë and Korçe**.

Bosnia and Herzegovina: there are 34 monitoring stations in Bosnia and Herzegovina (19 in FB&H: four in Sarajevo, four in Tuzla, four in Zenica, one in each of the following cities: Lukavac, Kakanj, Ivan Sedlo, Jajce, Gorazde, Mostar and Ilijas; 15 in RS: five in Banja Luka (two of which are inactive), one in Prijedor (inactive), one in Doboj (inactive), one in Brod, three in Bijeljina (of which one is inactive), one in Ugljevik, two in Ist.Sarajevo (one of which is inactive), one in Trebinje (inactive), one in Gacko) (Srpska, 2017) (FHMI, 2017).

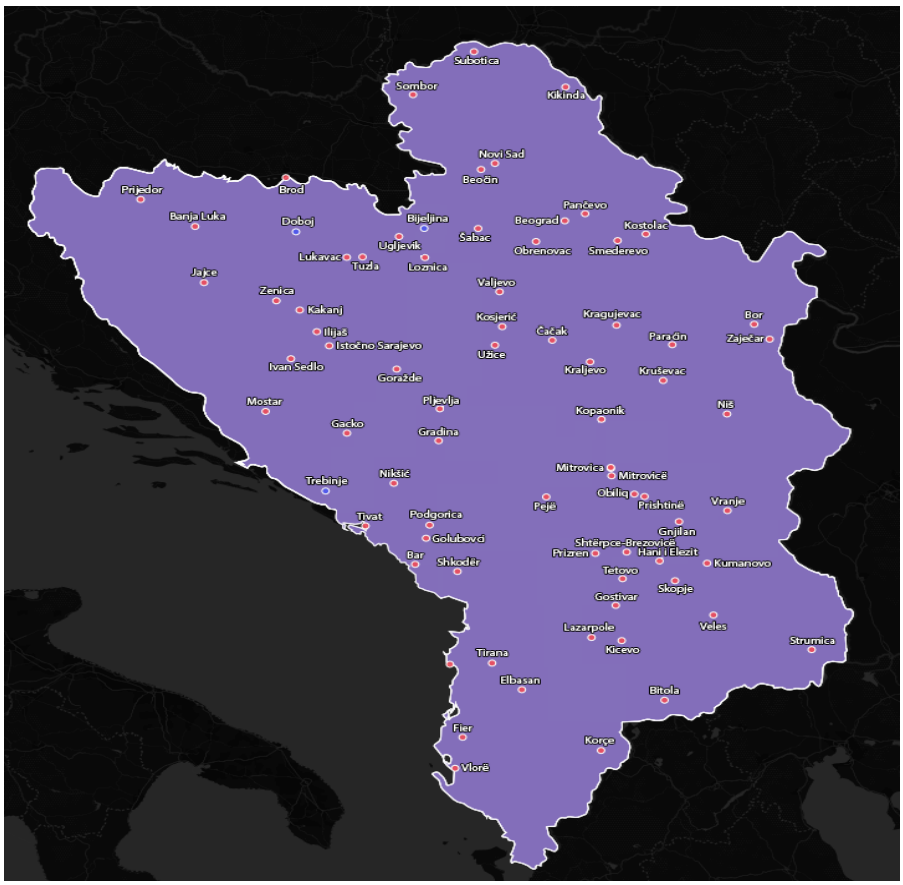


Figure 1 Air quality monitoring stations in the Western Balkans (stations marked in blue are not operational)

Kosovo's[16] air quality monitoring network consists of 12 automatic fixed stations and one mobile station, namely Gjilan, Hani i Elezit, Shtërpce-Brezovicë, Prizren, Pejë, Prishtinë, Drenas, Obiliq, Dardishte, Palaj and Mitrovicë. Brezovicë is the only rural station and is currently not operational.

North Macedonia: the ambient air quality monitoring system in North Macedonia consists of 17 fixed monitoring stations (Bitola-1, Bitola-2, Kicevo, Lazarpole, Tetovo, Gostivar, Veles, Kadavarci, Kumanovo, Strumica and Skopje). One mobile station is located in Skopje and provides additional monitoring results.

Montenegro: the country's air quality monitoring network currently comprises seven automatic stations, with three additional installations being planned by the end of 2019. Currently, air quality is being monitored in Pljevlja, Gradina, Podgorica, Golubovci, Nikšić, Bar and Tivat (one station each).

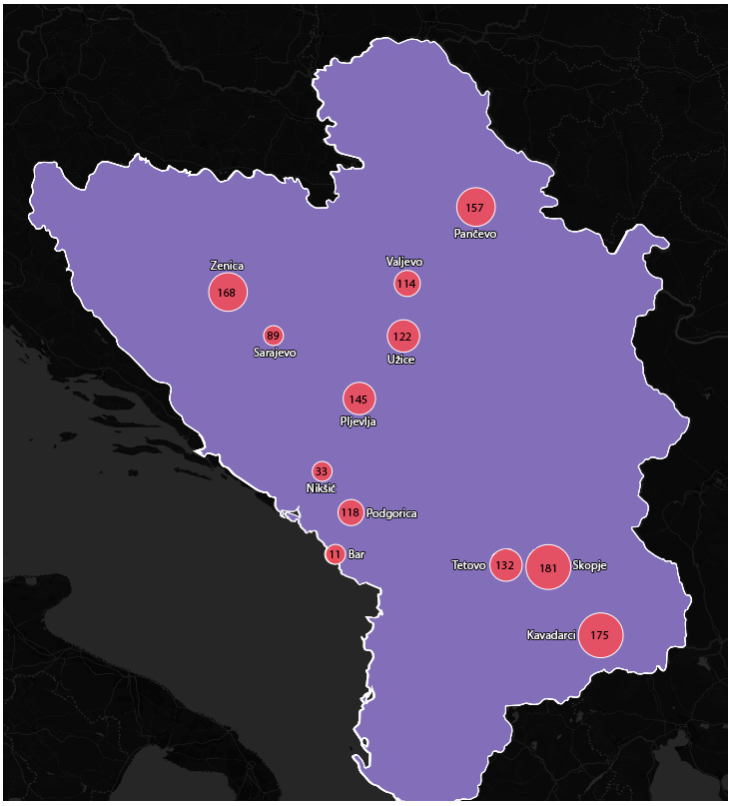
[16] This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

Serbia: in 2018, seven monitoring stations were operated by PS-APV[17], five by APV-PAN[18], one monitoring station was operated by BOR TIR[19] and 32 monitoring stations were operated by SEPA (SEPA, n.d.). The air quality monitoring network in Serbia is distributed across three zones and eight agglomerations (Subotica, Sombor, Kikinda, Novi Sad, Beočin, Mitrovica, Beograd, Šabac, Obrenovac, Loznica, Smederevo, Kostolac, Pančevo, Valjevo, Bor, Kosjerić, Uzice, Čačak, Kragujevac, Kraljevo, Paraćin, Zaječar, Kruševac, Niš, Kopaonik and Vranje).

The national annual air quality reports of the Western Balkans region emphasize the problems of inconsistent data, lack of financing for the maintenance of the stations and absence of both certified calibration laboratories and of air quality modelling. Although the number of air monitoring stations is decent[20], the lack of funding to maintain them results in unreliable data and consequently, does not accurately reflect the realities on the ground. Although automatic air quality monitoring is undertaken and data is available online, time lags of several hours are frequent or data may not be recorded at all. The number of operational stations is lower than the officially stated number, and despite efforts by the governments to invest in air quality monitoring, the available data are often inconsistent due to insufficient funding.

1.2 Status of air quality

Air pollution is one of the most serious environmental risks with major socio-economic consequences for the entire Western Balkans region. The region's topography, but primarily the low quality solid fuels used in coal-fired power plants, the burning of coal for domestic heating and cooking, outdated industry and old vehicles contribute to the high concentrations of pollutants in the air.



The annual limit of 50 μg/m^3 for PM_{10} may be exceeded 35 times per year. The daily PM_{10} concentrations in the selected Western Balkan cities exceed the national and EU limit values for PM_{10} up to 4-5 times per year (Figure 2). Higher PM_{10} values are recorded in the summer months in some Montenegrin towns due to the negative impact of wildfires – 14 days in Podgorica in August and 18 days in Bar in August.

Figure 2 Frequency of daily exceedance of PM_{10} concentrations in Western Balkan cities in 2017

[17] Provincial network of automatic stations Vojvodina.
[18] Provincial network of automatic stations Pančevo.
[19] Provincial network of automatic stations Bor.
[20] As shown in separate Air Quality research provided in the Annex.

$PM_{2.5}$ concentration levels are also high across the region. The annual ambient concentrations of particulate matter ($PM_{2.5}$) in all Western Balkan cities included in this study exceed the WHO's Air Quality Guideline value of 10 μg/m³ (with the exception of Vlorë in Albania), and the majority of cities (approx. 75 per cent) exceed the EU's less stringent limit value of 25 μg/m³ (Figure 3).

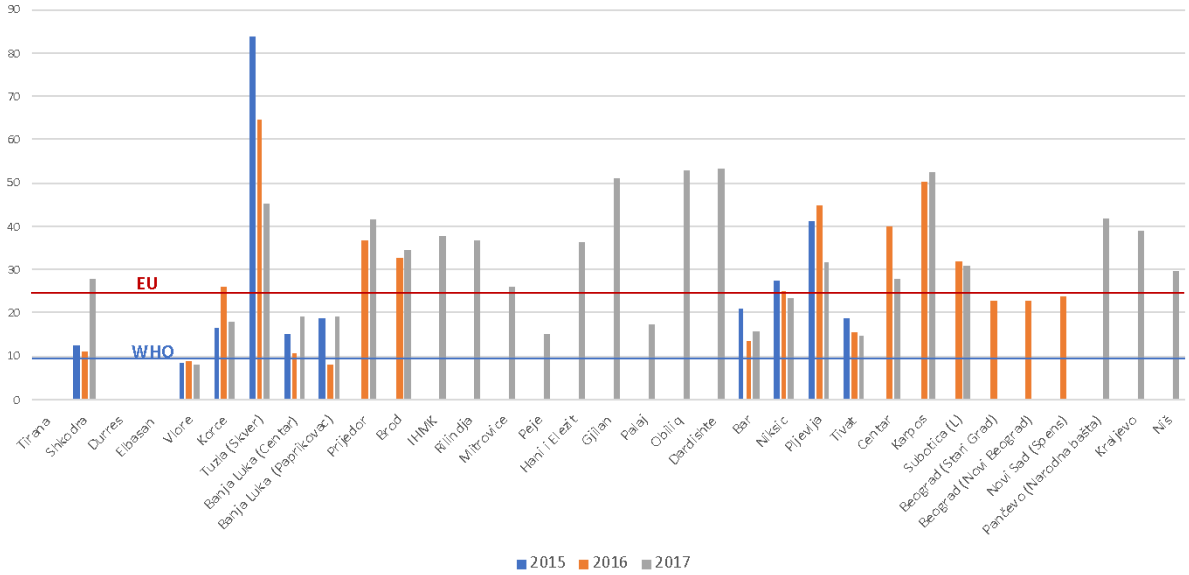


Figure 3 Annual $PM_{2.5}$ concentrations in Western Balkan cities (2015-2017)

PM_{10} concentrations in the selected Western Balkan cities show strong seasonal variations (Figure 4). Burning coal is widespread in the region, and PM_{10} concentrations increase considerably during the winter months due to high heating demands as well as to the region's specific topography.

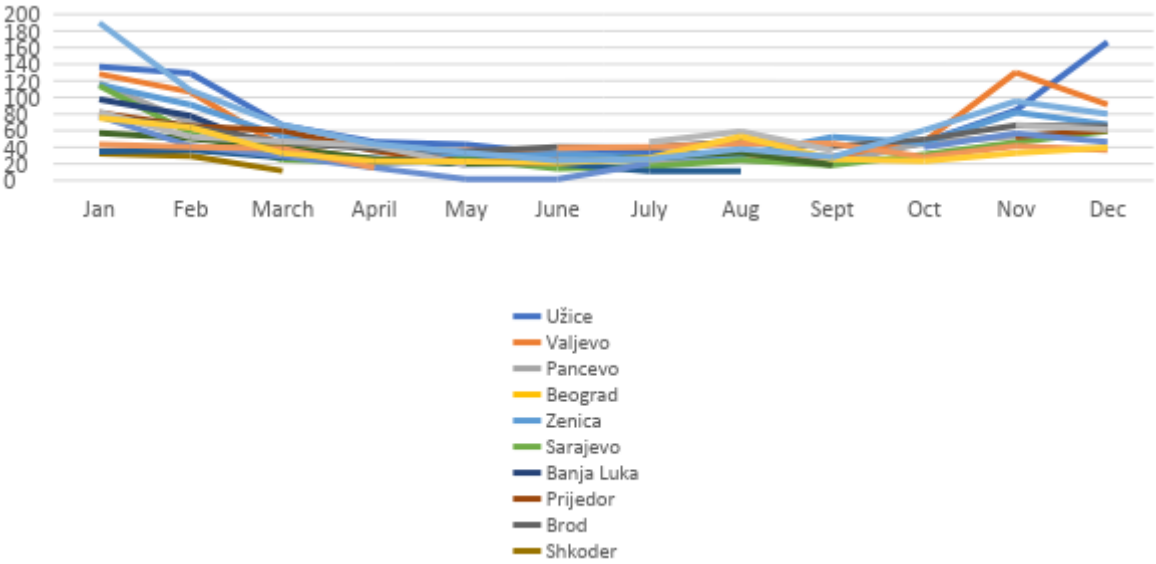


Figure 4 Monthly variations in PM_{10} concentrations in Western Balkan cities

The annual average NO_2 concentration levels recorded in most cities of the region were below the WHO's AQG value (40 μg/m³), with the exception of some stations in Belgrade and the new stations in Dardishte, Gjilan and Pristinë (Figure 5).

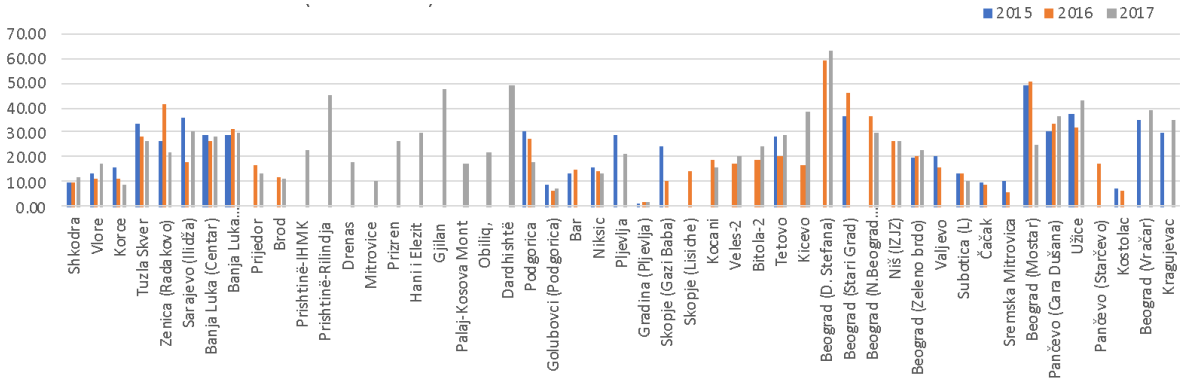


Figure 5 Annual average NO_2 concentration levels (2015-2017)

1.3 Sources of air pollution in the Western Balkans

Although some improvements have been made in recent years, air pollution in Western Balkan countries remains a serious concern in the region's urban and industrial areas. The main problems include emissions from thermal power and manufacturing plants, traffic, domestic heating and mines (Figure 6). The impact of energy generation and consumption on the environment is an important factor influencing energy choices in the region, given that many of the countries aim to join the EU.

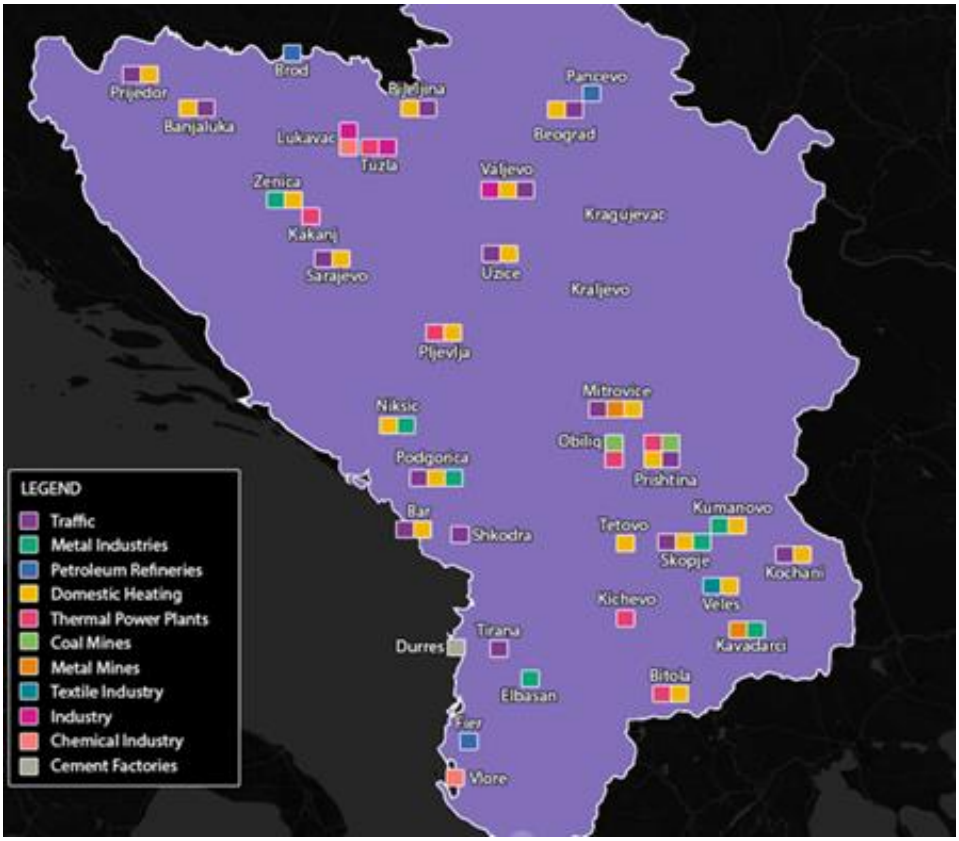


Figure 6 Emission sources in the Western Balkans[21]

High carbon intensity is attributable to the region's low energy conversion efficiency and its high dependency on lignite-fired power generation. Electricity generation from thermal power plants

[21] Based on the annual country reports on air pollution and emission sources (FHMI, 2017) (Srpska, 2017) (database, 2013) (Macedonia, 2018).

(mostly lignite-fired) produces substantial amounts of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and dust or particulate matter (PM). Lignite power plants in North Macedonia, Bosnia and Herzegovina, Montenegro and Serbia are major sources of SO_2 in the region, while high concentrations of dust (particulate matter) are mostly attributed to plants in Kosovo[22], North Macedonia and Serbia (Bank, 2018). One common feature of the Western Balkan countries is their high share of fossil fuels in the supply mix (coal in particular) and their heavy reliance on oil, petroleum and natural gas imports (Figure 7). Energy production is predominantly based on hydropower in Albania only, which does not impact air quality negatively. The only thermal power plant in Vlorë is currently non-operational.

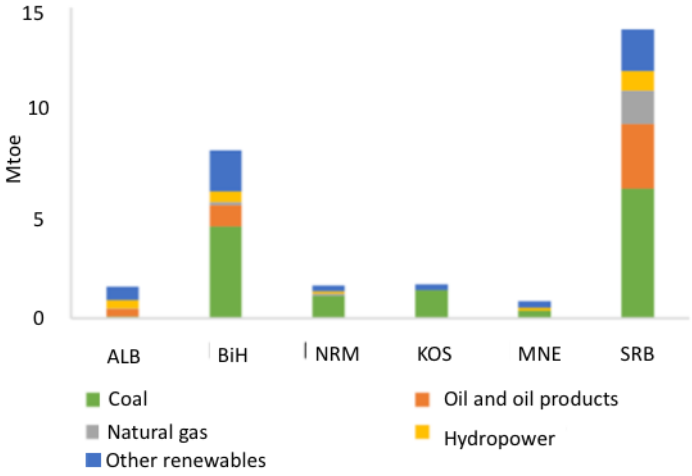


Figure 7 Total primary energy supply in the Western Balkans region (Bank, 2018)

There are currently 15 active coal-fired power stations in five of the Western Balkan countries, with 35 units and an installed capacity of 8.1 GW.[23] While some of the older installations will be replaced with new coal-fired plants—hence not adding new capacity—some of the new plants are intended to increase current capacity. Coal is a major source of heating, especially for individual furnaces, resulting in higher air pollutant concentrations during the winter months.

In *Bosnia and Herzegovina*, $PM_{2.5}$ emissions are generated by residential combustion (25 per cent - **Sarajevo, Zenica and Tuzla**), combined heat and power plants (29 per cent), industrial processes (24 per cent – Zenica and Tuzla); and waste (11 per cent).

Kosovo[24] lacks reliable data on emissions and no results are therefore presented here.

In *Montenegro*, residential heating and public electricity production equally contribute to the total emission of $PM_{2.5}$ (together – 42 per cent) and have a negative impact on air quality. The road transport sector is responsible for a large share (32 per cent) of NO_x emissions (expressed as NO_2), but electricity generation is the dominant source of NO_x emissions (52 per cent), contributing between 95 per cent to 96 per cent of total SO_2 emissions in the country. The thermal power plant in **Pljevlja** is the largest emitter of SO_2.

In *Serbia*, electricity and heat generation contribute the largest share (50 per cent) of total NO_x emissions, followed by road transport (20 per cent to 25 per cent). The two major emission sources of $PM_{2.5}$ and PM_{10} are industrial processes and stationary combustion sources, which together account for around 80 per cent of total emissions. The thermal power plants (TPP) **Kolubara, Nikola Tesla** and associated surface mines, as well as the iron, steel and heating industries (**Užice and Valjevo**) are also major sources of air pollution.

In *North Macedonia*, the energy industry *(*public electricity and heat production – **TPP Bitola and Oslomej***)* is responsible for nearly all SO_2 emissions (91 per cent). The manufacturing sector contributes

[22] This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.
[23] Albania is not included because it has no coal-fired plants.
[24] This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

around 11 per cent of total emissions. The main sources of NO_x emissions are the transport and energy industries (electricity and heat production), which contribute 31 per cent and 41 per cent, respectively, to total national emissions, while the manufacturing sector contributes 20 per cent. The main sources of PM_{10} emissions in North Macedonia are residential heating (46 per cent), industrial processes (mainly ferroalloys production) (22 per cent) and energy generation (11 per cent) – **Skopje, Tetovo, Bitola and Veles**. Similarly, the main sources of $PM_{2.5}$ emissions are residential heating (58 per cent), industrial processes (mainly ferroalloys production) (20 per cent) and energy generation (6 per cent) (MoEPP, 2008).

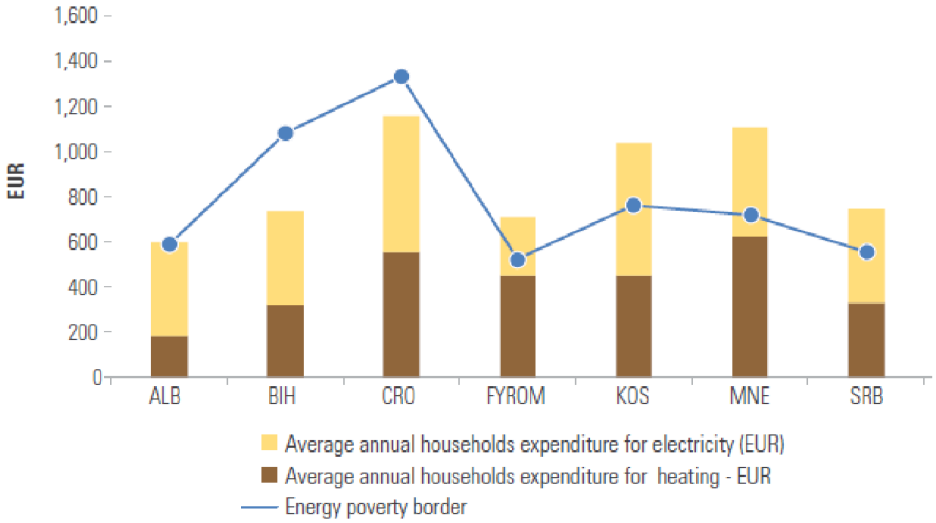


Figure 8 Average annual household expenditure on heating and electricity (MoEPP, 2008)

The Western Balkan countries have started reducing emissions from large combustion plants[25] since 1 January 2018 to align their national laws and regulations with those of the EU. This process is based on the Energy Community rules requiring coal power plants currently operating in the Western Balkans to gradually cut their emissions by the end of 2027.

The transition to more sustainable and eco-friendly residential heating systems will, however, take time. Approximately 88 per cent of the 7.3 million buildings in the Western Balkans use decentralized heating systems such as stoves and heat only boilers, while only 12 per cent of the buildings are connected to district heating. There are no district heating systems in Albania and Montenegro. Apart from the widespread use of coal, biomass is the most important source of energy in the Western Balkans region, accounting for 42 per cent of the energy required for heating (Framework, 2017). Most biomass is used inefficiently due to outdated heating equipment and lack of wood drying before use, resulting in high particulate emissions.

The share of annual household expenditure on heating and electricity is very high, with most of the Western Balkan countries exceeding the energy poverty line (Figure 8).

2 Methodology

Data used in this analysis were obtained from the air quality management institutions that measure and report air quality data. The list of institutions and their respective air quality roles and responsibilities is presented in Table 2.

Table 2 Air quality management institutions in the Western Balkans

[25] Combustion installations with a rated thermal input exceeding 50 MW.

Country	Air quality management, policy and legislation	Management of air quality monitoring networks /stations	Air quality monitoring	Air quality /emissions reporting
Albania	Ministry of Tourism and Environment	National Environmental Agency Institute for Public Health	IPH and NEA	National Environmental Agency
Bosnia and Herzegovina	Ministry of Spatial Planning, Construction and Ecology of Republika Srpska (MSPCERS) Federal Ministry of Environment and Tourism (FMOiT)[26]	FHMI, HMI RS[27]	FHMI, HMI RS	FHMI, HMI RS
Kosovo[28]		KEPA/IHMK	IHMK	
North Macedonia	Ministry of Environment and Physical Planning – MoEPP	MEPPM[29]	MEIC	MEIC
Montenegro			NEPA	NEPA
Serbia	Serbian Environment Protection Agency (SEPA), Province of Vojvodina, Secretary of Environmental Protection, Belgrade City Public Health Institute	No certified national laboratory	SEPA	

Recent air quality data (2015-2017) were obtained from national or local air quality monitoring networks (see Acknowledgements). These included annual mean concentrations of particulate matter ($PM_{2.5}$ and/or PM_{10}) and of nitrogen dioxide (NO_2), as well as annual SOMO35 levels (ozone indicator). Only air quality data collected on minimum 274 days per year were used to reduce the sampling bias when estimating the annual mean. When possible, the multi-year average concentration was calculated to determine the population's long-term exposure to air pollutants. Data from urban background monitoring stations were preferred to reduce the impact of local emission sources (industry, traffic) on measured concentrations. In case no $PM_{2.5}$ data were available, $PM_{2.5}$ concentrations were calculated using the $PM_{2.5}/PM_{10}$ ratio of other cities in the same region or country.

Mortality serves as the most common epidemiological indicator of health in studies on the health effects of air pollution; the results of cohort studies are included in meta-analyses to derive concentration-response functions. Data on mortality statistics by cause of death of persons aged 30 years and older from cities for which air quality data was available were used in the analysis. Age-specific (5-year age groups) natural mortality data (ICD10 codes A00-R99) were collected for the years 2015-17, or for the

[26] The Constitution of Bosnia and Herzegovina (BiH) states that jurisdiction over environmental issues is divided between the entities (Federation of Bosnia and Herzegovina - FBiH and Republika Srpska - RS), the district of Brčko (BD) and the cantonal/municipal level. The only institution at state level with jurisdiction over environmental issues is the Ministry of Foreign Trade and Economic Relations (MoFTER).

[27] The station in Mostar, managed by the Faculty of Natural Sciences and Mathematics and Educational Sciences, does not regularly provide data to the FHMI. The automated stations in Kakanj ("Transport" and "Dom Kulture") operated by the Kakanj thermal power plant are currently not operational. In Republika Srpska, the Brod station is maintained by the Refinery Brod.

[28] This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

[29] There is no official accreditation of the laboratory.

most recent year available. Data on population by age (5-year age groups) were also collected for the selected cities.

The effect of air pollution on mortality was calculated using the AirQ+ software developed by the WHO (AirQ+tool, n.d.). WHO AQG level for annual mean (10 μg/m³) was used as a cut-off concentration for $PM_{2.5}$. For NO_2, the cut-off concentration for annual mean of 10 μg/m³ was used. Ozone effects were estimated for days with maximum daily ozone concentration over 70 μg/m³. Details on the methodology are provided in the Annex.

National analyses of $PM_{2.5}$ concentrations in all areas of the countries were conducted by the WHO using the DIMAQ model (al., n.d.) combining data from atmospheric transport models, satellite observations and air quality monitoring. Mortality due to $PM_{2.5}$ exposure in each of the Western Balkan countries as well as EU countries was based on the results of the WHO's global analysis, which provides national estimates for all countries around the world based on standardized methodology (WHOa, n.d.).

3 Impacts of air pollution on human health in the selected cities of the Western Balkans region

The health effects of exposure to air pollutants are well established by global toxicological, clinical and epidemiological research. The WHO's Air Quality Guidelines (WHO, 2005) review the evidence about the health effects associated with particulate matter, ozone and nitrogen dioxide, and recommending the concentrations of pollutants in the air necessary to reduce the adverse health effects of exposure. Recent WHO reviews confirm the Guidelines' validity (WHO R. , 2013). Epidemiological studies and their meta-analyses provide data on the functional relationships between air pollutant concentrations and increased health risks due to exposure (WHO H. , 2013). Well established health risk assessment methods allow estimations of the health impacts of air pollution in the populations for which exposure estimates as well as background health data are available (Health risk assessment of air pollution, 2016).

Estimates of the health impacts of air pollution in the Western Balkans presented in this report focus on the populations in cities (Korca, Banja Luka, Brod, Prijedor, Sarajevo, Tuzla, Zenica, Bar, Niksic, Pljevlja, Podgorica, Tivat, Bitola, Skopje, Tetovo, Beograd, Pancevo, Uzice and Valjevo) since the data from the national air quality and health monitoring systems were available for these cities. In addition, country-wide estimates for the Western Balkans based on global analyses conducted by the WHO are presented.

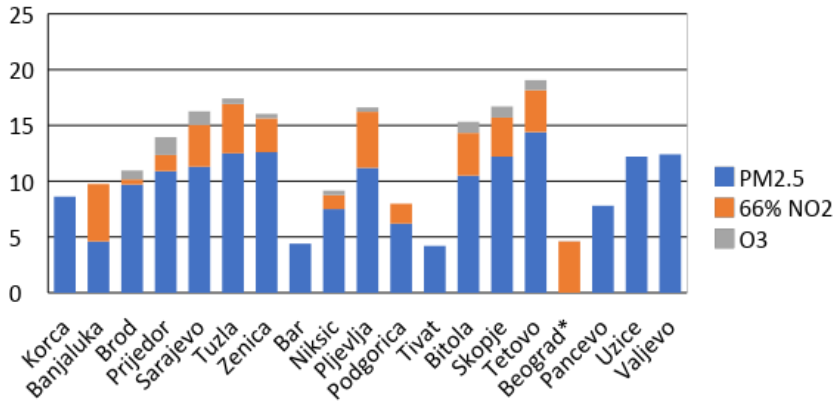


Figure 9 Proportion of all (natural) causes mortality attributable to air pollution exposure exceeding selected cut-off concentrations among individuals aged 30 years and older in cities (*for Belgrade, 100 per cent of NO_2 effects are presented as no data on $PM_{2.5}$ were available)

Data on pollutant concentrations were available for 20 cities in five countries (no data for Kosovo[30] was available); however, data on all three pollutants ($PM_{2.5}$ and/or PM_{10}, NO_2) were not available for all cities.

Proportion of all (natural) causes mortality attributable to the three air pollutants (attributable proportion – AP) varied between 4 per cent (in Bar and Tivat) and 19 per cent in Tetovo (Figure 9). The estimates on the impact of exposure to air pollutants in Bar and Tivat would most likely be higher if NO_2 and O_3 data were available for these cities. For most cities, the cumulative impact ranged between 10 per cent and 15 per cent of total mortality, with $PM_{2.5}$ exposure responsible for ca. 75 per cent of the effects. In Tetovo, $PM_{2.5}$ alone was responsible for over 14 per cent of all deaths.

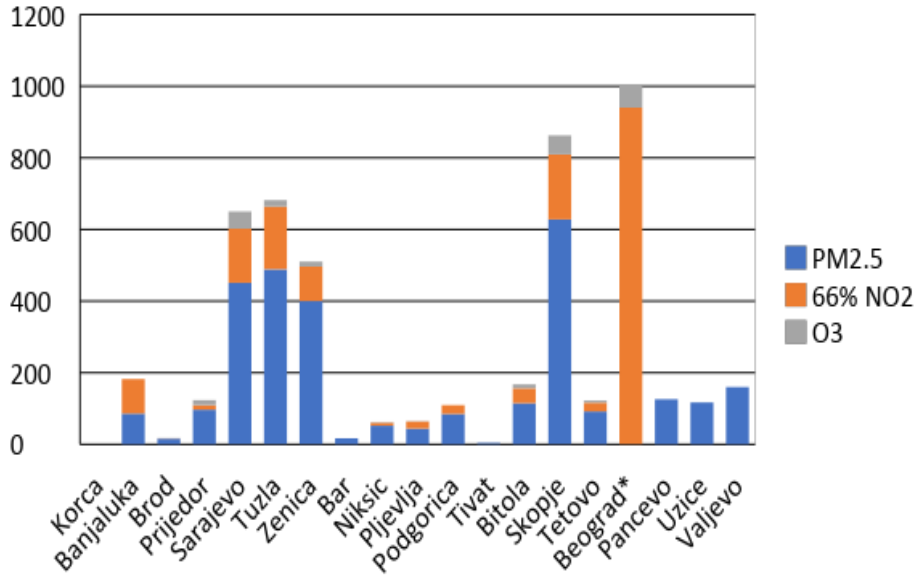


Figure 10 Number of deaths per year from all (natural) causes attributable to air pollution exceeding selected cut-off concentrations in cities (*for Belgrade, 100 per cent of NO_2 effects are presented)

For the 19 cities for which baseline mortality data were available, the attributable proportion was used to calculate the number of deaths per year attributable to air pollution exposure. The sum of all deaths directly attributable to air pollution in the Western Balkan cities covered by this study is nearly 5,000 per year, with the highest number in the region's largest city, Belgrade (1 004 deaths attributable to air pollution exposure per year), albeit in the absence of $PM_{2.5}$ data, this estimate results from consideration of all deaths attributable to NO_2 exposure only (Figure 10).

The absolute number of deaths depends on the size of the population; comparisons of the impact of air pollution on health between the different cities is better indicated by the rate of mortality due to air pollution exposure per 100 000 population (Figure 11). Considering population size, the impact of air pollution was highest in Pljevlja (ca. 310 deaths per 100 000 population). Deaths attributable to air pollution varied between 150-250 per 100 000 population in most cities.

[30] This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

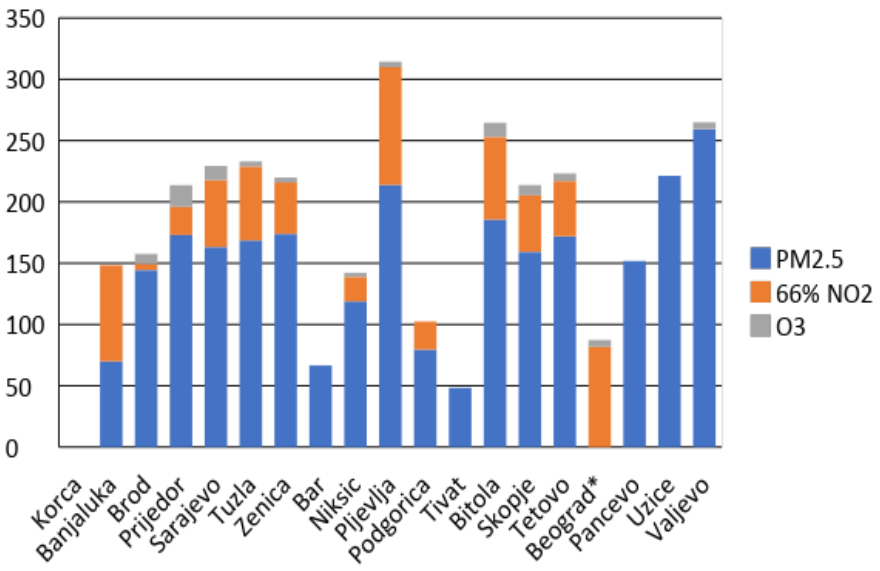


Figure 11 All (natural) cause mortality rates (per 100 000 pop.) attributable to air pollution exceeding selected cut-off concentrations in cities (*for Belgrade, 100 per cent of NO_2 effects are presented)

Air pollution exposure increases the risk of premature death in all individuals aged 30 and older. This results in decreased life expectancy of the region's entire population. The decline in life expectancy attributed to $PM_{2.5}$ exposure ranges from 0.4 years (Banja Luka, Bar and Tivat) to 1.3 years (Sarajevo, Uzice and Valjevo) (Figure 12).

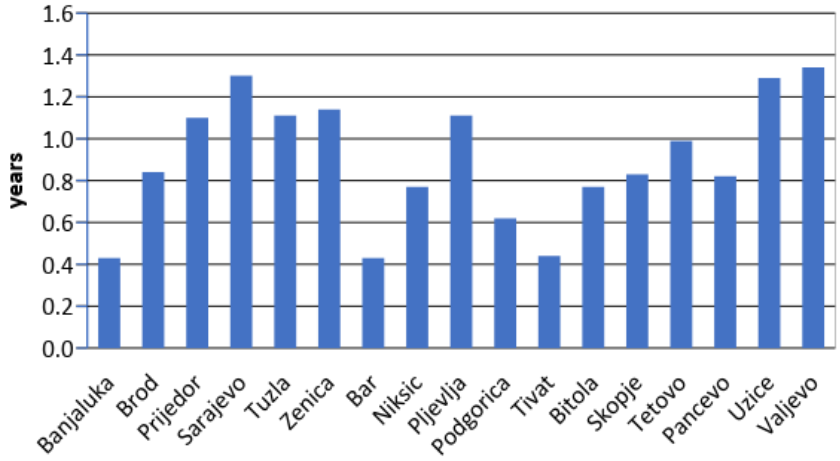


Figure 12 Loss of life expectancy at age of 30 years due to $PM_{2.5}$ exposure exceeding the WHO's AQG level in cities

In all cities analysed, nearly 130 000 years of potential life are lost over a 10-year period due to premature deaths attributable to air pollution exposure. On average, 20 per cent of the years of life lost occurs due to death at age below 65 years. This share ranges from 15 per cent in Prijedor, Užice and Valjevo to 23 per cent in Bitola and Tetovo.

3.1 Exposure to $PM_{2.5}$ and cause-specific mortality

Using integrated exposure-response functions available in the AirQ+, cause-specific mortality rates attributable to $PM_{2.5}$ exposure were calculated for each of the cities based on $PM_{2.5}$ data. AP estimates for COPD and lung cancer range between 15 per cent and 20 per cent in several cities; the estimates for cerebrovascular diseases and IHD are lower (5 per cent to 10 per cent) (Figure 13). The AP estimates for both groups of circulatory diseases are lower than those for all-cause mortality in all cities.

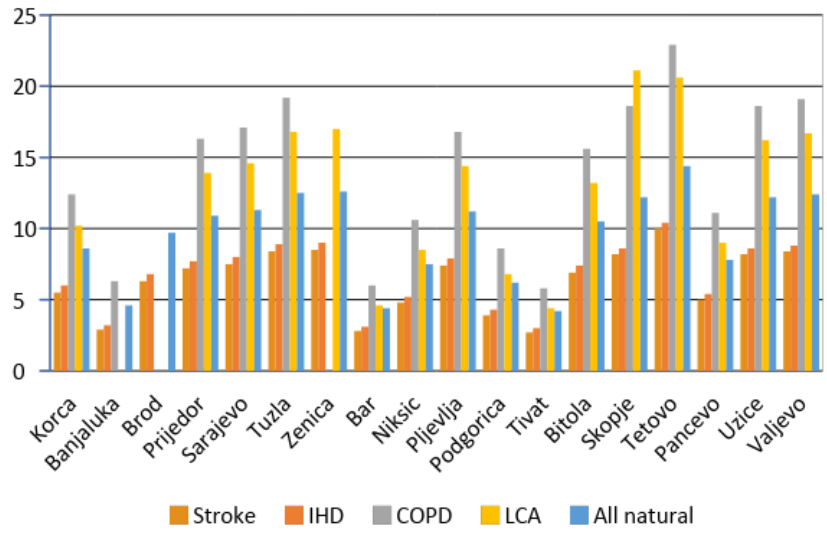


Figure 13 Cause-specific mortality rates attributable to $PM_{2.5}$ exposure exceeding the WHO's AQG level in cities

For cities with specific-cause mortality data, the absolute number of deaths due to those specific causes as well as the cause-specific mortality rates attributable to $PM_{2.5}$ exposure were calculated. Cause - specific estimates contributed small proportion of all deaths attributable to $PM_{2.5}$ exposure: from 11 per cent in Bitola to 28 per cent or 29 per cent in several other cities (Figure 14).

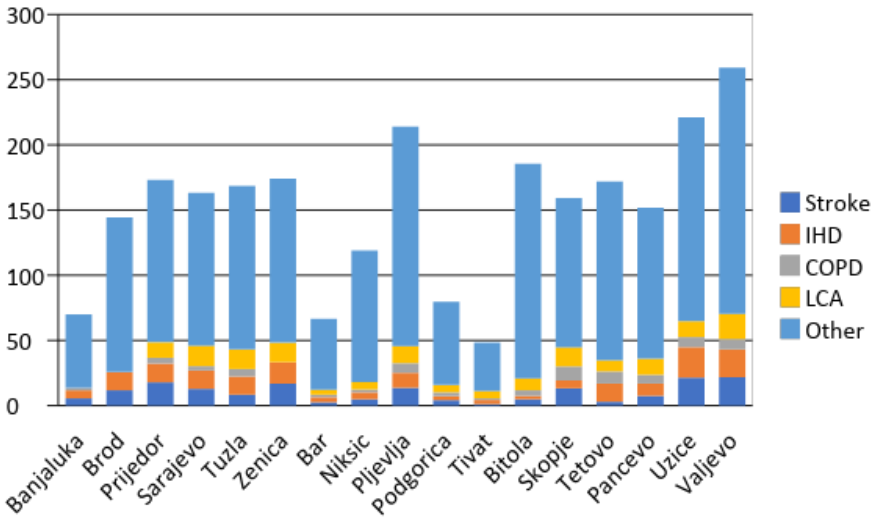


Figure 14 Mortality rates (per 100 000) attributable to $PM_{2.5}$ exposure exceeding the WHO's AQG level by registered cause of death in cities

3.2 Comparison with national estimates

Average long-term concentrations of $PM_{2.5}$ in the cities included in this analysis are higher, on average, than the national (population weighted) $PM_{2.5}$ concentrations estimated by the WHO for 2016 in all countries, except Albania (Figure 15).

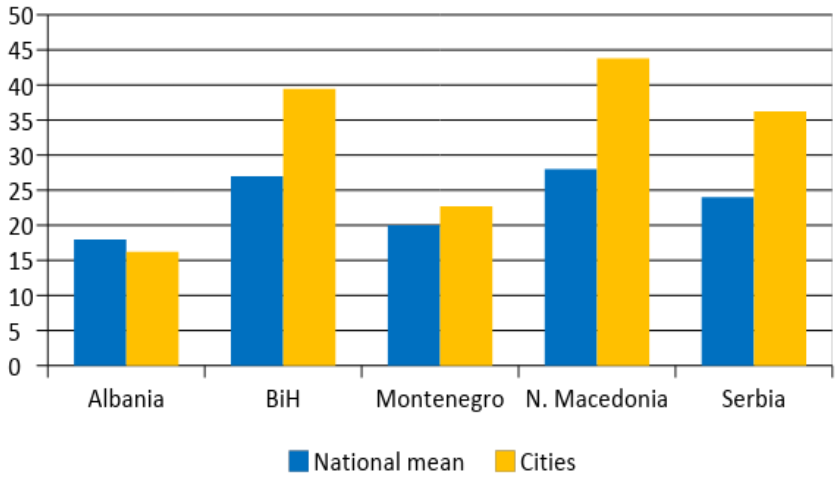


Figure 15 Population weighted annual mean $PM_{2.5}$ concentrations for all countries and for the cities with $PM_{2.5}$ monitoring

A WHO assessment of the burden of disease due to $PM_{2.5}$ exposure is based on estimates of selected causes of death (the same causes of death used in the analysis of the Western Balkans cities, plus lower respiratory infections, adding between 3 per cent and 4 per cent to estimates of deaths attributable to $PM_{2.5}$ exposure) (WHOb, n.d.). The WHO's analysis uses the lowest $PM_{2.5}$ levels observed in epidemiological studies (2.4-5.9 μg/m³) as the counterfactual, also calculating the impact of exposure below the AQG and interim target levels (Figure 16). For all five countries considered in this study, the WHO's estimates attribute around 13 640 deaths to $PM_{2.5}$ exposure, of which only 4 733 (35 per cent) are attributable to $PM_{2.5}$ concentrations that exceed the AQG level.

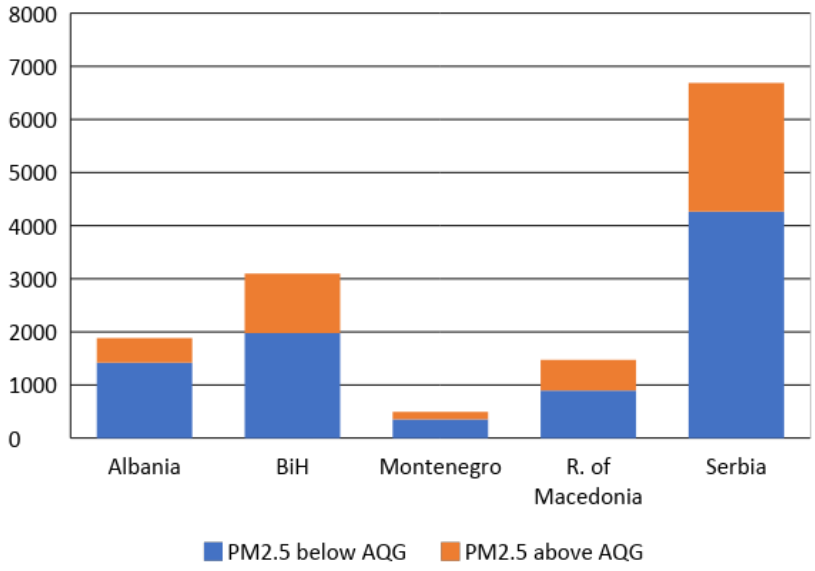


Figure 16 WHO estimates of the number of deaths attributable to $PM_{2.5}$ exposure in the Western Balkans in 2016

The estimates of the mortality rates attributable to exposure to $PM_{2.5}$ concentrations exceeding the WHO's AQG level in Bosnia and Herzegovina, Montenegro, North Macedonia and Serbia are higher than in most EU Member States (Figure 17). In some EU countries, only a very small share of the population is exposed to $PM_{2.5}$ concentrations that exceed the WHO's AQG level, and the impacts of such exposures are marginal.

The national estimates of PM-attributable mortality based on the selected cities' air pollution and specific-cause mortality data are lower than the WHO's estimates of the impact of $PM_{2.5}$ concentrations that exceed the AQG level for all countries except Serbia (Figure 17).

4 Conclusions and a way forward

The main challenges the existing air quality monitoring systems in the Western Balkans currently face are inconsistent data due to lack of financing for the stations' maintenance, the absence of certified calibration laboratories and of air quality modelling. The number of stations in the region is relatively high, but their location and the lack of financing to operate and maintain them often affect data quality negatively.

Air pollution is a serious problem in all Western Balkan countries. Air pollutant concentrations usually exceed the permitted values. The region's topography, but primarily the low quality solid fuels used in coal-fired power plants, the burning of coal for domestic heating and cooking, outdated industry and old vehicles contribute to the high concentrations of pollutants in the air.

Air pollution in the Western Balkan cities causes between 15 per cent to 19 per cent of total mortality and reduces life expectancy by up to 1.1 years to 1.3 years. Around 20 per cent of years of life lost due to exposure are a result of premature deaths of persons under the age of 65 years. The majority of these deaths (approx. 75 per cent) are attributable to exposure to fine particulate matter, even though only those deaths associated with PM concentrations exceeding the WHO's AQG level were considered in this analysis. It is important to note that according to the WHO's analysis, about 60 per cent to 75 per cent of total deaths attributable to $PM_{2.5}$ exposure in the Western Balkans may actually be associated with exposure to PM concentrations below the WHO's AQG level .

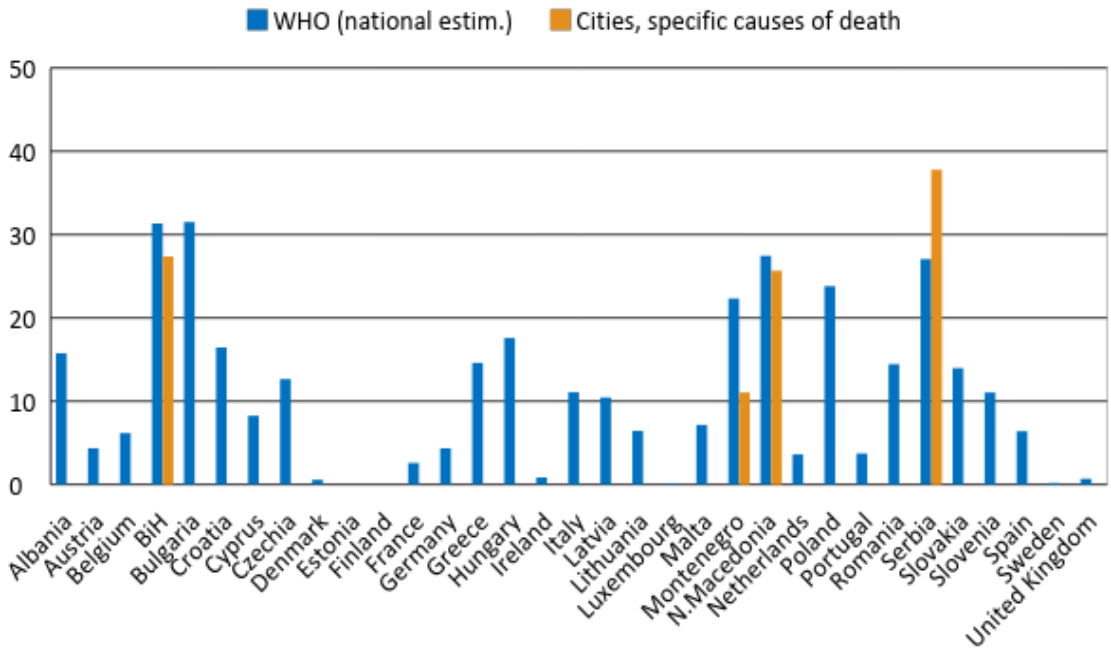


Figure 17 Specific-cause mortality rates (all ages) attributable to $PM_{2.5}$ exposure exceeding the AQG level: comparison of national and city-based estimates in the Western Balkan countries with the estimates for EU countries

This analysis, which is based on data from 18 selected cities in the Western Balkans region, **confirms the WHO's estimates for these countries**. According to the WHO's analysis, cause-specific mortality associated with $PM_{2.5}$ exposure contributes up to 29 per cent of all deaths from natural causes attributable to the exposure (Figure 17). The cities' specific-cause mortality rates attributable to air

pollution are lower than the national estimates, which is inconsistent with the higher $PM_{2.5}$ concentrations found in the cities when compared with other parts of the countries. This might be due to an under-registration of deaths to specific diagnostic categories in the cities[31]. The discrepancy between the estimates might also be due to the fact that the mortality rate attributable to air pollution increases when a broader set of diseases than those included in the four specific diagnostic categories for which concentration-response functions are available, is considered. The discrepancy may also be due to an under-estimation of the risks by the applied concentration-risk functions. If all (natural cause) mortality rates attributable to air pollution exposure are considered, the cities' mortality rates associated with exposure actually exceed the national (WHO) estimates by a factor of two in BiH and by more than ten-fold in Montenegro. The WHO's national estimates on specific-cause mortality may, in fact, underestimate the real burden of disease from air pollution in the Western Balkans.

This study confirms that the data available in the selected countries allow for a comprehensive analysis of the burden of disease from air pollution and of the potential health benefits of air pollution reduction in the selected cities. The policy recommendations for the governments of the Western Balkans region are as follows:

- create national, regional and international frameworks to address the environmental challenges;
- inform their citizens about the health risks associated with air pollution, and to take measures to minimize those risks;
- introduce stricter emission standards for vehicles, power plants and large- and small-scale industry;
- raise awareness about air pollution by publishing air quality monitoring data and promoting awareness campaigns among citizens, in schools and in other educational establishments;
- support the renewable energy sector and promote the reduction of fossil fuel use to generate electricity;
- enable citizens to switch to cleaner heating and cooking technologies;
- require industry to reduce and eliminate emissions of harmful air pollutants;
- prioritize emission reductions from highly polluting industrial facilities such as coke ovens, smelters, refineries, cement plants and brick kilns;
- join UN Environment's air quality programme, which supports governments at all levels, to build evidence around the effects of air pollution.

[31] Possible problems with reporting cause of death indicate considerable variability in specific-cause mortality rates between the cities.

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Annex