AIR QUALITY, HEALTH AND THE CITY: THE CASE OF SKOPJE

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ABSTRACT

Air pollution is a major global environmental concern that has significant impacts on public health. With increasing urbanization, cities are an appropriate unit for the analysis of this issue. Investigating the correlation between air quality, respiratory diseases, and urban parameters in five micro-locations in the case of Skopje the study finds that air quality is influenced by a variety of factors including urban parameters, land use, types of heating systems, and proximity to the burning of stubble and use of harmful fuels. To address the issue of air pollution in Skopje, the study recommends implementing measures such as promoting the use of open block typologies in urban planning, encouraging the use of sustainable heating systems, implementing stricter regulations on industrial activities, increasing the use of green spaces, and reducing the built footprint. Overall, addressing air pollution in Skopje requires a comprehensive approach that considers individual and structural factors.

Keywords: air quality, health, urban morphology
Thematic clusters: 2. City and Environment
Topic: Environment, landscape, resilience and climate change

Introduction

Skopje, as the capital of North Macedonia, has gained negative popularity in recent years by continually holding high positions in the charts of the most polluted cities, both in Europe as well as in the world. The general population of Skopje was made aware of the high levels of toxicity in 2015 when an online web and mobile app provided an explicative and easy-to-understand way to track the daily levels of air pollutants and overall air quality. Although both local and national governments point towards the low average income, energy poverty, the natural position of Skopje, temperature inversions etc. as the main culprits for the air quality, using short-term measures to gain popularity votes, little has been done in terms of actual improvements.

This research aims to investigate the correlation between air quality, respiratory diseases, and urban form in the city of Skopje, Republic of North Macedonia. The following research questions will guide this study: Is there a difference in air quality and respiratory disease prevalence between different neighbourhoods in Skopje? How are air quality and respiratory health impacted by urban form, land use, topography, wind, temperature, and heating systems of households in Skopje? Based on these research questions, the hypothesis of this study is that there is a correlation between air quality, respiratory diseases, urban form, natural factors, and heating systems of households in the city of Skopje. To achieve the objectives of this study, a comparative case study approach will be used, focusing on four municipalities (Karposh, Centar, Aerodrom, and Gazi Baba) in Skopje. The location of the monitoring stations will be the main selection criteria in choosing these four locations, and differences in urban morphology, built density, and land use will also be considered.

The study finds that air quality is influenced by a range of factors including urban parameters such as block typology, built density, and type of street network, as well as land use, types of heating systems, and proximity to the burning of stubble and use of harmful fuels. Although various measures have been implemented, such as the creation of an air quality monitoring system, the adoption of action plans for emission reduction and the regulations and standards have also been established to control emissions of pollutants there is still much work to be done to improve air quality in the region and protect the health of its inhabitants.

Born in Skopje and continuously exploring the urban matrix of this city I believe that investigating the correlation between air quality, respiratory diseases and the urban form, especially focusing on the neighbourhood (local) scale is the interdisciplinary view needed to gain a more holistic understanding and to offer more encompassing solutions towards the management of the air quality in Skopje.

Figure 1. The photo on the left was taken in June 2022 after a rainstorm. The photo on the right was taken on December 27, 2022, when Skopje was ranked 11th in the world in the city ranking for air quality and pollution with an index of 165. Source: Author's archive.

1. Literature review

Air pollution and its effect on human health have been extensively studied in recent years. There has been a surge in research and knowledge production on air quality, air pollution, and its correlation to human health, with a progressive increase in scientific publications since 2014 (Dominski et al., 2021). According to the European Environment Agency air pollution is the single largest environmental health risk in Europe, a leading factor in causing cardiovascular and respiratory diseases that lead to loss of healthy years to life and premature deaths. In 2020 96% of Europe's urban population was exposed to fine particulate matter levels above the latest health-based guideline set by WHO. Air pollution has been flagged as a major public health issue accounting for more than two third of the environmental burden worldwide (Evangelopoulos et al., 2020).

Air quality standards for the protection of health are given in the EU Ambient Air Quality Directive (EU, 2008). Several pollutants such as particulate matter, PM10 and PM 2.5, nitrogen dioxide NO_2, and ozone O_3 are tracked by the European Environment Agency to monitor the national air quality in European countries. Although levels of air pollution in Europe are steadily decreasing, with EU directives set an annual mean limit of ambient pollution at 25 µg/m³ for PM2.5 and 40 µg/m³ for NO_2, and the WHO limit set at 10 µg/m³ for PM2·5 and 40 µg/m³ for NO_2, studies have shown associations between air pollution and mortality at levels below these guidelines with no safe exposure threshold (Khomenko et al., 2021). A study (Hime et al., 2018) conducted a comparison of the health effects of ambient particulate matter air pollution from different emission sources concluding there is no clear hierarchy of harmfulness for PM from the different emissions. It is also important to note that subjective measures of air quality should also be taken into consideration, as this social dimension is crucial in sustainable urban development (Chiarini et al., 2021).

Given that the percentage of people living in cities is projected to reach 68% by 2050 (United Nations Department of Economic and Social Affairs, 2018), cities are a more appropriate unit for an in-depth analysis of air pollution and its effects on public health. Moreover, the biggest urban growth and expansion are expected to occur in smaller-scale cities (Liang & Gong, 2020). Given that the majority of research on air pollution concentrates on the urban, regional, national and global scales (Gao et al., 2019), it is therefore important to study the heterogeneity of air pollution on the neighbourhood (local) scale.

Research has explored the link between the urban form, air pollution and public health (Hankey & Marshall, 2017) on several occasions with an increased focus on how planning decisions affect human health and the environment (Giles-Corti et al., 2016). The stance towards urban fragmentation as a contributor to air quality is divided. Although there are studies that promote compact cities with high residential density and mixed land use thus reducing car dependencies and in that manner mitigating air pollution, there has been an equal push toward the idea of a dispersed city form by decentralizing the industry thus lessening traffic congestion and alleviating street canyon effects among other things (Martins et al., 2008). However, a study (Borrego et al., 2006) was conducted on three different city models (compact, corridor and disperse) and concluded that the corridor model is characterized by the highest emission rates, while compact cities with mixed land use provide better air quality compared to disperse cities with lower densities and segregated land use or network cities equipped with intensive transport structures.

Although the urban form cannot solely and thoroughly influence and eliminate air pollution its optimization can lead to a substantial drop in pollution levels (Yang et al., 2020). Using urban morphology as a passive tool to promote air quality has been crucial in understanding city ventilation. To ensure proper ventilation there are four major factors to have in mind: built density, building permeability, building disposition and building height (da Silva et al., 2022). New urban models are being introduced on the local as well as on the urban scale to reduce air pollution, but also noise and heat islands effects by inversing the transport planning pyramid (Nieuwenhuijsen, 2021). By offering guidance for more accurate and effective air quality forecasts, air quality modelling is crucial in addressing air pollution control and management strategies. Predicting air pollution concentrations appears to be a priority for enhancing life quality since air pollution is a complicated composition of pollutant components with a significant influence on human health. It is shown that understanding how pollution develops enables better urban management concerning residents, enabling the creation of risk maps, particularly when air quality indicators serve as a tool for alertness, which is crucial for vulnerable groups. The goal of pollution modelling is to forecast specific levels for certain circumstances so that residents have the chance to change their behaviours to reduce exposure (Croitoru & Nastase, 2018).

2. Air pollution in the city of Skopje

According to the 2021 World Air Quality Report, the Republic of North Macedonia is in 34th place in the 2021 ranking for average PM2.5 concentration (μg/m³) in descending order by country[1]. The 25.4 average is considered to exceed the WHO PM2.5 guideline by 5 to 7 times. The capital, Skopje, is in 25th place in the 2021 regional capital city ranking for average annual PM2.5 concentration for regional capital cities in descending order again exceeding WHO PM2.5 guideline by 5 to 7 times with its 27.7 average. When compared to Europe, North Macedonia ranks 4th with its 25.4 μg/m³ average only preceded by Serbia, Bosnia and Herzegovina and Montenegro (all part of the Balkan Peninsula) as the most polluted countries in Europe in regards to PM2.5 emissions.

To transpose the EU directive for air quality management into domestic legislation, North Macedonia has developed some of the basic pillars of air quality management required for combating the harmful levels of air pollution observed in the city of Skopje and the country as a whole. The legislation for ambient air defines the limit and target values, long-term goals and thresholds for informing and alarming regarding air pollution. Border and target values for SO_2, NO_2, CO, PM10, PM2.5, O_3, benzene, PAHs and certain concentrations of heavy metals are defined to preserve the quality of life. The threshold of alert indicates a concentration level above which there is a health risk of short exposure and that immediate steps should be taken to improve air quality. The inventory of emissions of polluting substances as inputs data or so-called activity rates uses statistical data from the energy, industry, waste and agriculture sectors, calculated data received from the operators of the installations, as well as data from the monitoring, that is, the measurements of the emissions of the individual installations with greater capacity, which continuously arrive at MEIC.

3. Data collection

To examine the correlation between air quality, air pollution, respiratory diseases, urban parameters, urban land use, wind and heating systems, the following steps are taken:

1. Five micro-locations[2] (Karposh, Centar, Rektorat, Gazi Baba, Aerodrom) are determined. The main criteria for the selection of micro-locations is the placement of air monitoring stations at the city level (fig. 2). The area being surveyed is within a 500 m radius of the air monitoring station. So, each micro-location covers an area between 60ha and 70ha. Each micro-location varies in urban parameters, land use, access, etc. to gain a more diverse understanding of the aforementioned correlations.

[1] **2021 Country/region ranking** Population weighted, 2021 average PM2.5 concentration (μg/m³) for 117 countries, regions, and territories in descending order

[2] The name of the micro-location should not be confused with the name of the municipality

Figure 2. Map of the placement of monitoring stations in Skopje. Source: Google Earth

2. From orthophotos and a geodetic base map, several data and parameters were obtained:

- Regarding the urban parameters: type of monitoring station, altitude of the monitoring station, type of street network, type of blocks, the average percentage of built-up area, average height, and average built-up area ratio.
- In terms of land use: green areas, housing areas, educational facilities, industrial areas, commercial and institutional areas, health facilities, and street networks.
- Regarding access: access to industry, access to public transport, access to parks, and access to a water surface.

3. The information regarding the heating systems of the houses as well as the use of harmful alternative fuels and the burning of stubble was obtained from the report made by the UNDP on the heating habits of the citizens of Skopje.

4. In addition, municipal-level respiratory disease trend data from the State Statistical Office of the Republic of North Macedonia and a report from the Institute of Public Health of the Republic of North Macedonia will be processed. Given the administrative organization of the city of Skopje, the data scale will be used at the municipal level, as this is the level where most of the data is collected and processed.

5. The monitoring of air quality and air pollution is carried out for a period of two months, from October 6, 2022, to December 6, 2022. The data from the monitoring stations are available at the following link (https://aqicn.org/station/@198100/es). The data is taken twice a day, in the morning between 08:00 and 11:00 and between 19:00 and 22:00. Daily measurements and monthly averages are to be plotted.

6. The monitoring of the wind direction is carried out for a period of two months, from October 6, 2022, to December 6, 2022. The data from the monitoring stations are available at the following link (https://www .meteoblue.com/en/ weather/maps/skopje_north-macedonia). The data is taken twice a day, in the morning between 08:00 and 11:00 and between 19:00 and 22:00.

		Micro-location
urban parameters	type of monitoring station	background/ traffic
	altitude of the monitoring station	meters
	type of street network	primary/secondary
	housing blocks	perimeter/open
	total area	hectares
	average percentage of built-up area	%
	average height	meters
	average floor area ratio	coefficient
land use	green areas	hectares
	housing footprint area	hectares
	education facilities footprint	hectares
	industry footprint area	hectares
	commercial & institutions footprint area	hectares
	health	hectares
	street network	hectares
	other	hectares
access	access to industry	immediate/ within 1km/ greater than 1km
	access to public transport	easy/difficult
	access to parks	immediate/ within 300m/ greater than 300m
	access to a water surface	immediate
wind	wind direction average	southwest
	wind velocity average	km/h
air quality	air quality index highest	/
	air quality index lowest	/
	air quality index average value	/
heating	primary source of heating	central heating/ electrical/pellets/wood
	use of alternative harmful fuels and burning stubble	immediate/within 1km/ greater than 1km
respiratory disease 2017	0-6	/
	7--14	/
	15--19	/
	20++	/

date	Micro location	air quality index	PM 2.5	PM 10	O_3	NO_2	SO_2	CO	temperature	wind direction	wind speed

Table 1&2 show the monitored parameters at five micro-locations

The data in the tables shown above will be used to create graphs to follow the air quality index trend, graphs to follow the trend of prevalence in respiratory diseases and Pearson's correlation analyses which will showcase the strength of the relationship between variables. With Pearson's correlations, the hypothesis and the objectives will be tested. The air quality index will be observed based on the Air Quality Index Values where Good is 0-50, Moderate is 51-100, Unhealthy for Sensitive Groups is 101-150, Unhealthy is 151-200, Very Unhealthy is 201-300 and Hazardous is 301+.

4. Discussion of results

There are some limitations and uncertainties in the evaluation of the levels of harmful substances in the air of the Skopje region. These issues are related to the reliability and completeness of the air quality measurement data. There may be gaps in the data due to problems with the equipment or the quality of the data itself. Additionally, there may be limited data available for certain key pollutants. Nevertheless based on the available data it can be assessed that the location of Karposh has continuously shown the lowest air quality index values meaning that it has the lowest air pollution of the five micro-locations that are examined.

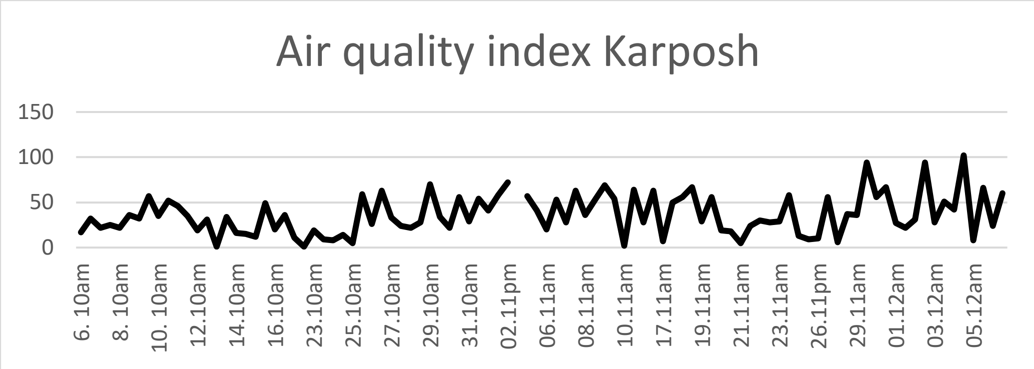


Table 3. shows the air quality index in the Karposh micro-location

Commenting on the average value of the air quality index Karposh has an average of 36 which falls in the good levels of health concern meaning air quality is considered satisfactory and air pollution poses little to no risk. The Centar and Gazi Baba locations fall under the moderate levels of health concern meaning that air quality is acceptable, however, there may be a moderate health concern for several people who are unusually sensitive to air pollution.

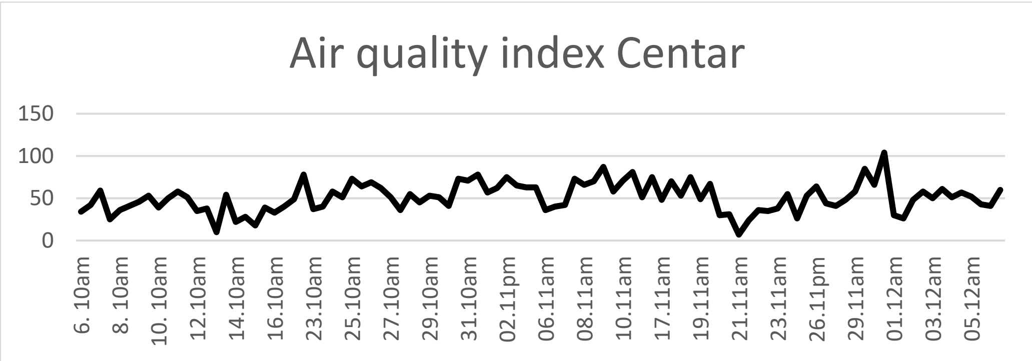


Table 4. shows the air quality index in the Centar micro-location

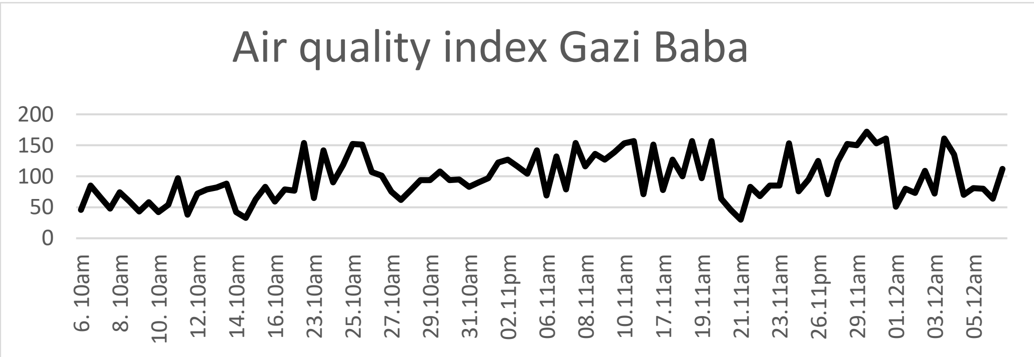


Table 5. shows the air quality index in the Gazi Baba micro-location

The locations of Aerodrom and Rektorat exhibit values above 100 which fall under the Unhealthy for Sensitive Groups levels of Health concern meaning that members of sensitive groups (people with respiratory disease, elder adults and children) may experience health effects and are advised to reduce prolonged outdoor exertion.

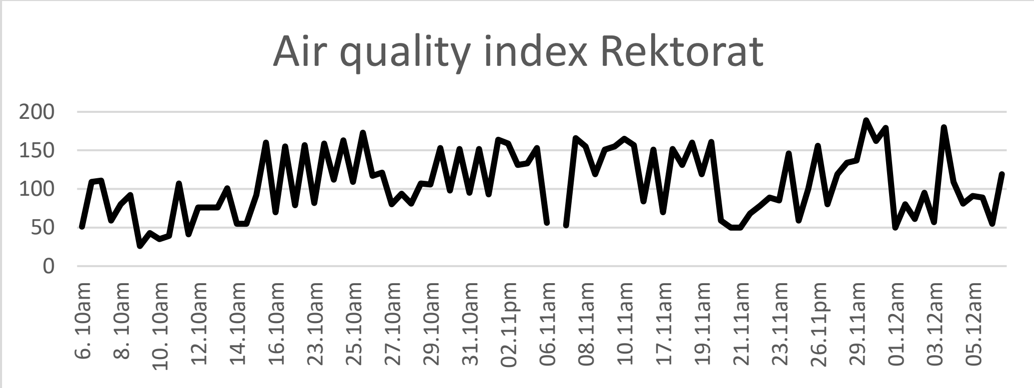


Table 6. shows the air quality index in the Rektorat micro-location

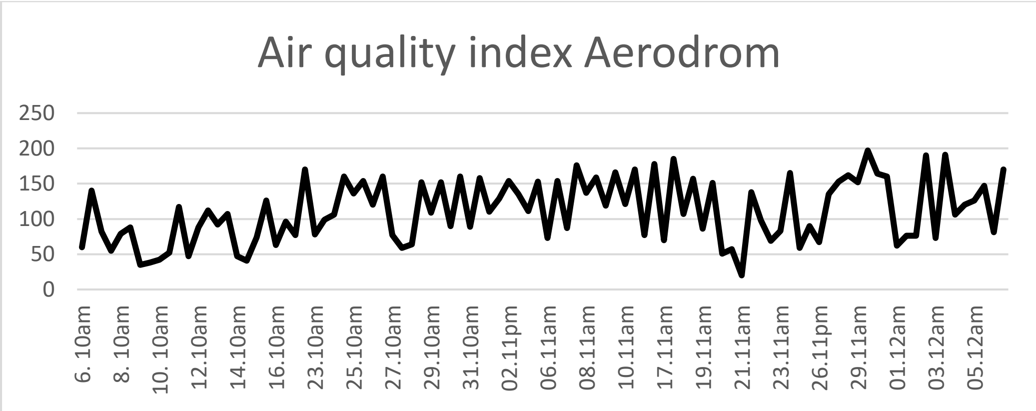


Table 7. shows the air quality index in the Aerodrom micro-location

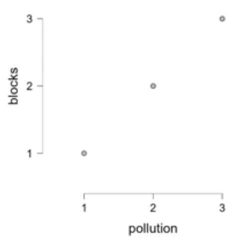
It is important to note that the location of Aerodrom which is predominantly a housing neighbourhood has shown values close to 200 on several occasions which falls under the unhealthy levels of health concern meaning sensitive groups should avoid prolonged outdoor exertion and the general public should limit prolonged outdoor exertion.

When compared the five micro-location give a diverse overview of different urban morphologies, respiratory disease trends and air pollution. From Pearson's correlations, we can conclude that air quality i.e. air pollution has a strong positive link to block typology, percentage of built-up area and type of street network.

Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- Block typology	1.000 ***	< .001	1.000	1.000

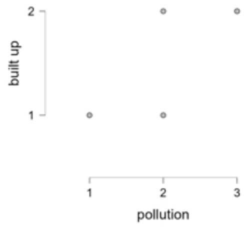
* p < .05, ** p < .01, *** p < .001



Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
Air quality index	- Percentage of built-up area	0.764	0.133	-0.363	0.983

* p < .05, ** p < .01, *** p < .001



Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- Type of street network	0.786	0.115	-0.315	0.985

* p < .05, ** p < .01, *** p < .001

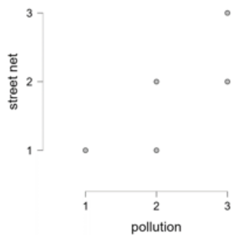
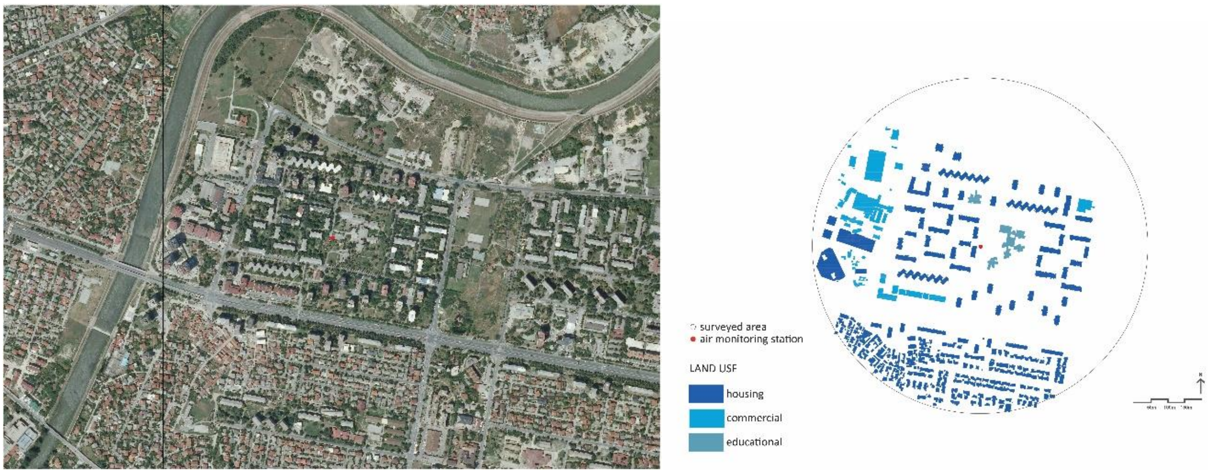


Table 8. Pearsons' correlations show how air quality is linked to block typology, percentage of built-up area and type of street network

The block typology link suggests that neighbourhoods with an open block typology have lower air pollution than those with perimeter blocks. This can be best observed at the Karposh location which is predominantly a socialist mass housing neighbourhood consisting of an open block and having the lowest air quality index meaning that the air pollution is lowest in this location compared to the other four. The strong link to the percentage of the built area suggests that higher air pollution is expected in areas that have high built percentages such as the location of Rektorat with 49.56% as opposed to Karposh with 23% (fig.3).



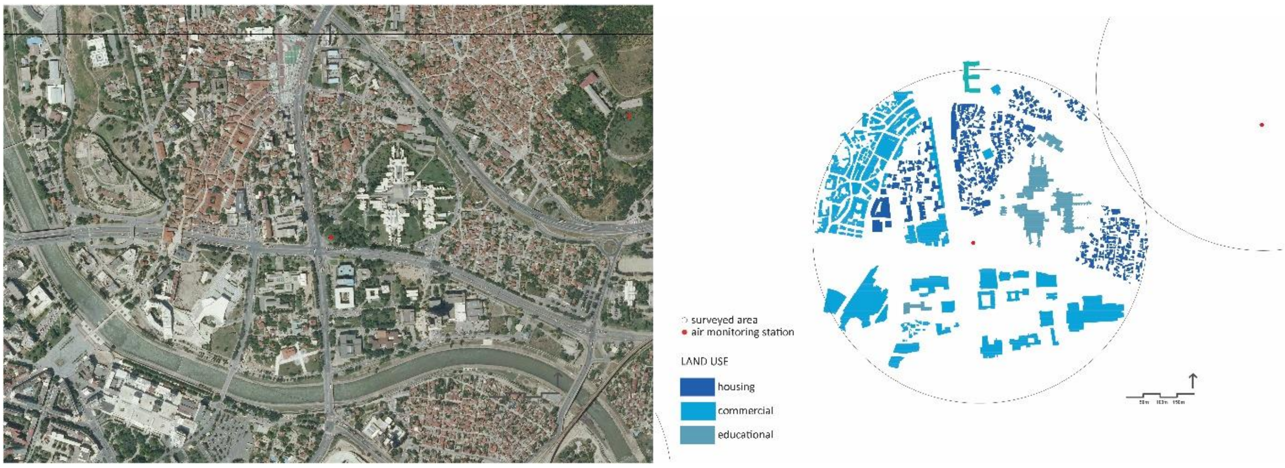


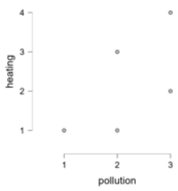
Figure 3. Karposh and Rektorat micro-locations. The red dot marks the air monitoring station. Different colours mark different land uses. Source: Territorial Planning Agency, personal file of the author, Google Earth

The correlations demonstrate that areas with primary street networks have higher pollution, which is to be expected given that primary street networks have wider street profiles and a higher intensity of traffic. This is best demonstrated at the Rektorat location which has its monitoring station at the intersection of two primary network streets (boulevards). Additionally, there is a strong link between air pollution levels and the type of heating systems households use. This is best seen when we compare the location of Karposh that is a housing neighbourhood that uses the central heating system provided by the city and has the lowest air pollution levels and the location of Aerodrom, also a housing neighbourhood, however not part of the central heating system and therefore using a variety of heating systems such as electrical, pellets, wood and alternative harmful substances and having one of the highest air pollution levels. An even stronger link exists between the air pollution levels and the vicinity of the burning of stubble, where locations such as Aerodrom that have burning of stubble in their immediate surroundings show a significantly higher level of air pollution as opposed to locations that have a distance greater than 1km from such activity.

Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- Type of heating systems	0.642	0.243	-0.555	0.973

* p < .05, ** p < .01, *** p < .001



Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- Vicinity of the burning of stubble	0.786	0.115	-0.315	0.985

* p < .05, ** p < .01, *** p < .001

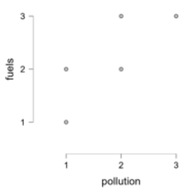


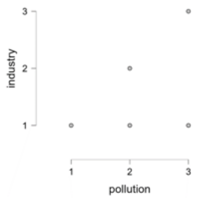
Table 9. Pearsons' correlations show how air quality is linked to the types of heating systems and the proximity of stubble burning

When discussing the link between air pollution levels and green areas it is important to have in mind the proximity of industrial areas.

Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- Proximity to industrial areas	0.468	0.427	-0.706	0.956

* p < .05, ** p < .01, *** p < .001



Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- Green areas	-0.535	0.353	-0.963	0.658

* p < .05, ** p < .01, *** p < .001

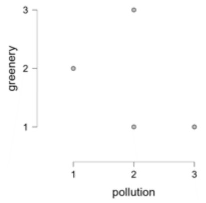


Table 10. Pearsons' correlations show how air quality is linked to the proximity to industrial and green areas

Although the correlation indicates that there is a strong negative link between air pollution and green areas, meaning that where there are fewer green areas higher air pollution levels are expected the location of Gazi Baba is interesting to observe. Although the location of Gazi Baba has 66.17% of its area covered in green spaces it is important to note that the location is in close proximity to one of the biggest industrial areas in the city which corresponds to the strong positive link between air pollution and proximity to industry (fig.4). This demonstrates that air pollution levels are linked to numerous variables.

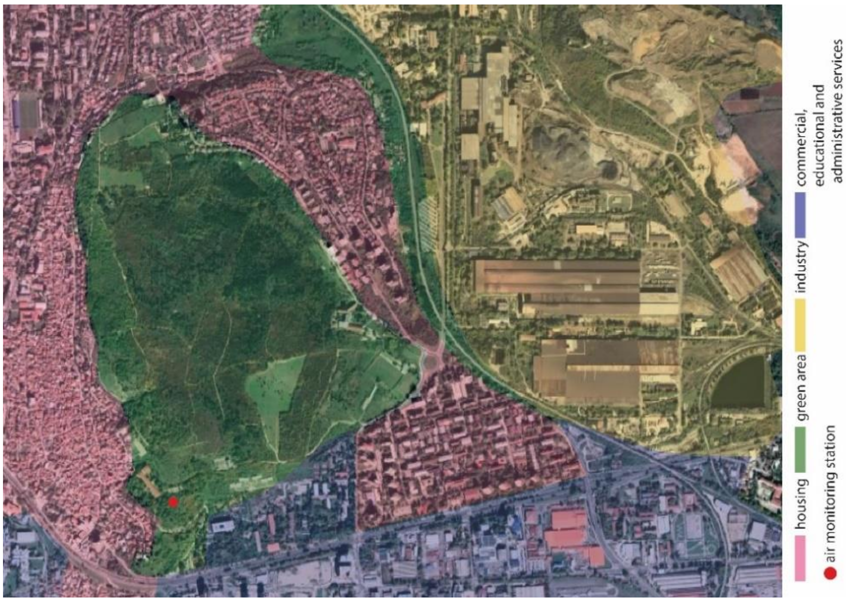


Figure 4. Gazi Baba micro-location. The red dot marks the air monitoring station. Different colours mark different land uses. Source: Territorial Planning Agency, personal file of the author, Google Earth

An interesting observation is made when discussing the link between air pollution and floor area ratio, demonstrating the built area's density. There is a strong negative link, meaning that locations that have higher built densities such as the location in Karposh have lower air pollution levels. This corresponds to the study made by Borrego et al. in 2006 mentioned in the literature review.

Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- Floor area ratio	-0.643	0.242	-0.973	0.553

* p < .05, ** p < .01, *** p < .001

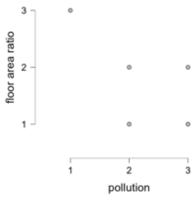


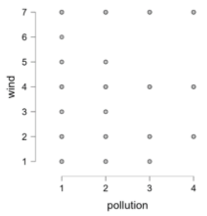
Table 11. Pearsons' correlations show how air quality is linked to the floor area ratio

The wind direction and wind velocity have no impact on the air pollution levels in all five locations. This is to be expected given that Skopje is situated in a valley and is subject to a temperature inversion, especially in the winter months.

Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- wind direction	-0.008	0.866	-0.097	0.082

* p < .05, ** p < .01, *** p < .001



Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- wind speed	-0.030	0.510	-0.119	0.059

* p < .05, ** p < .01, *** p < .001

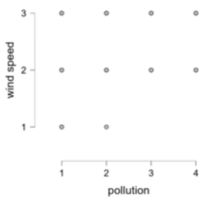


Table 12. Pearsons' correlations show how air quality is linked to wind direction and velocity

When discussing the prevalence of respiratory diseases by age groups and locations, the age group with the highest score for respiratory disease prevalence is the 0-6 year age group for all five locations. This corresponds to the strong positive correlation between air pollution levels and this age group. Another strong positive correlation is with the 20+ age group which is logical given that elderly people are one of the most vulnerable groups when it comes to health.

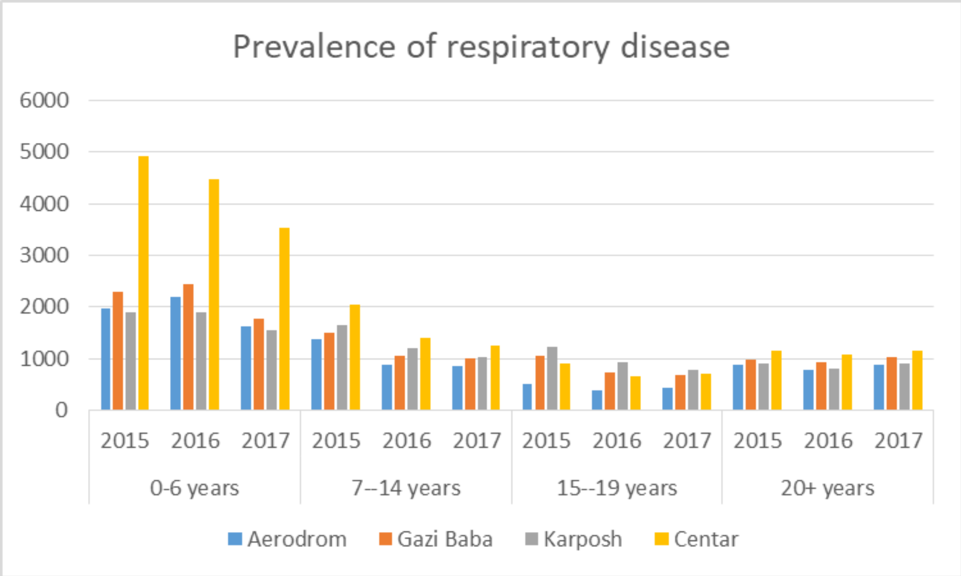
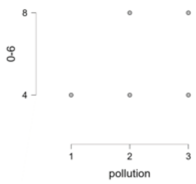


Table 13. A graph shows the prevalence of respiratory disease by age group on the municipal level

Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- respiratory disease 0-6	0.327	0.591	-0.780	0.939

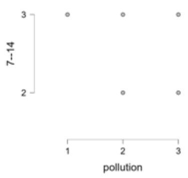
* p < .05, ** p < .01, *** p < .001



Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- respiratory disease 7-14	-0.327	0.591	-0.939	0.780

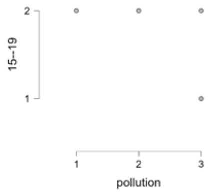
* p < .05, ** p < .01, *** p < .001



Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- respiratory disease 15-19	-0.535	0.353	-0.963	0.658

* p < .05, ** p < .01, *** p < .001



Pearson's Correlations

		Pearson's r	p	Lower 95% CI	Upper 95% CI
pollution	- respiratory disease 20+	0.218	0.724	-0.822	0.923

* p < .05, ** p < .01, *** p < .001

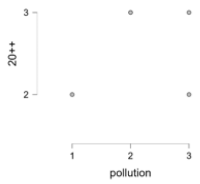


Table 14. Pearsons' correlations show how air quality is linked to respiratory diseases

5. Conclusion

In conclusion, air pollution is a significant public health issue that leads to cardiovascular and respiratory diseases, premature death, and loss of healthy years of life. With the majority of people living in cities, cities are an appropriate unit for an in-depth analysis of the effects of air pollution on public health. The optimization of urban form can lead to a substantial drop in pollution levels and new urban models are being introduced to reduce air pollution, noise, and heat islands. Air quality modelling is crucial in addressing air pollution control and management strategies, with the goal of forecasting specific levels for certain circumstances to enable residents to change their behaviours to reduce exposure. Investigating the correlation between air quality, respiratory diseases and urban form in Skopje is important to better understand this problem and find more comprehensive solutions to improve air quality in the city.

The city of Skopje in the Republic of North Macedonia has been used as a case study in this research paper. Five micro-locations (Karposh, Centar, Rektorat, Aerodrom and Gazi Baba) have been selected based on the placement of the monitoring stations and urban morphology, built density and land use. The main sources of pollution in Skopje are industry, traffic and transportation, domestic heating, waste management, construction sites, agriculture, energy production, and fugitive sources. This study examines the correlation between air quality, air pollution, respiratory diseases, urban parameters, urban land use, wind, and heating systems in five micro-locations in the city of Skopje. The results of this study are used to understand the factors that contribute to air quality and pollution in Skopje and to identify potential interventions that could improve air quality and reduce the risk of respiratory diseases in the city. This study has shown that air quality and air pollution in the city of Skopje are influenced by a range of factors including urban parameters such as block typology, percentage of built-up area, and type of street network, as well as land use, access, and heating systems. On the other hand, there is a strong negative relationship between air pollution and variables such as green areas and built density. Additionally, the study found that respiratory disease prevalence is higher in certain age groups, particularly in children under the age of 6 and adults over the age of 20 (fig.5).

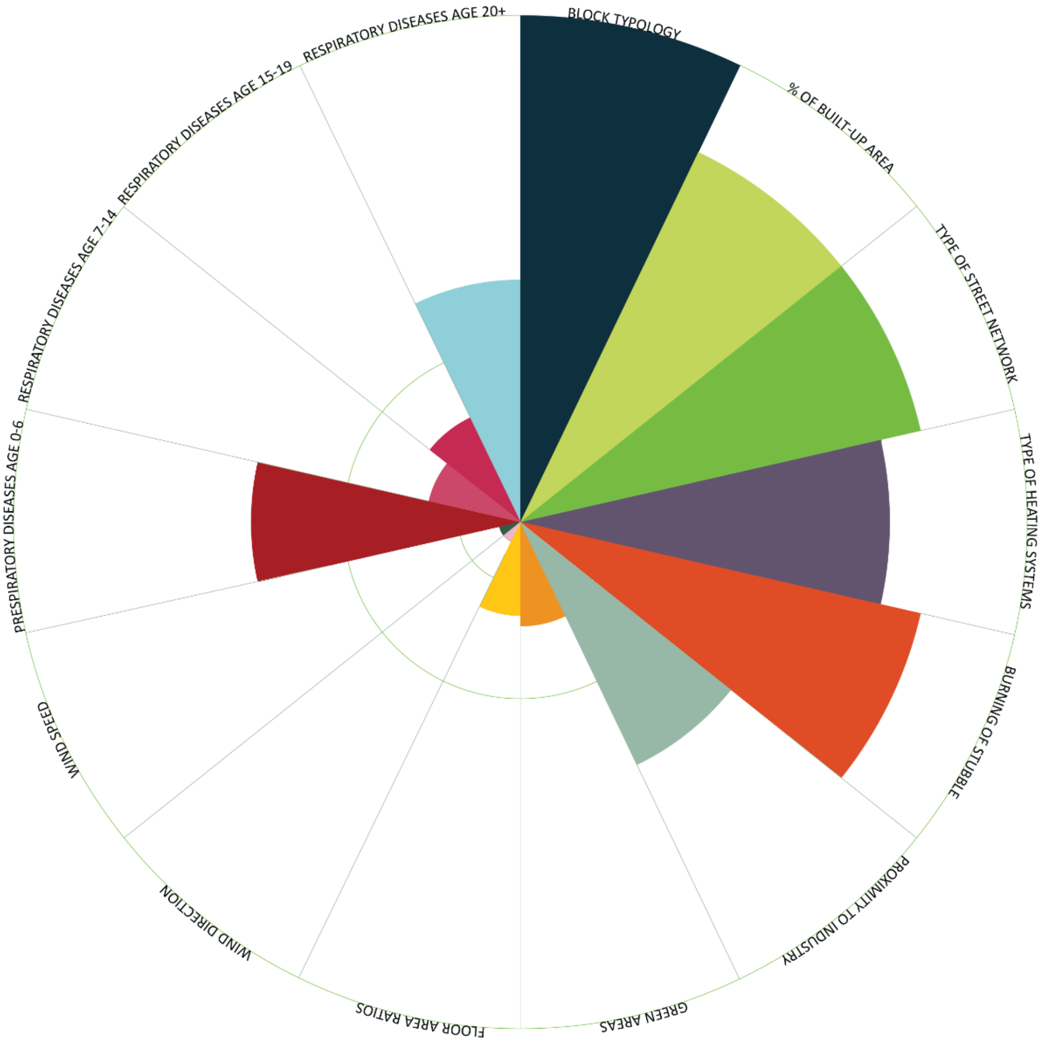


Figure 5. The radar chart shows the strength of the relationship between air pollution and different variables Source: personal file of the author

These results highlight the importance of considering the impact of urban design and land use on air quality and the potential health consequences of air pollution. Overall, the findings of this study can be used to inform policy and interventions that aim to improve air quality and reduce the risk of respiratory diseases in the city of Skopje.

Given the results of this study, several actions can be taken to lessen air pollution in the city of Skopje. The strong positive link between air pollution and block typology suggests that neighbourhoods with open block typologies may have lower air pollution levels. Therefore, urban planners and policymakers should consider promoting the use of open block typologies in future development projects. The strong link between air pollution and heating systems suggests that transitioning to more sustainable heating systems, such as central heating systems or low-emission fuels, could help reduce air pollution. The strong positive link between air pollution and proximity to industry highlights the importance of regulating industrial activities to reduce their impact on air quality. This could include stricter emissions standards, monitoring and enforcement, and the implementation of green technologies. The strong negative link between air pollution and green spaces suggests that increasing the amount of green spaces in urban areas could help improve air quality. Raising awareness about the negative impacts of air pollution on health and the importance of reducing emissions can help encourage individuals and communities to take action to reduce air pollution. This could include promoting sustainable transportation options, reducing energy consumption, and adopting low-emission technologies. The strong link between air pollution and the burning of stubble and other harmful substances suggests that efforts to reduce or eliminate this practice could help to lower air pollution levels. This could be achieved through regulations and enforcement efforts, as well as through education and awareness campaigns to promote the use of alternative methods for disposing of agricultural waste. To effectively address air pollution, it is important to have accurate and reliable data on air quality and pollution levels. This could be achieved through the expansion and improvement of air quality monitoring networks and through efforts to improve data collection and analysis.

6. Limitations of the study

The study has had several limitations such as the air monitoring station oftentimes being out of use or under maintenance, the administrative division of the city itself, the municipality being the smallest unit of governance, insufficient data on demography and insufficient data concerning the prevalence of respiratory disease.

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