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USE OF AIRQ+ SOFTWARE IN ASSESSING THE IMPACT ON HEALTH FROM EXPOSURE TO AIRBORNE PARTICLES IN BOR, SERBIA

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Abstract

The World Health Organization (WHO) has developed and made available the AIR Q+ software tool to assess the health risks associated with exposure to pollutants. The average value of $PM_{2.5}$ (particulate matter) in Bor was calculated over a ten-year period (2014-2023), by year and as an average. Deaths from defined causes, which can be attributed, were calculated with the available data of the Statistical Office of the Republic of Serbia. The long-term effects of $PM_{2.5}$ were calculated to provide a good picture of the health consequences of air pollution. In analysis we used Estimated Attributable Proportion, Estimated Number of Attributable Cases and Estimated Number of Attributable Cases per 100,000 Population at Risk. In order to estimate the impact of air pollution on mortality from certain types of disease, the analysis also used trends in showing the estimated death rates per 100,000 people at risk of all causes of death, cardiovascular disease and respiratory diseases, lung cancer and chronic obstructive pulmonary disease (COPD) in adults, by years of follow-up and $PM_{2.5}$ values. Trend of increasing mortality rates is registered in the case of all causes of death and deaths due to cardiovascular diseases, and a decreasing trend is registered in the case of death from lung cancer and COPD.

The use of AIR Q+ has shown the huge impact of air pollution, i.e. $PM_{2.5}$, on the health of the population of Bor over a ten-year period.

***Key words**: AIR Q+, mortality, $PM_{2.5}$, Bor*

1. INTRODUCTION

Air pollution presents a significant environmental challenge that must be addressed at local, regional, and global levels. Despite substantial progress, it continues to pose threats to human health and the environment [1, 2]

Industrial facilities, motor vehicles, and household combustion devices are common sources of air pollution, emitting pollutants such as particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulphur dioxide. Particulate matter (PM) is a combination of solid and liquid particles present in the air, including “inhalable coarse particles” (PM_{10}) and “fine inhalable particles” ($PM_{2.5}$). $PM_{2.5}$ with a diameter of 2.5 micrometers or less is a significant component of ambient air pollution and poses the greatest risk to health as it can penetrate deep into the lungs and even enter the bloodstream, leading to serious health problems. Long-term exposure to fine particulate matter, or $PM_{2.5}$, is associated with a significant burden of disease including ischemic heart disease (IHD), lung cancer (LC), chronic obstructive pulmonary disease (COPD), acute lower respiratory infection (ALRI), stroke and adverse birth outcomes. This long-term exposure has been linked to increased morbidity and mortality, particularly in people with chronic heart or lung diseases, and reduced lung function growth in children [3,4,5].

In 2013, the International Agency for Research on Cancer(IARC) categorized particulate matter in Group 1 (carcinogen group), both of ambient and indoor air [6]. Adverse health effects of $PM_{2.5}$

may be different, as the main sources, area characteristics, and PMs' chemical specificity are not the same [7]. Some toxicological and epidemiological studies have concluded that PM can cause oxidative stress and inflammation on the human respiratory system [8, 9].

One of the largest copper mines, as well as the copper smelter in Europe, is located in the Town of Bor. Mining production started in 1903 with exploitation of the only underground mine, followed by exploitation of three other open pits in the Bor area (Bor, V.Krivelj and Cerovo). Fugitive emissions from the open pits, ore waste heaps, flotation waste heaps, and copper smelter, together with the emissions from point sources in the copper smelter are the main sources of PM in the Town of Bor (see Fig. 1)[10].

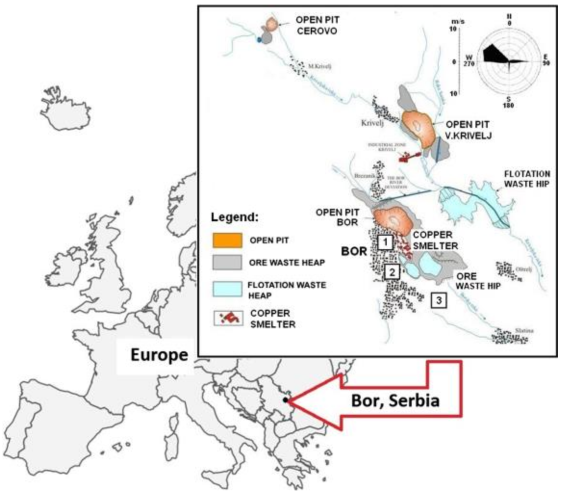

Figure 1 Location of Mining and Smelter Complex Bor with sampling points marked (1 – Park, 2 – Institute, 3 – Jugopetrol)[10]

Concerning the longevity of the established industrial site and the intensity of mining and smelting activity, the town of Bor, over time has acquired the attributes of an *industrially contaminated site,* baring all the public health risks for its population chronically exposed to pollution of all environmental media. The term „contaminated site" can have different meanings. A general definition, following the public health perspective, is "areas hosting or having hosted human activities which have produced or might produce environmental contamination of soil, surface or groundwater, air, and food chain, resulting or being able to result in human health impacts" [11,12].

2. EXPERIMENTAL

Assessments of the impact of air pollution on health were calculated using AirQ+ version 2.2 software tool of the WHO European Region, freely downloadable on-line [13]. This tool allows researchers to assess the burden of both ambient and household (indoor) air pollution. Ambient air pollution assessments are based on the WHO recommendations [14].

Data for the ambient air PM_{10} concentrations in Bor for the period 2014–2023 derived from the data base of Serbian Environment Protection Agency (SEPA), collated from the State Network of Automatic Measuring Stations (AMS) [15]. For the locations where $PM_{2.5}$ is not measured, with existing PM_{10} AMS, WHO developed Country specific conversion factors which were estimated as the mean ratio of $PM_{2.5}$ to PM_{10} of stations for the same year [16]. The conversion factor for Serbia, as given by the AirQ+ is 0.67. The average value of $PM_{2.5}$ in Bor was calculated over a ten-year period (2014–2023), by year and as an average. The average annual $PM_{2.5}$ value was used as a summary indicator for assessing the impact of air pollution on health [17]. Deaths from defined causes, which can be attributed, were calculated with the available data of the Statistical Office of the Republic of Serbia for the period under observation [18].

The long-term effects of $PM_{2.5}$ were calculated to provide a good picture of the health consequences of air pollution. Estimates are based on the assumption that there is a 6% change in deaths from all causes for every 10 μg/m^3 change in average $PM_{2.5}$ concentrations. Estimates of mortality from all causes of death, cardiovascular disease, and respiratory illness attributable to exposure to particulate matter air pollution are based on the number of deaths in adults aged 30 years or older. Also, in the analysis, estimates of mortality from lung cancer in adults and from COPD in adults over 25 years of age were made; the number of inhabitants used in the analysis is people of a certain age, the so-called population at risk, in the period from 2014 to 2023. Estimated Attributable Proportion (Proportion or Percentage of All Cases Attributable to a Particular Exposure), Estimated Number of Attributable Cases (Estimated Number of Cases Attributable to a Particular Exposure), and Estimated Number of Attributable Cases per 100,000 Population at Risk (Estimated rate of illness or death per 100,000 people at risk, attributable to specific exposure). The analysis also used a linear trend expressed through the estimated death rates per 100,000 people at risk of all-cause death, cardiovascular disease and respiratory disease, lung cancer, and COPD in adults [16, 19].

3. RESULTS AND DISCUSSION

During the analysis, common but specific parameters were used for evaluation, such as: type of analysis, type of pollutant, location, total population, years of observation, size of the area, latitude and longitude. In estimating deaths from defined causes, the percentage of all cases attributable to a particular exposure, the estimated number of cases attributable to a particular exposure, and the estimated death rate per 100,000 people at risk attributable to a particular exposure were used.

The percentage of deaths from all causes of death attributable to exposure to air pollution is based on the number of deaths in adults aged 30 years and older. The average percentage of mortality from all causes of death attributable to exposure to air pollution registered in Bor was 13.4% with an average $PM_{2.5}$ value of 23.66 μg/m^3, while the average estimated number of deaths from all causes of death in Bor, attributable to exposure to air pollution in the observed period (2014-2023) was 32 persons of both sexes aged 30+ years. and the average mortality rate was 103.3 per 100,000 for both sexes aged 30+ years.

In the case of the percentage of mortality from cardiovascular diseases attributable to exposure to air pollution in adults aged 30 years, the average registered percentage was 17.7%, and the average estimated number of deaths from cardiovascular disease attributable to exposure to air pollution in the observed period was 20 people of both sexes aged 30+ years, and the average mortality rate was 63.9 per 100,000 for both sexes aged 30+ years.

Analyzing the percentage of mortality from respiratory diseases attributable to exposure to air pollution in adults aged 30 years or older, an average value of 16.3% was registered. The average estimated number of deaths from respiratory diseases in Bor attributable to exposure to air pollution was 2 people of both sexes aged 30+ years, and the average mortality rate was 7.7 per 100,000 for both sexes aged 30+ years.

As in the case of, all-cause mortality, cardiovascular disease, and respiratory disease, the average mortality rate from lung cancer attributable to exposure to air pollution in adults was 16.8%. The average estimated number of lung cancer deaths attributable to exposure to air pollution was 2 people of both sexes, and the average mortality rate was 5.04 per 100,000 for both sexes.

In analyzing the percentage of mortality from chronic obstructive pulmonary disease attributable to exposure to air pollution, which is based on the number of deaths in adults aged 25 years and older, for calculation it was used GBD 2020 (integrated function 2019).

The percentage of mortality from COPD attributable to exposure to air pollution was 16.4% at an average $PM_{2.5}$ value of 23.66 μg/m^3. The average estimated number of deaths from COPD attributable to exposure to air pollution in this period (2014-2023) was 1 person of both sexes of all ages, and the average mortality rate was 2.95 per 100,000 for both sexes.

Also, in order to estimate the impact of air pollution on mortality from certain types of disease, the analysis also used linear trends in showing the estimated death rates per 100,000 people at risk of all causes of death, cardiovascular disease and respiratory diseases, lung cancer and COPD in adults, by years of follow-up and $PM_{2.5}$ values (Figure 2). A trend of increasing mortality rates was registered in the case of all causes of death and death due to cardiovascular disease, and a decreasing trend is registered in the case of death from lung cancer, respiratory diseases and COPD (Figure 3).

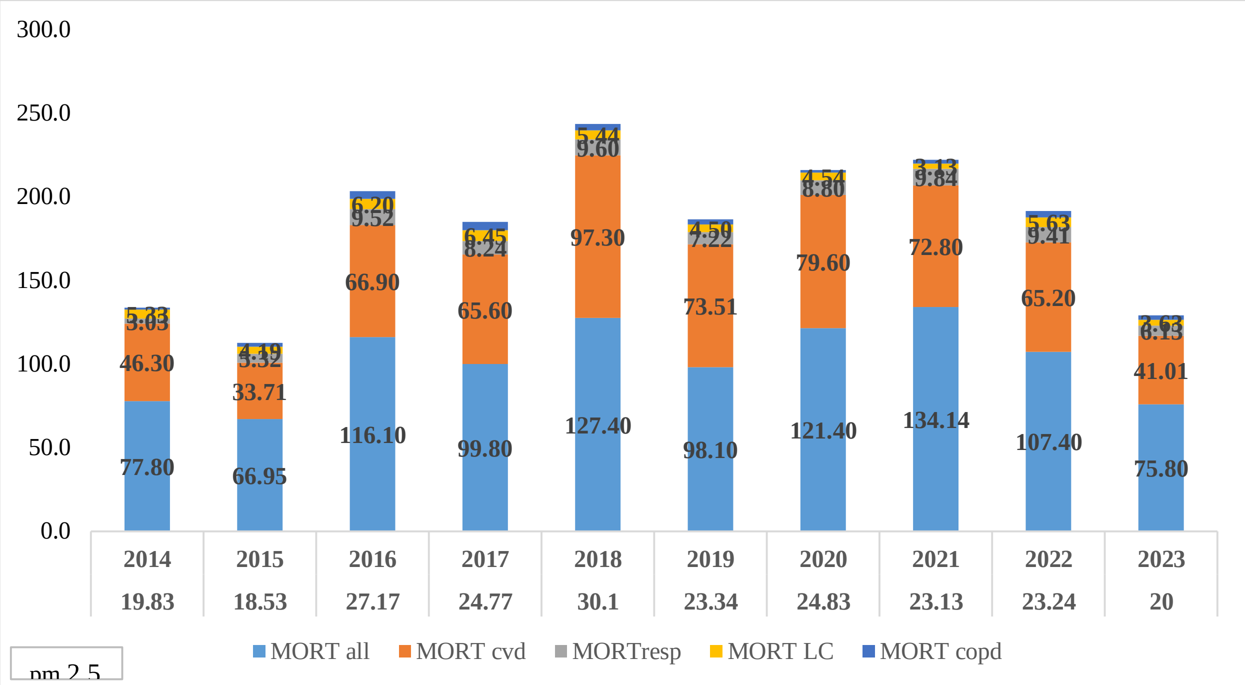

Figure 2 Estimated death rates per 100,000 people at risk of all causes of death, cardiovascular disease and respiratory diseases, lung cancer and COPD in adults, by years of follow-up and $PM_{2.5}$ values

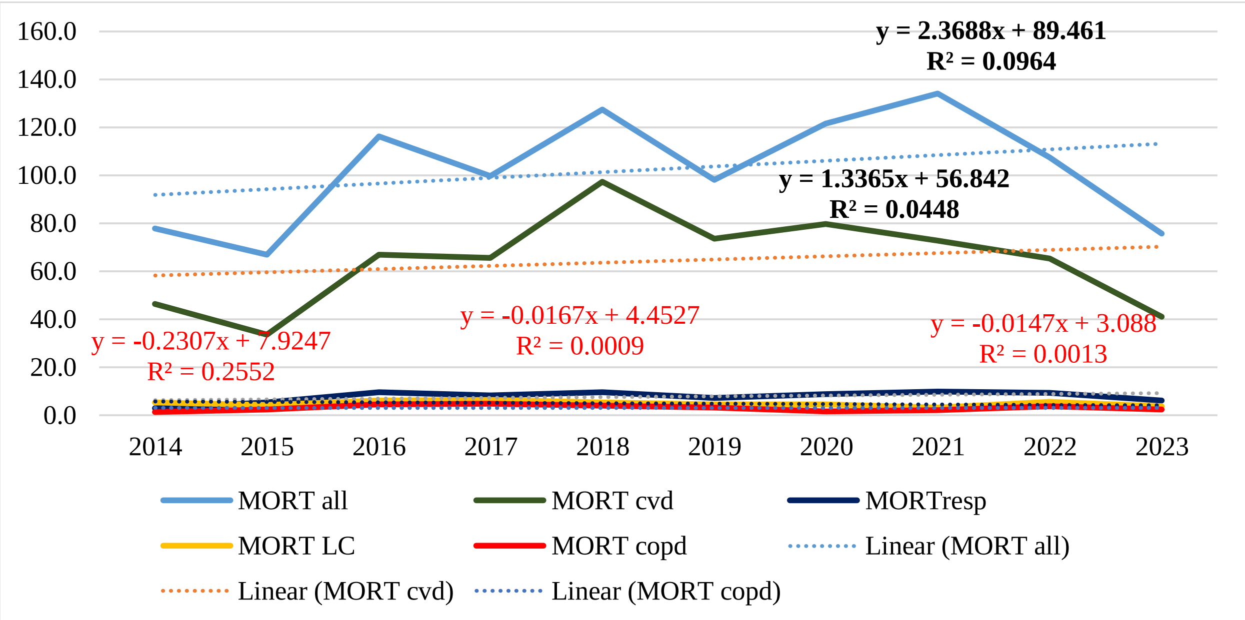

Figure 3 Trend in estimated death rates per 100,000 of all causes of death, cardiovascular disease and respiratory diseases, lung cancer and COPD by years of follow-up

The impact of air pollution on the health of the inhabitants of Bor was observed in the ten-year period from 2014 to 2023. This period is long enough to conclude on the increase or decrease in mortality from certain defined diseases and/or conditions, but certainly the COVID-19 pandemic had a great impact, especially in the period from March 2020 to the end of 2021. This is also shown in our analysis, especially when it comes to estimated mortality rates from all causes of death.

The average value of $PM_{2.5}$ particles in Bor for the observed period was 23.66 $\mu g/m^3$. Compared to the average values over 6 years out of 10, the registered values were lower than average (the lowest value was registered in 2015 and amounted to 18.53 $\mu g/m^3$). In contrast to the average, the highest values, almost 20% more, were registered in 2016 and 2018 (27.17 and 30.1 $\mu g/m^3$). In 2018, the estimated mortality rates from all causes of death, cardiovascular disease, respiratory disease, lung cancer and COPD were higher by 18.9, 34.3, 20.2, 7.4 and 24.4% compared to the average estimated rates for these defined diseases.

There are some limitations in this analysis, primarily related to the numbers obtained in the analysis which must be considered as estimates and should be used carefully. There is no threshold observed in mortality studies below which adverse health effects would not be detected, and estimates using only PM should be considered conservative, that is, they underestimate the impacts. It is important to note once again that estimates of mortality attributable to exposure to air pollution are based on the number of deaths in adults aged 30 years or older. This means underestimating the real burden and cost of air pollution, even if few deaths are expected among those under 30. Estimates of the attributed deaths were obtained by summarizing data over a ten-year period in Bor and at one measuring point. On the other hand, estimates of the impact of air pollution on health have been calculated using AirQ+ software produced by WHO European Region and available online free for download. AirQ+ allows to assess the burden of ambient air pollution as well as household air pollution and estimates for ambient air pollution are based on WHO recommendations [14].

CONCLUSION

The findings suggest that in Bor, long-term exposure to $PM_{2.5}$ had a noteworthy impact on public health, leading to a significant number of mortality cases. It is, thus, of utmost importance to reduce ambient air $PM_{2.5}$ levels in order to ultimately reduce the adverse effects on public health in the broader area of this industrially contaminated site. AirQ+ can be utilized in understanding the specific outcomes associated to ambient air pollution exposure and the extent of its impact. Together with the policy-makers and public health authorities targeted interventions could be planned and developed in order to reduce air pollution levels downsizing it to the level that could no longer present a public health threat to the potentially exposed population.

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