

Vulnerabilities to air pollution in North Macedonia

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Question

Provide an overview of key vulnerabilities to air pollution in North Macedonia (where possible the focus should be on at-risk populations, occupations and locations)?

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1. Summary

This literature review collates available evidence on vulnerabilities to air pollution in North Macedonia. It draws on a diverse range of sources from multiple academic disciplines and grey literature. Air pollution is a global environmental health threat contributing to an estimated three to seven million deaths per year worldwide. The economic cost of this health loss is also significant, the World Bank estimates that globally in 2013 air pollution led to an estimated \$5.11 trillion in welfare losses, and \$225 billion in lost labour income. Whilst these headline figures are alarming, they tend to gloss over the disproportionate impact of poor air quality on certain populations, locations and occupations.

The literature highlights that the Republic of North Macedonia (here after North Macedonia) is considered to have some of the worst air quality in the West Balkans, and consequently some of the worst globally. Whilst air pollution is acknowledged to be a particular issue for the nation's population, there have been limited analyses of who or where is most vulnerable to air pollution or why. Understanding vulnerability to air pollution presents unique challenges for researchers. Vulnerability is commonly referred to as the level of exposure of human life, property and resources to the impact from hazards. Factors, such as sex, age, education, and occupation can modify the relationship between air pollution and mortality. Further to this, the effects of air pollution exposure on health are considered greater in people with lower socio-economic status: Three dimensions of vulnerability are identified in the literature:

- Exposure i.e., the degree to which the subjects or areas could be effected by air pollution.
- Susceptibility i.e., the likelihood of being harmed by air pollution.
- Adaptive capacity i.e., the ability to take actions to either reduce or avoid risk.

Key messages include

Location related vulnerability

There are a number of factors that may increase an individual's exposure to air pollution including time-activity patterns, modes of transport, recreational activities and pivotally, proximity to sources of air pollution whether major roads or polluting industries.

- **Urban areas:** Several areas in North Macedonia suffer from poor air quality, with concentrations significantly exceeding the global air quality guideline for Particulate Matter (PM_{2.5}) established by the WHO and the air quality limit values for PM₁₀ and PM_{2.5} of the EU. Especially in winter, urban areas face severe pollution episodes, caused by the increased demand for heat from the residential and commercial sector, which is mainly associated with fuelwood use.
- **Place of residence:** Household fuel use is consistently identified as the predominant source of PM emissions in North Macedonia. Source apportionment analysis conducted by the World Bank (2019) indicates that at the national level, the residential sector is the largest source of exposure to harmful PM_{2.5} associated with the burning of solid fuels in homes (World Bank, 2019).
- **Air pollution hotspots:** Whilst the majority of studies exploring air pollution monitor background ambient air pollution levels, air quality at particular hotspots are also a

concern, particularly in locations where large numbers of people spend significant amounts of time e.g., bus stations, schools, hospitals etc. This review did not identify any studies that identified potential air pollution hotspots or assessed air pollution at such locations highlighting a need to assess how air quality varies within cities.

- **Valley's:** More broadly, North Macedonia's unique geographic location has a particular impact on air quality. In cities surrounded by mountain ranges the most severe pollution episodes are created during specific atmospheric conditions, so called temperature inversions where air pollutants are trapped near the valley floor.

Population related vulnerability

Air pollution is considered to impact on all groups especially when exposed over prolonged periods of time. However, some groups are considered to be more susceptible than others when considering exposure to air pollution. Vulnerable groups include young children, the elderly, persons with certain underlying diseases, foetuses, groups exposed to other toxicants that interact with air pollutants and those with low socio-economic status.

- **Older age:** The age structure of a society is relevant to health statistics, as older people are more likely to die as a result of the air pollution. Population projections highlight that the demographic make-up of North Macedonian society is slowly changing. In 2020 it was estimated that 14.49% of the population was aged 65+, by 2030 this is forecast to increase to 17.86% and by 2050 the percentage of population aged 65+ is estimated to reach 23.61% of the population. Older groups are more susceptible to the health impacts of poor air quality.
- **Poverty:** Poverty and well-being of North Macedonians greatly depends on place of residence. Regions affected by high poverty are mainly located in the north (which hosts more than half the economy's population), including the Polog, Skopje and Northeast regions, with poverty rates as high as 42.8% in the latter. It is broadly acknowledged that lower household incomes increase the risk of living in areas with higher levels of air pollution (i.e., closer to point sources such as busy roads or factories) and increase the likelihood of being dependent on polluting fuels for household cooking, lighting and heating. Further to this, poverty may decrease adaptive capacity i.e., access to knowledge, technologies or resources that may reduce exposure. This may include access to cleaner forms of energy or appliances.
- **Minorities:** Ethnic inequality in North Macedonia is stark, and minority groups are in many ways excluded from society. Over 40% of the poorest quintile are estimated to belong to households of ethnic Albanian origins, with disposable incomes two-thirds those of households of ethnic Macedonian origins (World Bank, 2018). Roma communities, which constitute 2.7% of the population according to the 2002 Census, are left behind in multiple ways. For instance, Roma women have worse health indicators than the general population.
- Experiences of marginalisation influence vulnerability in a complex array of ways. This may include physical marginalisation e.g., living in areas where air quality levels may be particularly concerning. Marginalisation also influences access to information e.g., limited access to knowledge of the causes and consequences of air pollution or means to reduce exposure. In North Macedonia, more research is needed to explore how marginalisation exacerbates (or not as the case may be) vulnerability to air pollution.

- **Gender:** Exposure to indoor air pollution from the burning of solid fuels for cooking, heating, and lighting accounts for a significant portion of the global burden of death and disease, and disproportionately affects women and children. This review was not able to identify any studies that explored the impact of air pollution on women and girls versus men and boys.

Occupational vulnerability

Despite a growing body of evidence of the health impacts of exposure to air pollution, particularly on the cardiovascular system, relatively little attention has been given to the effects of occupational exposures

According to World Bank Data¹, in 2019 31% of the employed population worked in industry, 14% in agriculture and 55% in services. More studies are required to explore how different occupations may impact on vulnerability.

2. Vulnerability to air pollution

Air pollution is a global environmental health threat contributing to an estimated three million deaths per year worldwide (Lelieveld et al., 2015). The Global Burden of Disease project (World Bank & IHME, 2016) estimates a figure for premature deaths closer to 5.5 million per year (one in every ten and the fourth highest factor for causing early death). The most extreme estimates are presented by the World Health Organisation, reporting that in 2012 seven million people died - one in eight of total global deaths - as a result of air pollution exposure (WHO, 2014). In North Macedonia, it is estimated that 1,903 people die annually from exposure to particulate matter (PM_{2.5}) alone, 22.3% of total all-cause mortality (Dimovska & Gjorgjev, 2018)².

The effects of air pollution on human health are well documented in a range of epidemiological studies; exposure may increase the risk of lung cancer, heart disease, bronchitis and other cardiorespiratory conditions (Kelly & Fussell, 2015). The economic cost of this health loss is also significant, the World Bank estimates that globally in 2013 air pollution led to an estimated \$5.11 trillion in welfare losses, and \$225 billion in lost labour income (World Bank & IHME, 2016). The World Bank concludes that air pollution “is not just a health risk but also a drag on development...By causing illness and premature death, air pollution reduces the quality of life. By causing a loss of productive labour, it also reduces incomes” (IBID: 2). The World Bank (2019) estimated the economic cost associated with mortality from exposure to air pollution in North Macedonia to be in the range of US\$500–900 million annually, equivalent to 5.2–8.5% of GDP in

¹ <https://data.worldbank.org/indicator/SL.IND.EMPL.ZS?locations=MK>

² PM or atmospheric aerosols is the term used to indicate any solid or liquid particle suspended in the atmosphere. Atmospheric particles vary widely in their physical parameters such as size and chemical composition. PM of small size fractions are considered to be particularly detrimental to public health as they can enter the respiratory system and lead to respiratory disease, asthma, strokes, cancer and heart disease. PM_{2.5} and PM₁₀ are particulate matter with aerodynamic diameters less than 2.5 and 10 µm, respectively (Seinfeld & Pandis, 2016). The PM_{2.5} size fraction is the focus of many air pollution studies because it is associated with adverse health outcomes, it is also the focus of this review.

2016 (World Bank, 2019: iv-v). This valuation only quantifies economic impacts from premature mortality associated with specific diseases.

Whilst these headline figures are alarming, they tend to gloss over the disproportionate impact of poor air quality on certain populations, locations and occupations. Common approaches to assessing the impact of air pollution have tended to assume an equal vulnerability, sensitivity or susceptibility to air pollution (Stilianakis, 2015). This assumption masks differences in exposure and risk across populations, locations and occupations with air quality varying both spatially and temporally (Kathuria & Khan, 2007). Although average changes in risk associated with exposure to air pollution are considered small, some individuals or groups can be considered more vulnerable or susceptible than others.

In the context of this rapid review, exposure to high levels of particulate matter (PM) is a particular focus. PM of small size fractions is considered to be especially detrimental to public health as it can enter the respiratory system and lead to respiratory disease, asthma, strokes, cancer and heart disease (Thurston et al., 2016). A key contributor to heightened levels of PM is the combustion of solid and liquid fuels e.g., for power generation, domestic heating and in vehicle engines.

Assessments of risk of exposure to air pollution are typically communicated via an Air Quality Index Scale, these illustrate how different levels of air pollution contribute to different health impacts amongst different groups. An ambient air quality standard (AAQS) or index identifies limits on the amount of a given pollutant in the air. The standards are designed to protect people's health and have been calculated to allow a margin for people most at risk e.g., the young and old and people with pre-existing health problems. The ambient air quality standards most often utilised include those developed by the European Union, the United States and the World Health Organisation (WHO). The WHO air quality standards are not legally binding, rather they represent a guideline for countries. The standards proposed by the WHO are significantly tougher than those suggested by others. Table 1 below provides a guide to different levels of exposure to PM_{2.5} over a 24-hour period according to the Common Air Quality Index (CAQI), an air quality index used in Europe since 2006.

Table 1: The Common Air Quality Index (CAQI) (authors own summary)

Qualitative name	Pollutant (hourly) concentration PM _{2.5} µg/m ³
Very Low	0-15
Low	15-30
Medium	30-55
High	55-100
Very High	>110

Vulnerability dimensions

Understanding vulnerability to air pollution presents a unique challenge for researchers. Authors commonly refer to vulnerability as the level of exposure of human life, property and resources to the impact from hazards (Fussell, 2007). Factors, such as sex, age, education, and occupational exposure, can modify the relationship between air pollution and mortality (Kan et al., 2008). Further to this, the effects of air pollution exposure on health are considered greater in people with lower socio-economic status (O'Neil, 2003).

The WHO (2004) defines vulnerability as the likelihood of being unusually severely affected by air pollutants either as a result of susceptibility to the effects of these substances or as a result of a greater than average exposure. Three dimensions of vulnerability are commonly identified in the literature (Howe et al., 2013):

- Exposure denotes the degree to which the subjects or areas could be affected by air pollution. The level of exposure to air pollution is generally defined by several components and measures, including: the frequency and intensity of exposure; the presence or absence of mechanisms that could amplify or lessen the severity of exposure and the location relative to sources of air pollution. Exposure to air pollution is thus largely determined by the concentration of air pollutants in the environments where people spend their time, and the amount of time they spend within them.
- Susceptibility to air pollution is more difficult to assess than exposure. One needs to consider both the components of susceptibility and measures of that susceptibility. Demographic factors such as age, gender, and socio-economic status play an important role in assessing susceptibility to air pollution. However, these factors are highly context-specific, and can also interact with one another.
- Adaptive capacity refers to actions taken either to reduce or avoid risk. While greater exposure and higher susceptibility to air pollution increase vulnerability, adaptive capacity enables people to reduce their vulnerability. The concept of adaptive capacity is important because while exposure and susceptibility, characterise vulnerability in a negative way, adaptive capacity recognises the ability to learn and change behaviour.

Finally, it is important to note that the root causes of vulnerability are constructed over time and influenced by social relationships. These relationships are in turn determined by a number of intersecting factors, such as gender, ethnicity, class, age and disability, coupled with situational variables, such as where people live, their health, household composition and size and the resources available to them to cope.

3. Vulnerability to air pollution in North Macedonia

Location related vulnerability

There are a number of factors that may increase an individual's exposure to air pollution including time-activity patterns, modes of transport, recreational activities and pivotally, proximity to sources of air pollution whether major roads or polluting industries etc. Despite this acknowledgment, risk assessment studies often ignore within city variations of air pollutants. For example, low-income populations may live in areas likely to increase exposure to air pollutants –

notably in locations of high pollution and low-quality housing e.g., proximity to high traffic areas or factories. Studies that have included socio-economic factors have identified poor and less affluent population groups as most exposed to environmental risk in their place of residence (WHO, 2010). The WHO (2010: 33-34) highlight that inequalities were reported for environmental risks experienced within the dwelling (such as exposure to biological and chemical contamination, noise, temperature extremes and absence of sanitary facilities) as well as the residential environment (lack of urban amenities, proximity to pollution sites or polluted areas, exposure to traffic related pollution).

Housing market dynamics in land use decisions may also explain why certain populations experience both poor socio-economic status and heightened air pollution exposure. As good housing and environmental quality are in high demand in urban areas, they command a financial premium (WHO, 2010). Consequently, poor and less affluent population groups tend to be affected to a greater extent by inadequate housing conditions and higher environmental burden in their residential environments (WHO, 2010). Further to this, poor housing offers little protection from indoor infiltration of ambient pollution, extreme temperatures, or allergens (Lipfert, 2004).

Risk studies of air pollution that rely on background stations to estimate air pollution levels may underestimate the attributable risk. However, due to the variety of studies and methodological approaches as well as the lack of data for many regions and countries (including North Macedonia), it is not possible to make a general assessment or quantification of the magnitude of inequality faced by poorer population groups.

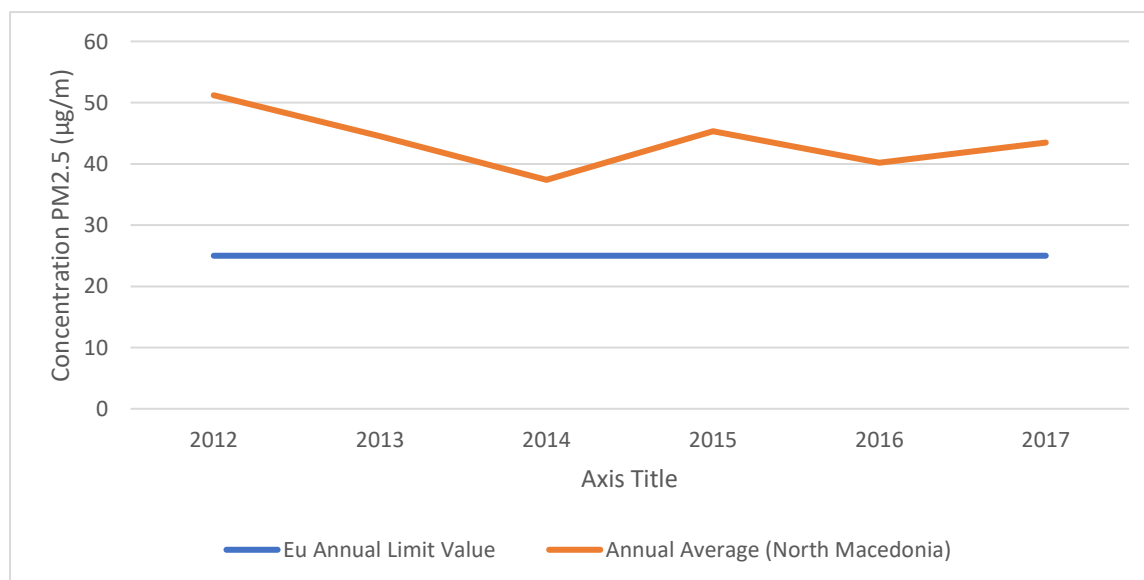
Urban areas

Several areas in North Macedonia suffer from poor air quality, with concentrations significantly exceeding the global air quality guideline for PM_{2.5} established by the WHO and the air quality limit values for PM₁₀ and PM_{2.5} of the EU. Especially in winter, urban areas face severe pollution episodes, caused by the increased demand for heat from the residential and commercial sector, which is mainly associated with fuelwood use (World Bank, 2019: 55).

The European Environmental Agency (2021) has consistently reported that levels in Skopje across all stations are at levels considered moderately polluted in terms of trend in annual mean concentration (see figure 1).

Figure 1: Trend in annual mean concentration across all stations (North Macedonia) against the EU standard PM_{2.5} (µg/m³ for the years 2012-2017) (EEA, 2021

<https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/north-macedonia-air-pollution-country>)



Analysis of average annual PM_{2.5} levels across North Macedonian cities where PM_{2.5} is monitored illustrates that levels are consistently reported to be moderately polluted (table 2). More specifically it is during winter months where air quality is at its worst, driven by a combination of fuel use patterns and meteorological conditions (see table 3:)

Table 2: Average annual values of PM_{2.5} across select cities colour coded according to CAQI air quality index (adapted from Idrizi et al., 2021: 93

<https://dergipark.org.tr/en/download/article-file/1812432>)

City	Location	2013	2014	2015	2016	2017	2018	2019
Skopje	Centar	40	50	39	27	38	28	34
	Karposh	32	41	50	52	48	29	42
	Butel						38	48
Tetova						44	42	50
Manastir	Manastir 2					32	35	
Kuman						38	37	38

Table 3: Average Annual Values for PM_{2.5} particles by season, for the period 2017 – 2019 colour coded according to CAQI air quality index (Idrizi et al., 2021: 95 <https://dergipark.org.tr/en/download/article-file/1812432>)

City	2017		2018		2019	
	Winter	Summer	Winter	Summer	Winter	Summer
Skopje	63	23	47	22	41	23
Tetova	60	20	66	19	61	19
Manastir	43	15	56	17	50	10
Kuman	53	17	56	19	48	18

Place of residence

Household fuel use is consistently identified as the predominant source of PM emissions in North Macedonia. Source apportionment analysis conducted by the World Bank (2019) indicates that at the national level, the residential sector is the largest source of exposure to harmful PM_{2.5} associated with the burning of solid fuels in homes (World Bank, 2019). Household fuel use is a socially sensitive issue with household income often determining fuel types utilised³ (World Bank, 2019).

In particular, the use of polluting fuels for heating of households in the winter period causes serious problems with air quality in densely populated residential areas since many households and administrative entities in the country still use fuelwood as a primary source of heating (World Bank, 2019). The primary energy supply profile for North Macedonia indicates that coal and peat accounted for about 50% of primary energy supply in 2012, followed by oil products and biomass and waste accounting for about 20% each respectively (World Bank, 2019: 41).

There exists a dearth of household air quality studies in North Macedonia that assess the impact of household activities on indoor air quality. One study identified, undertaken by Vilčeková et al. (2017: 6) in Prilep (North Macedonia) reports that mean PM_{2.5} concentrations in selected houses ranged from 16.80 µg/m³ to 30.70 µg/m³. Indoor pollutants such as cigarette smoking and cooking were identified as major sources of indoor PM_{2.5} concentration. Vilčeková et al. (2017) reported the following results:

- smoking led to an increase in the level of indoor concentration to as much as 1280 µg/m³;

³ Europe's energy price crisis will likely influence household fuel use in North Macedonia.

- indoor concentration in a room subjected to smoking was about 0.6 times higher than that of a control room;
- cooking activities contributed to the PM_{2.5} concentration in the kitchen, to a level of 3000 µg/m³;
- human activities such as walking, dressing and sweeping contributed to an increase of indoor concentration by about 33%.

More studies are required that assess indoor air pollution across a range of settings and income groups to ascertain how household air pollution impacts on individuals. In particular, it is important to ascertain who might be most exposed within the household and why (see section on gender).

Air pollution hotspots

Whilst the majority of studies exploring air pollution monitor background ambient air pollution levels, air quality at particular hotspots are also a concern, particularly in locations where large numbers of people spend significant amounts of time e.g., bus stations, schools, hospitals etc. Studies of air quality that focus on background readings or fixed location monitoring alone may fail to provide an accurate estimation of variance in exposure between different locations (WHO, 2005: 68).

Locations with locally increased air pollution are often referred to as hotspots. The elevated pollution levels in such locations may be the product of limited dispersion of pollutants (e.g., a street canyon) or high local emissions (e.g., near a highway, railway station, airport, harbour, a bus station or bus). Air pollution levels in such hotspots warrants further exploration, however, few studies have examined exposure in such locations (WHO, 2005: 68).

This review did not identify any studies that identified potential air pollution hotspots or assessed air pollution at such locations highlighting a need to assess how air quality varies within cities.

Valley's

More broadly, North Macedonia's unique geographic location has a particular impact on air quality. Mountains generally reduce the flows of air in valleys and allow pollutant levels to increase at ground level. In North Macedonia, the atmosphere tends to be stable (lower wind speeds) during night and neutral to unstable during days (higher wind speeds). This explains, in part, why air pollution concentrations increase during the night even though the emissions are typically lower during this time (Antilla et al., 2016). In cities surrounded by mountain ranges the most severe pollution episodes are created during specific atmospheric conditions, so called temperature inversions (World Bank, 2019). These inversions occur during the winter months when normal atmospheric conditions (cool air above, warm air below) become inverted and the normal vertical mixing of warm and cold air is prevented. Inversions trap a layer of cold air under a layer of warm air. The warm layer acts much like a lid, trapping pollutants in the cold air near the valley floor. Pollutants do not disperse or dilute but remain trapped at the ground level (Antilla et al., 2016).

Population related vulnerability

Air pollution is considered to impact on all groups especially when exposed over prolonged periods of time. However, some groups are considered to be more susceptible than others when considering exposure. Further to this, different pollutants may affect groups in varying ways. WHO considers as vulnerable groups; young children, the elderly, persons with certain underlying diseases, foetuses, groups exposed to other toxicants that interact with air pollutants and those with low socio-economic status (WHO, 2004).

Studies have shown that those with pre-existing disease are at higher risk of seeking medical attention or of using more medication to control their condition. For instance, increases in the use of asthma medication in children has been associated with ambient levels of air pollution (Gauderman, 2005). More specifically, for:

- People with asthma: exposure to air pollution might worsen symptoms or trigger asthma attacks.
- People with lung disease, such as chronic bronchitis (also called chronic obstructive pulmonary disease or COPD): exposure to air pollution might worsen symptoms.

Young children are among the most susceptible to the effects of air pollution (WHO, 2005). Children have higher breathing rates than adults and therefore a higher intake of air pollutants per unit of body weight. They also spend more time outdoors than adults, thereby adding to their exposure potential (WHO, 2005). The developing lung may also have a limited metabolic capacity to address the inhalation of toxic substance. Some children are especially vulnerable. This includes children with underlying chronic lung conditions such as asthma and cystic fibrosis etc. Exposure of pregnant women to high levels of air pollution may also impact on the development of foetuses with the potential for health impacts later in life.

Alongside the young, older people are more likely to be affected by air pollution due to generally weaker immune systems, or undiagnosed respiratory or cardiovascular health conditions. As people age, their bodies are less able to compensate for the effects of environmental hazards. Exposure to air pollution of elderly populations may lead to higher morbidity and mortality predominantly as a result of cardiovascular and respiratory disease (Hoek et al. 2013). The increases in mortality associated with PM air pollution are thus greatest among older age groups. The prevalence of COPD and other chronic respiratory diseases increases with age. However, many physiological changes associated with aging may increase susceptibility to particle effects.

The elderly may also be more susceptible to particle exposure because of lifetime exposure to PM, as well as previous respiratory infections. Exposure to air pollution of this group can aggravate heart disease and stroke, lung diseases such as COPD and asthma. A number of features thus influence air pollution vulnerability among older age groups.

- With increasing age, lungs become less capable of filtering air and disposing of pollutants.
- The elderly often have weaker immune systems.
- Issues with sight often manifest as individuals age. This issue is exacerbated when dust particles are present in the air.

- With aging, heart functions decline, those with pre-existing heart conditions may face increased risk of heart attacks if exposed to heightened levels of air pollution

Exposure to indoor air pollution from the burning of solid fuels for cooking, heating, and lighting accounts for a significant portion of the global burden of death and disease, and disproportionately affects women and children (WHO, 2016). Given differences in time activity patterns of men and women associated with the allocation of household tasks, indoor air pollution (particularly exposure to unclean cooking fuels) will disproportionately impact on women. More broadly, whether men and women differ in their responses to air pollution exposure is subject to debate with findings considered limited and inconclusive. According to Clougherty (2010: 167), it remains unclear whether modifications are attributable to socially derived gendered exposures, to sex-linked physiological differences, or to some interplay thereof.

Factors such as socio-economic status are also considered to be part of the vulnerability burden of populations exposed to air pollution. Epidemiological studies often treat socio-economic status as a confounder or effect modifier, since it correlates with other variables that modify risk (Villeneuve et al, 2003). An inadequate nutritional status, limited access to health care and higher exposures may be some reasons for the higher burden. However, in studies where socio-economic factors were included, a relationship between income, education or disadvantage has been noted (WHO, 2004). Such analyses suggest that economically deprived communities are the most affected by exposure.

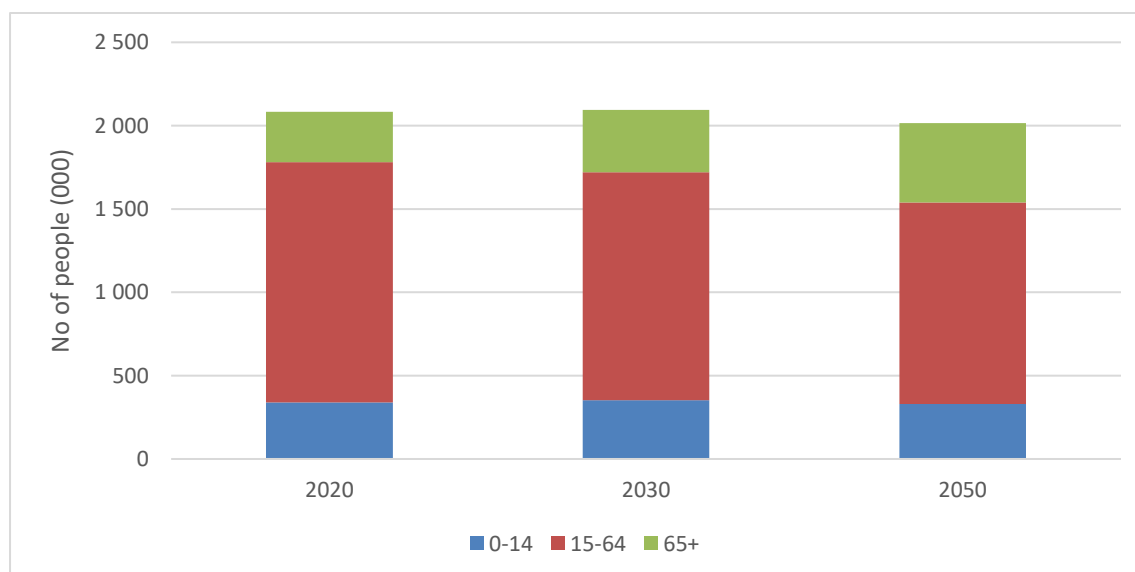
This review identified a dearth of studies within North Macedonia, that explored population related issues in depth. In what follows, I provide an overview of factors that may influence vulnerability.

Age

The age structure of a society is relevant to health statistics, as older people are more likely to die as a result of the air pollution. Most European countries are aging rapidly (World Bank, 2019). Population projections highlight that the demographic make-up of North Macedonian society is slowly changing. In 2020 it was estimated that 14.49% of the population was aged 65+, by 2030 this is forecast to increase to 17.86% and by 2050 the percentage of population aged 65+ is estimated to reach 23.61% of the population (PopulationPyramid.net⁴).

⁴ <https://www.populationpyramid.net/tfyr-macedonia/2035/>

Figure 2: North Macedonian population by age group (2020, 2030 and 2050)
 (PopulationPyramid.net <https://www.populationpyramid.net/tfyr-macedonia/2035/>)



As noted by the World Bank (2019: 36), in total about 1,600 people die from causes associated with ambient air pollution in North Macedonia every year. About 80% of the deaths are from cardiovascular diseases. About 61% of deaths from ischemic heart disease and 69% of deaths from strokes occur in people over 70 years of age. Cardiovascular diseases mostly affect population groups older than 65 years of age (World Bank, 2019: 36). With an ageing society, it is likely that air pollution will impact most significantly (both in terms of morbidity and mortality) on older age groups.

Estimated attributable deaths in terms of IHD (Ischemic heart disease) due to ambient air pollution was 245 (19.1% of total IHD deaths). Estimated attributable deaths in terms of stroke due to ambient air pollution was 254 (29.9% of total stroke deaths) (Dimovska, 2021: 10). The estimated health burden is significantly increasing in the age group 65 and over in terms of IHD, stroke and all-cause mortality in general (Dimovska, 2021: 10).

Poverty and wellbeing

OECD (2022) reports that North Macedonia is confronted by a range of development challenges that influence vulnerability to air pollution:

1. People's well-being varies significantly across regions and poverty disproportionately affects numerous ethnicities in North Macedonia.
2. Weak labour market institutions and lack of skills due to an inadequately developed education system result in low employment inclusiveness, particularly for young people.
3. Lack of child and elderly care services, restrictive parental leave policies and traditional cultural norms prevent many women from seeking paid employment.
4. The rising burden of lifestyle diseases needs to be addressed through increased healthcare funding and more efficient organisation.

5. Despite recent reforms, the current social protection system is not fully financially sustainable in the face of a low formal worker contribution base.

In 2019 it was reported that North Macedonia had a Human Development Index of 0.774, ranking 82 out of 189 countries. This puts the country below Albania and all the other Yugoslav successor states except Kosovo (BTI, 2022: 17). The North Macedonian poverty rate was 9%, in 2017 and was the highest in the Western Balkan region (BTI, 2022: 17). Poverty rates have significantly dropped since 2008 but are still high, with 18% of the population living on less than USD 5.5 a day. The COVID-19 pandemic has worsened this situation, given that the most vulnerable categories are the most affected (BTI, 2022: 17).

OECD (2022) comments that the well-being of Macedonians greatly depends on their place of residence. Regions affected by high poverty are mainly located in the north (which hosts more than half the economy's population), including the Polog, Skopje and Northeast regions, with poverty rates as high as 42.8% in the latter. The north is largely dependent on agriculture, and almost 33% of the working poor are active in this sector, compared to 13% of the working non-poor (OECD, 2022). Employment rates range from 37% in the Northeast region to 63.3% in the Southeast region. Labour force rates are also very low in some regions, indicating that a significant share of people are not economically active anymore. Labour force participation rates were lowest in the Polog and Northeast regions (51.9% and 55.2% in 2019, respectively) and were the highest in the Southeast region (67.6% in 2019).

Table 4: Selected indicators, 2019 or latest available year (OECD, 2022 <https://www.oecd-ilibrary.org/sites/e232493b-en/index.html?itemId=/content/component/e232493b-en>)

Regions	Population	Population (%)	Employment rate (%)	Labour force participation rate	GDP per capita (USD)	Annual gross earnings (USD)	Poverty	Infant mortality rate (per 1 000 live births)
Skopje	630 873	30.4	45.6	53.5	7 724	9 496	23.80%	5.1
Polog	322 338	15.5	37.1	51.9	2 572	6 804	38.10%	8.7
Pelagonia	227 919	11	56	64.5	5 285	7 282	10.70%	4.1
Southwest	219 580	10.6	43.1	57	4 367	6 446	13.20%	4.8
Northeast	176 196	8.5	37	55.2	3 187	5 850	42.80%	5.3
East	174 877	8.4	54.3	58.9%	5 308	6 589	14.00%	7.2
Southeast	173 327	8.3	63.3	67.6	6 396	6 605	23.50%	6.5

Vardar	152 022	7.3	55.2	61.8	5 639	6 523	14.00%	4
Total	2 077 132		47.3	57.2	5 446	8 114		

More analysis is required of how poverty and wellbeing intersect with vulnerability to air pollution. It is broadly acknowledged that lower household incomes increase the risk of living in areas with higher levels of air pollution (i.e., closer to point sources such as busy roads or factories) and increase the likelihood of being dependent on polluting fuels for household cooking, lighting and heating. Further to this, poverty may decrease adaptive capacity i.e., access to knowledge, technologies or resources that may reduce exposure. This may include access to cleaner forms of energy or appliances.

Minorities

As in other Western Balkan economies, ethnic inequality in North Macedonia is stark, and minority groups are in many ways excluded and society (OECD, 2022). Over 40% of the poorest quintile are estimated to belong to households of ethnic Albanian origins, with disposable incomes two-thirds those of households of ethnic Macedonian origins (World Bank, 2018). Roma communities, which constitute 2.7% of the population according to the 2002 Census, are left behind in multiple ways. For instance, Roma women have worse health indicators (e.g., fewer prenatal visits, lower quality of care), and their children suffer from stunting more than the rest of the population (World Bank, 2018). Moreover, about 33% of ethnic Roma children complete upper secondary school by age 25, compared to 87% of non-Roma youth, and virtually no Roma are enrolled in tertiary education (World Bank, 2018). In 2017, about 20% of Roma aged 15 to 64 were employed, compared to 40% of non-Roma in neighbouring communities – a slight improvement since 2011 but a widening of the gap with non-Roma (OECD, 2022).

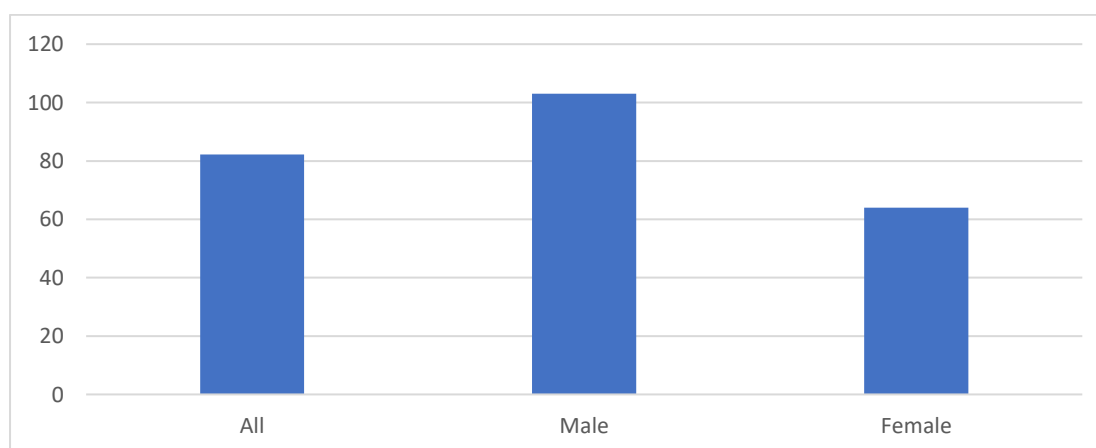
Experiences of marginalisation influence vulnerability in a complex array of ways. This may include physical marginalisation e.g., living in areas where air quality levels may be particular concerning. Marginalisation also influences access to information e.g., limited access to knowledge of the causes and consequences of air pollution or means to reduce exposure. In North Macedonia, more research is needed to explore how marginalisation exacerbates (or not as the case may be) vulnerability to air pollution.

Gender

Exposure to indoor air pollution from the burning of solid fuels for cooking, heating, and lighting accounts for a significant portion of the global burden of death and disease, and disproportionately affects women and children (WHO, 2016). Given differences in time activity patterns of men and women associated with the allocation of household tasks, indoor air pollution (particularly exposure to unclean cooking fuels) will disproportionately impact on women. More broadly, whether men and women differ in their responses to air pollution exposure is subject to debate with findings considered limited and inconclusive. According to Clougherty (2010: 167), it remains unclear whether modifications are attributable to socially derived gendered exposures, to sex-linked physiological differences, or to some interplay thereof.

This review failed to identify any studies that explored the impact of air pollution on women and girls versus men and boys. Available data gleaned from the World Bank suggests the men are more at risk of death from exposure than women (see figure 3).

Figure 3: Mortality rate attributed to household and ambient air pollution, age-standardised (per 100,000 population) - North Macedonia 2018 (World Bank Data)
<https://data.worldbank.org/indicator/SH.STA.AIRP.P5>



More analysis is required to assess how gender and air quality exposure intersect, particularly in contexts where women and girls may spend increased periods of time in more polluted environments (e.g., household locations). It is reported that unemployment is particularly high among women, who account for 64.5% of the economically inactive population. The latter is primarily because women are expected to care for children and the elderly – especially when public services are not available or accessible – and due to their informal, often unpaid work in family farming, this is particularly the case in rural areas (BTI, 2022: 17).

Occupational vulnerability

Despite a growing body of evidence of the health impacts of exposure to air pollution, particularly on the cardiovascular system, relatively little attention has been given to the effects of occupational exposures (Fang et al., 2010). Exposure to air pollution can also result from occupational factors (e.g., outdoor work) and exposure to high concentrations of certain air pollutants. Certain types of work (e.g., in transport or construction) may lead to higher exposure (Rotko et al., 2000).

Findings from systematic reviews suggest that occupational exposure differs from general ambient exposures in both particle type (e.g., composition), as well as exposure frequency (e.g., environmental exposures are relatively constant while occupational exposures are more variable), duration (e.g., a work-shift and working lifetime vs. an entire day and lifetime), and intensity or concentration (i.e., occupational exposures are generally higher than ambient levels) (Fang et al., 2010: 1774). These differences in exposure composition, duration, frequency and population exposed may have implications on how occupational exposures impact on individual and group health.

According to World Bank Data⁵, in 2019 31% of the employed population worked in industry, 14% in agriculture and 55% in services. More studies are required to explore how different occupations may impact on vulnerability.

4. Adaptive capacity

The concept of adaptive capacity remains contested but can broadly be defined as the ability of individuals, communities, organisations, nations or other actors to take actions to either reduce or avoid risk. While greater exposure and higher susceptibility to air pollution increase vulnerability, adaptive capacity refers to the means by which people can reduce their vulnerability. The concept of adaptive capacity is important because while exposure and susceptibility, characterise vulnerability in a negative way, adaptive capacity recognises the ability of actors to learn and change behaviour.

Whilst many studies of air pollution focus on efforts to reduce air pollution levels and improve air quality (i.e., mitigation), some recent literature has explored how various actors can protect themselves against the impacts of pollution by developing adaptive capacity. This focus on adaptation stems from an awareness that due to a lack of air quality regulations, enforcement institutions or effective agreements on air quality management, improvements may be difficult to achieve (Ebert & Welsch, 2011). Indeed, mitigation requires consensus and cooperation across a number of stakeholder groups (public and private sector and civil society) and levels (local, regional, national and global). In contrast to mitigation, adaptation requires less consensus, and some actions may be taken at an individual, organisational or city level.

Factors that may impact upon the adaptive capacity of lower income groups include livelihoods, underlying health issues (such as respiratory illness, heart disease etc.), social, economic and political exclusion and reduced access to resources and knowledge.

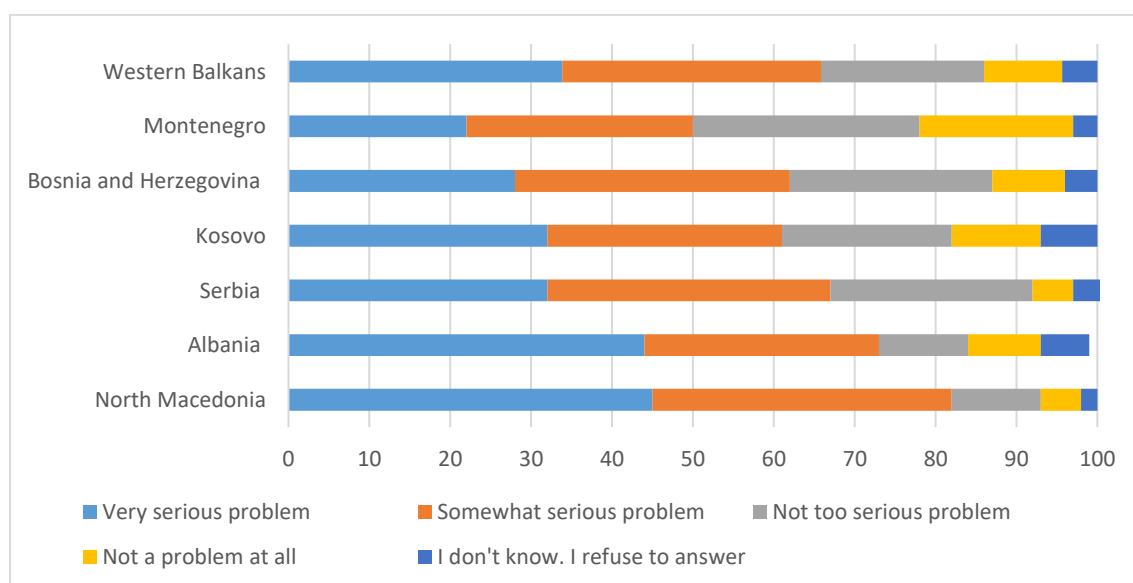
Low-income groups are likely to be most affected by continued exposure to high levels of indoor and outdoor air pollution. Consequently, a key focus of 'soft' actions for adaptation should be directed at developing the adaptive capacity of low-income groups in the environments in which they spend significant periods of time. Finding reliable ways to measure adaptive capacity and promote behaviours, particularly of low-income groups, is challenging and remains a priority for researchers and policymakers. Numerous indicators have been developed, including 'education, income, and health' as well as access to financial, technological and institutional resources. More broadly, recent literature has attempted to identify determinants of adaptive capacity and specify the processes through which those determinants interact. Eakin et al. (2014), for example, explore the relationship between socioeconomic development and in the context of their research climate risk reduction, as an interaction between 'generic' and 'specific' capacities and explore how those capacities might complement or undermine each other. In a similar vein, the Local Adaptive Capacity (LAC) framework, seeks to understand how different determinants of adaptive capacity influence each other at household and community levels.

Whilst studies that explore the adaptive capacity of North Macedonians to reduce vulnerability to air pollution exposure are largely absent recent data suggests that the importance attributed to

⁵ <https://data.worldbank.org/indicator/SL.IND.EMPL.ZS?locations=MK>

addressing air quality issues is increasing. Government has identified action as a priority and concern amongst the public has increased in recent years. Figure 4 highlights that 45% of North Macedonian respondents to the question “Do you consider pollution to be a problem in your place of living?” considered it a very serious problem.

Figure 4: Do you consider pollution to be a problem in your place of living? (Balkan Barometer 2019 cited in OECD. 2022)



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