The Nelson A. Rockefeller Center at Dartmouth College
The Center for Public Policy and the Social Sciences

The Class of 1964 Policy Research Shop/ Dartmouth Global Health Policy Lab

THE BURDEN OF AIR POLLUTION IN PRISHTINA, KOSOVO

The Impact of Air Pollution, How to Reduce It and Mitigate Health Impacts

Presented to the Municipality of Prishtina, Kosovo
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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Kosovo faces dangerously high rates of air pollution that often reach levels far exceeding international health limits. Approximately 3,700 Kosovars die prematurely because of high air pollution annually, more than any other country in Europe.[1,2] The harmful effects of air pollution are most concentrated in Prishtina. The Mayor of Prishtina has proposed a series of policies to address air pollution in the city at two of its sources: vehicle emissions and home heating. This report seeks to explore the potential impacts of the proposed policies to address the effects of air pollution on population health in Prishtina. Specifically, this study aims to estimate the current impact of air pollution on health and the healthcare system in Prishtina and evaluate how policies to reduce air pollution could mitigate that health impact.

Benefits of Reducing Air Pollution in Prishtina	
Health	**Economic**
❖ Improve children's health ❖ Reduce cardiopulmonary morbidity ❖ Improve quality of life ❖ Increase life span	❖ Decrease healthcare spending ❖ Improve productivity ❖ Save up to €163 million

INTRODUCTION

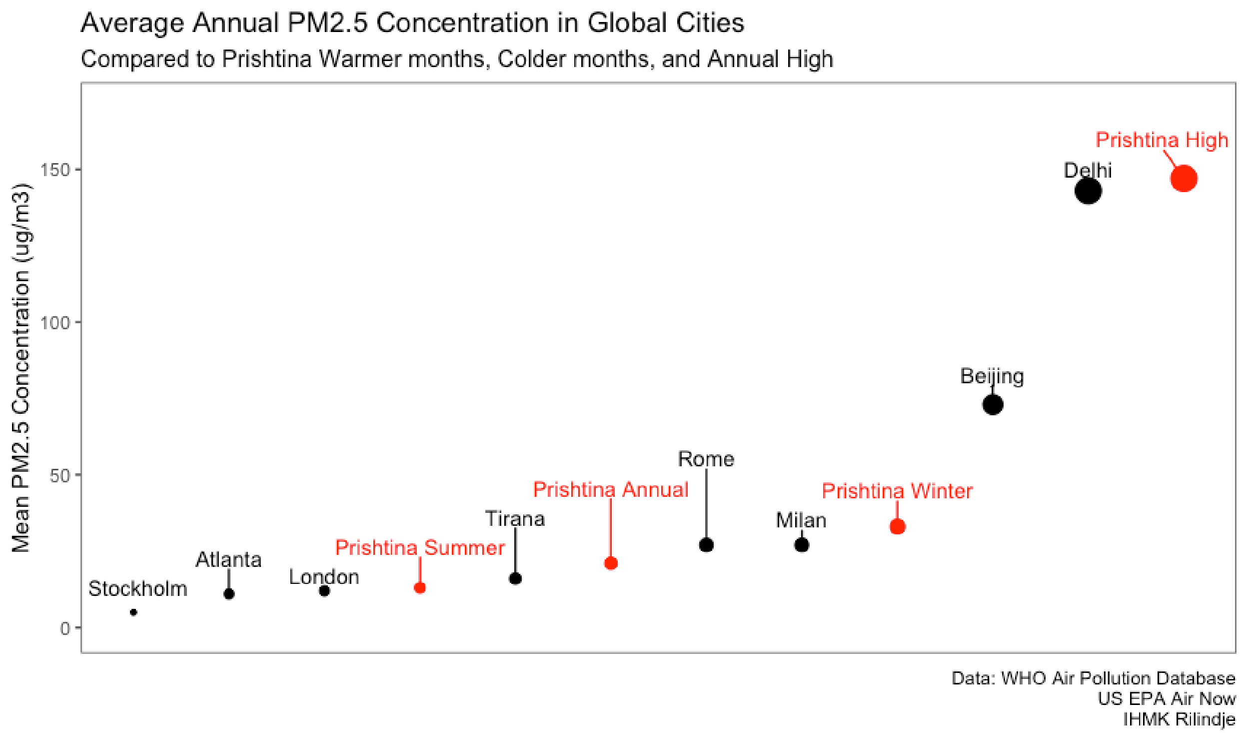
AIR POLLUTION IN PRISHTINA

Kosovo faces dangerously high rates of air pollution, reaching levels far exceeding international health limits. As a result, Kosovo suffers approximately 3,700 premature deaths due to air pollution annually. [3,4] The total percentage of mortality attributable to air pollution is eight times higher in Kosovo than in the European Union.[5,6] Overall population health is directly affected by air pollution, which causes an array of acute and chronic cardiopulmonary illnesses. Such illnesses include pneumonia, bronchitis, lung cancer, shortened life span, decreased cognitive function, chronic obstructive pulmonary disease (COPD), heart attack, and stroke.

During the winter in Prishtina, air pollution regularly reaches dangerous levels due to inversion. The location of the city in a valley, combined with cold temperatures, traps air pollution, preventing its dispersal.[7] In addition to the challenges posed by the topography of the region, the three main contributors to the high air pollution concentrations (home heating, thermal power plants, and vehicle emissions) are most concentrated in Prishtina.[8] The severity of air pollution and associated adverse health outcomes place a harsh and unsustainable burden on the Kosovar healthcare system and the welfare of its people.

PRISHTINA IN GLOBAL CONTEXT

In the summer, air pollution in Prishtina is relatively low, but is still higher than the recommended annual average of the World Health Organization (WHO) (Prishtina summer $PM_{2.5}$ = 13 ug/m3, WHO annual limit = 10 ug/m3).[9] In the winter in Prishtina, air pollution levels are regularly above the WHO recommended limit of 25 ug/m3 (Prishtina winter average = 33 ug/m3).[10] The average annual $PM_{2.5}$ concentration is 21 ug/m3, twice the WHO annual limit.[11] A few times a year, Prishtina faces extremely severe levels of air pollution, far higher than the annual mean in Beijing and equivalent to the annual mean in Delhi, a city that is notorious for dangerous air quality.[12]



PROJECT GOAL

The Mayor of Prishtina has proposed a series of policies to address this problem, targeting two of the primary contributors to air pollution in Prishtina: vehicle emissions and home heating. This report seeks to explore the potential impacts of the proposed policies to address the effects of air pollution on population health in Prishtina. This study aims to estimate the current impact of air pollution on health and the healthcare system in Prishtina and evaluate how policies to reduce air pollution could mitigate associated health impacts. The policies analyzed include low emissions zones, congestion pricing, and central heating that would be implemented during the winter months. Additional measures are also discussed, that if integrated with the proposed policies would increase the financial and health benefits.

BACKGROUND

AIR POLLUTION IN PRISHTINA

Kosovo suffers from severe air pollution during the winter months, with the majority of the pollution concentrated in Prishtina. In 2019, $PM_{2.5}$ in Prishtina exceeded the mandated World Health Organization (WHO) limit 86 days of the year.[13]

The pollutant in Kosovo that has the most significant impact on health is fine **particulate matter (PM)**. These particles range in shape and size and can be composed of hundreds of different chemicals. **$PM_{2.5}$**, or PM measuring no more than 2.5 micrometers in diameter, **poses the greatest threat to human health.**

The high rates of air pollution in Prishtina are caused by a series of factors. The three primary contributors to air pollution in Prishtina are vehicle emissions, residential heating, and the lignite-power plants.

Rapid urbanization in Prishtina has caused serious traffic congestion and increased air pollution.[14] Between 2012-2018 the average annual vehicle growth rate was 8.5 percent.[15] The estimated annual cost of these vehicle emissions is €39 million.[16] A number of factors contribute to high emissions from road transportation in Kosovo. These include vehicle age, road congestion, and a high share of diesel cars. In 2018, the average age of registered vehicles was 19 years, with 61 percent being produced before 1999.[17] Although vehicles will become more modern over time as some of the older vehicles become too old to drive, it is estimated that emissions will continue to grow at the same rate unless significant interventions are implemented.[18] Currently only 18 percent of people in Kosovo use public transportation.[19]

Residential heating and a reliance on biofuels are identified as primary contributors to air pollution and its associated health effects in Kosovo.[20] The emissions in Kosovo related to high residential heating demands are largely driven by poor or absence of home insulation, energy inefficient appliances, and indoor biomass (mainly wood and charcoal) burning for cooking and heating purposes.[21] The cost of residential heating, rising cost of energy, and low household income due to high unemployment rates are the leading causes of fuel poverty and its associated poor health outcomes.[22] Unless addressed with comprehensive policies at the municipal level, these factors will remain barriers in Prishtina.[23]

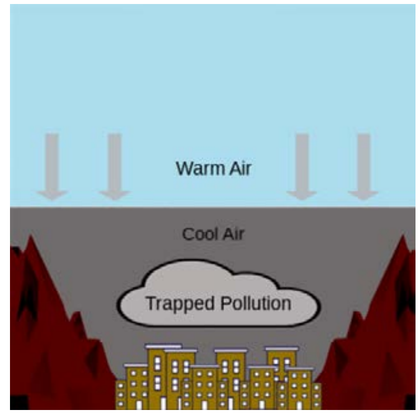
Ninety-seven percent of the energy produced in Kosovo is derived from two lignite coal burning power plants in Obiliq (5 km from Prishtina).[24] Kosovo A and B are the biggest emitters in Europe with a total of 7,500 tons of $PM_{2.5}$ annually.[25] In addition to high levels of $PM_{2.5}$, Kosovo A and B release sulfur dioxide, nitrogen oxides, and heavy metals, all of which contribute to the thousands of preventable premature deaths and illnesses Kosovo experiences annually.[26] Kosovo

C, a proposed lignite-power plant that will replace Kosovo A upon decommissioning is estimated to bare €34 million in health costs per year of operation in Kosovo.[27] Collectively, all active plants in the Western Balkans incur health costs between €70 and €169 million annually.[28]

Although the coal plants are the largest contributor to particulate matter in Kosovo, this report focuses on policy options to reduce air pollution from vehicle and home heating emissions at the municipal level.

The natural process of inversion amplifies air pollution's health effects during Prishtina winters. Its location in a valley, combined with cold temperatures, traps $PM_{2.5}$ and prevents the dispersal of air pollutants (see right).[29]

At this time, the costs of alternative energy sources like solar, geothermal, or hydro are not feasible.[30] Similarly, the cost for families to switch their individual use of energy sources from coal to gas is out of reach without significant financial subsidies.



Inversion

Like those in many other rapidly developing economies, owning a personal vehicle is an important status symbol in Kosovo.[31] Even when public transportation or walking is more convenient than using a car, Kosovars will frequently choose to drive their own vehicles. Some Kosovars the team spoke with said that they would rather drive their cars, even though they know about the negative health and environmental impacts.

Health Related-Costs of Air Pollution

Air pollution has significant financial implications for individuals, the healthcare system, and the nation. The burden of air pollution on the health system includes increased costs from hospital admissions, medications, and physician time.

Individual $PM_{2.5}$-related Health Expenses in Kosovo:

- One day of hospitalization due to chronic bronchitis: €2,748/patient[32]
- Doctor's visit resulting in hospital admission: €403/patient[33]

Damage costs of the health effects associated with high $PM_{2.5}$ in Kosovo are between €38 and €163 million annually, or up to five percent of the national GDP.[34]

According to the Lancet Commission, productivity losses from ambient and indoor air pollution are approximately 0.32 percent of GDP in LMICs. Using Lancet Commission estimates, the productivity loss associated with air pollution in Kosovo is €22 million.[35]

The consequences of air pollution in Kosovo are not bound by its borders. The annual damages to greater Europe are between €45 and €352 million per year.[36]

Kosovo has faced a series of challenges ranging from the reconciliation process to high rates of unemployment and poverty, which have been priorities for the last decade. However, given the young age of the population, now more than ever, the implementation of comprehensive policies at all levels is critical.

LITERATURE REVIEW

The following section briefly reviews the impact of air pollution on health. It then details policies that other comparable cities have implemented to reduce air pollution and improve population health. Although a wide variety of interventions to reduce air pollution have been implemented internationally, this review focuses on reducing vehicle and home heating emissions, two of the largest polluters identified in Prishtina.

IMPACTS OF AIR POLLUTION

PM has significant short and long term health impacts that negatively impact individuals and place an unsustainable burden on the healthcare system. The sections below describe major pollution-related health conditions and outline which groups are most affected.

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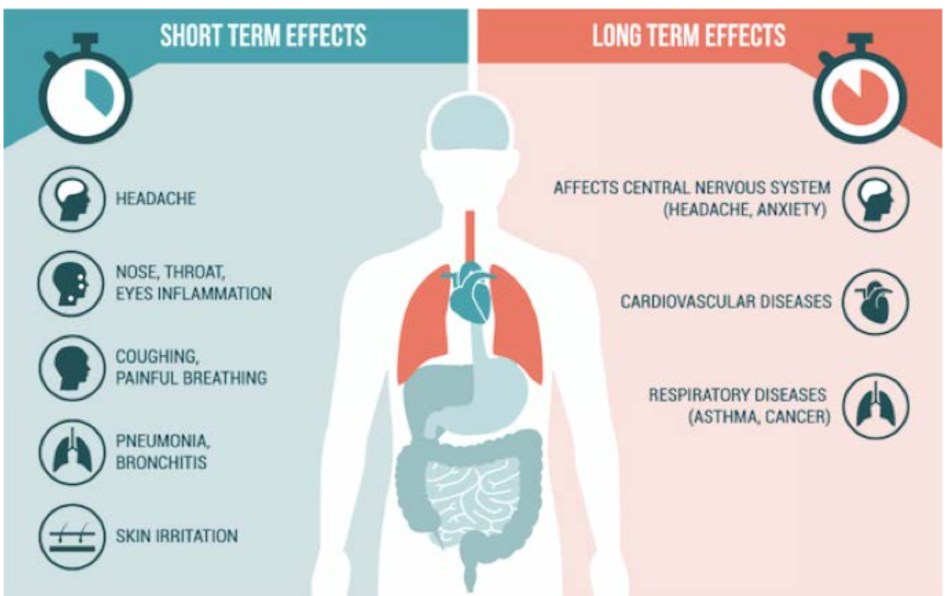


Respiratory

$PM_{2.5}$ can penetrate deeply into the lungs, impairing lung function with each breath.[38] Both short and long-term PM exposure causes and exacerbates a variety of respiratory conditions, including asthma, lung cancer, COPD, and bronchitis, frequently leading to emergency room visits, hospitalizations or resulting in deaths.[39]

A short-term increase in PM is associated with higher rates of emergency room visits and hospitalizations for all respiratory conditions.[40] Long-term exposure to PM results in reduced lung function.[41] As a result, people are more likely to contract respiratory diseases and take longer to get better. People are more likely to develop COPD, bronchitis, and lung cancer.[42,43,44] Air pollution also increases mortality rates from lung cancer.[45]

Cardiovascular

Air pollution accounts for approximately three million cardiovascular deaths annually and causes a number of cardiovascular conditions, including heart attack, stroke, and death.[46] The inhalation of $PM_{2.5}$ forces toxic particles into the bloodstream.[47] This results in the inflammation of the lungs, further straining the cardiovascular system.[48]

Consequences of this strain range in severity based on exposure concentration and duration. Short-term PM exposure is associated with an increased risk of heart attack, stroke, and acute heart failure.[49] Long-term PM exposure increases the risk and severity of all cardiovascular conditions and increases the risk of cardiovascular mortality by 10 percent.[50]

Children

Air pollution severely impacts children under the age of six, since their lungs are still developing.[51] Children exposed to air pollution experience higher rates of asthma, bronchitis, and pneumonia, among other respiratory illnesses.[52]

The impact of air pollution on child health starts in utero. Fetuses exposed to air pollution during gestation have lower birth weights and delayed cognitive and psychomotor development.[53,54]

Asthma, a chronic lung disease leads to potentially life-threatening consequences. It often develops during childhood and cannot be cured.[55] Fourteen percent of childhood asthma attacks in urban settings are attributable to traffic-related air pollution exposure.[56] In the United States, the cost of asthma-related medical expenses among children amounts to $4.6 billion.[57]

Children exposed to chronic levels of high vehicular air pollution are more likely to develop attention deficit disorders such as ADHD, significantly reducing their quality of life.[58] A study in Delhi demonstrated that children exposed to air pollution are more likely to have ADHD.[59] Schoolchildren residing in rural areas with less pollution had a 2.7 percent rate of ADHD, while those living in highly polluted Delhi experienced an 11.0 percent rate of ADHD.[60] ADHD results in behavioral disorders, impairs cognitive function and persists into adulthood. This hinders overall quality of life and reduces lifelong earning potential. Research shows that household income of adults with ADHD is significantly lower than those without, resulting in workforce productivity losses between $67 billion and $116 billion in the United States alone.[61]

Children exposed to traffic-related air pollution are far more likely to suffer from colds.[62] In a study conducted in Peru, researchers found that a 10 μg/m3 increase in airborne $PM_{2.5}$ was associated with an 83 percent increased risk of sinus infections.[63] Exposure to such illnesses increases school absenteeism and increases children's physical suffering.[64] When children are sick their family members often must miss work to care for them, reducing workforce productivity.

Long-term Effects:

Children's exposure to air pollution can have dire long-term consequences that arise later in life. These adverse long-term effects include chronic bronchitis, heart disease, and lung cancer.[65] Stunted lung growth increases future morbidity and mortality rates.[66]

People over 65

People over the age of 65 are the most susceptible to PM-related health complications.[67,68] Due to higher comorbidity rates, exposure to high PM concentrations are more likely to be fatal.[69]

Economic Impact

Air pollution poses serious economic strains as a result of lost productivity and an unnecessary burden on the national health system. According to the Organization for Economic Cooperation and Development (OECD), air pollution leads to "reduced capital accumulation and a slowdown in economic growth" that is equivalent to two percent of GDP across Eastern Europe.[70] The annual global welfare costs associated with pollution are projected to be at least €16.1 trillion, or approximately €1,880 per person, by 2060.[71]

ADDRESSING AIR POLLUTION

There are a wide range of cost-effective strategies to address air pollution from vehicles and home heating that have been successfully implemented in other settings. This section describes low emissions zones, congestion pricing, the expansion of district-wide central heating systems and complementary energy efficiency efforts.

LOW EMISSION ZONES

Low emission zones are one option for improving air quality by reducing the severity and duration of traffic in city limits. Low emission zones restrict the types of vehicles that can enter the city center. Area residents and public transportation have unlimited access, but other vehicles can only enter if they are designated as low-emission vehicles. Since fewer vehicles enter the city, there is less traffic and fewer highly-polluting vehicles on the road in densely populated areas, reducing their overall vehicle emissions.[72]

Low emission zones offer a promising option to reduce air pollution, but are only effective when they are strictly enforced and significantly limit the number of vehicles on the road.[73] When implementing a low emission zone, it is critical to offer transportation alternatives, such as a larger fleet of efficient public transportation vehicles. Although it seems logical that reducing vehicle use can reduce air pollution and improve health, the evidence in the literature is mixed.[74]

In Atlanta, efforts to reduce traffic during the Olympic games in 1996 led to PM reductions and improvements in children's health.[75] The city closed the downtown area to private automobile traffic, reducing inner-city morning traffic by 22.5 percent or 4,260 fewer vehicle trips per morning.[76] Overall, 24-hour traffic decreased by about three percent.[77] Public transportation use increased 217 percent, primarily due to the increase in tourist traffic during the games.[78] $PM_{2.5}$

concentrations decreased by 16 percent (from ~27 ug/m3 to ~22.5 ug/m3).[79] The number of pediatric acute asthma cases during the study period decreased by 11-44 percent (depending on the hospital).[80] However, these impacts only lasted during the 17-day period of the Olympic games, and impacts of a citywide campaign to reduce traffic after the games were much lower.[81] The authors cite fear of excessive traffic, lack of parking, and social pressure as major reasons that people reduced car use during the period of the Olympic games.[82]

Longer-term studies have not found the same positive health impacts. A study in London examined the impact of a low emission zone on children's health.[83] In London, vehicle restrictions are primarily on large diesel trucks rather than personal vehicles.[84] Concentrations of harmful nitrous oxide pollutants decreased over the study period but there was no change in PM levels.[85] Although pollution levels decreased, they were still over the recommended EU limit.[86] Children's lung function actually decreased during the four-year study period, even as some air pollution indicators improved.[87] The study indicates that although implementation of a low emission zone can be beneficial, it is critical to combine it with other air pollution reduction measures or to create even stricter standards (such as regulations on personal vehicles) in order to reduce air pollution enough to improve health.

In Rome, the implementation of a low emission zone led to significant reductions in air pollution but limited positive health impacts. PM and nitrous oxide decreased by 33% and 58% respectively, leading to a small increase in life expectancy (3 days per person living in the intervention area).[88] Although the authors only found a minimal increase in life expectancy, they emphasize the challenges of estimating health impacts and believe that the overall impacts were greater than the study found.[89] The authors believe that the small background changes in PM outside of the specific intervention area likely had a larger impact on health than they were able to model.[90] Additionally, they were not able to specifically measure what types of PM were reduced. Since $PM_{2.5}$ from vehicle emissions more severely impacts health than other sources and sizes of PM, it is likely that reducing vehicle emissions had a greater impact on health than they could model using their equation, which was based on past studies that looked at life years gained from general air pollution reduction.[91]

Low emission zones offer a potential method to reduce air pollution if effectively implemented, however there must be significant reductions in traffic to reduce air pollution enough to positively impact health. Short-term reductions in air pollution will lead to short-term health benefits. Implementing short-term low emissions zones could be an effective way to reduce air pollution during the most polluted days in the winter. To effectively reduce the burden on the health care system, it is necessary to develop long-term solutions that sustainably reduce traffic. In the past, congestion pricing, another method of restricting traffic, has been more successful at reducing air pollution over longer periods of time (years as opposed to months or weeks).

CONGESTION PRICING

Congestion pricing requires drivers to pay a fee during peak hours in heavily-trafficked portions of the city. It has effectively reduced air pollution by reducing the number of people driving in the city and incentivizing people to use public transportation. Similar to low emission zones, it is crucial to ensure that there is a robust public transportation infrastructure in place before implementing the charge to ensure accessible and efficient modes of transport.

In Stockholm, congestion pricing has had a positive impact on air pollution and health. Stockholm placed tolls around the inner city to prevent bottlenecks that usually occur in highly trafficked areas. The cost of the toll is €2 during peak commuting hours, €1.5 in the 30-minute buffer around those times, and €1 during all other times.[92] Although citizens were initially angry about having to pay to enter the city, the initiative became popular once people saw the positive impacts on transport time and reduced pollution.[93] Congestion pricing increased the usage of public transportation by five percent, walking and cycling by one percent, and decreased personal car use by three percent.[94] A 2019 study in Stockholm found that congestion pricing reduced ambient air pollution by 5-15 percent.[95] The rate of hospitalizations for acute asthma attacks in young children also fell by 50 percent.[96] In addition to pollution and health benefits, the city recouped the costs of the initial implementation and daily operations in four years.[97]

Milan introduced an effective congestion pricing scheme in 2011. Any vehicles entering the city center between 7:30 and 19:30 must pay a €5 toll.[98] Vehicle use decreased by 14 percent, leading to a 23 percent decrease in PM levels in the congestion pricing zone.[99]

Congestion pricing in London has also led to improved air quality and has a positive return on investment. The successfully implemented scheme led to reduced PM and mortality.[100] A cost-benefit analysis of the intervention found the cost of congestion pricing to be €181 million, and the social benefits (time saved for transportation) to be €232 million six months after implementation.[101] Congestion pricing in London has a net revenue of €90-130 million per year.[102]

Congestion pricing has had positive impacts on air pollution and health in a number of cities. If implemented, it is critical that the city has sufficient public transportation infrastructure to manage increased ridership. Congestion pricing typically has a high return on investment, so governments can use the revenue from congestion pricing to improve public transportation. Based on the literature, congestion pricing is one of the most effective methods to reduce air pollution in cities that face heavy traffic and high concentrations of vehicle emissions.

HOME HEATING

Although staying indoors is frequently recommended as the best way to prevent air pollution-related illness, recent studies have demonstrated that indoor pollution is at least as harmful to health as outdoor pollution.[103] Household air pollution kills four million people each year.[104] Many homes in low- and middle-income countries burn lignite coal or other biomass (such as wood) for home heating and cooking, which causes PM to accumulate indoors. Outdoor PM also easily permeates indoor spaces through air exchange, making the indoor air as unsafe as or less safe than the outdoor air.[105] As a result, the most effective way to prevent air pollution-related health conditions is to reduce indoor air pollution at its source. Home heating demands and emissions are considered to be the largest contributor to air pollution in low-income countries.[106] Interventions at the household and municipal levels can be implemented to effectively reduce these emissions and improve health.

Strong evidence supports the benefits of retrofitting old homes with insulation for human health.[107] Interventions in urban China demonstrate that significantly reducing the use of solid fuels to heat homes is the most straightforward and feasible approach to reducing indoor PM exposure.[108] Interventions include retrofitting older homes with insulation and constructing new buildings with high-tech, energy-efficient insulation.[109] With the installment of insulation, the cost of heating residential spaces decreases. With more heat retained, the required amount of biomass and fuel burned indoors is reduced, decreasing PM concentrations.[110] The health benefits and financial savings of insulation retrofitting outweigh the initial costs by a two-to-one ratio.[111]

Insulating previously uninsulated homes in low-income communities in New Zealand improved occupants' health and household heating efficiency.[112] While reducing the need to burn biomass indoors for heat directly reduces the concentration of PM, the full benefits of this intervention is not felt without the installation of proper ventilation. Without ventilation, concentrations of PM still accumulate indoors. Newly insulated homes had half the harmful nitrous oxide concentration of uninsulated homes.[113] Children reported lower levels of asthmatic symptoms, wheezing, and dry coughing.[114] Inhabitants of retrofitted homes also reported fewer hospital admissions and days out of work or school.[115]

Improving insulation in homes is an individual level intervention that can be supported by government subsidies. Although there are initial costs, it is an important investment that reduces indoor and outdoor pollution and saves money over time.

The expansion of central district heating and insulating the system's distribution lines are high-impact interventions that can be implemented at the municipal or nationwide level. A nationwide analysis of low-income English households that received central heating used 68.7% less gas than homes without central heating.[116]

Between 2005 and 2015, the Chinese government implemented a series of policy controls, including insulation and central heating expansions, that reduced the population-weighted exposure to $PM_{2.5}$ by 47 percent.[117] Almost 90 percent of this reduction was attributed to decreased household use of solid fuels and reliance on other sources of heating (i.e., electricity).[118] Researchers estimated that this intervention resulted in 400,000 fewer premature deaths annually in the intervention group, accounting for 33 percent of the $PM_{2.5}$-induced mortality in 2015.[119]

Interventions to improve heating efficiency are very effective at reducing indoor and outdoor air pollution. These interventions are most effective at improving health when coupled with complementary measures, such as improved ventilation. Although these interventions are expensive to implement, there is a high return on investment. If homes are heated with electricity, residents will be exposing themselves to less PM. If homes are heated with biomass or coal, residents will not need to burn as much, emitting less pollution. Because people are exposed to less PM, they will be less likely to experience air pollution-related conditions, reducing the individual burden of illness and overall healthcare system costs.

Ventilation and insulation measures that reduce indoor concentrations of PM should not be viewed as long-term solutions, but rather as intermediary interventions that can be implemented at the municipal level until cleaner fuels can be provided to all citizens.[120]

METHODS

This study uses a mixed-methods approach to explore the impacts that air pollution have on health in Prishtina and to estimate the positive effects of Municipality-endorsed policy options.

DATA SOURCES

Health Data

Data	**Source**	**Description**
Respiratory and cardiovascular diagnoses	Main Center Family Medicine (MCFM)	Daily number of respiratory and cardiovascular diagnoses (ICD J0-J99 and I0-I99) at MFMC for the year 2019
Cardiology inpatient cases	University Clinical Center of Kosovo (UCCK)	Monthly total number of inpatient cases in the cardiology unit at UCCK in 2019
Pediatric hospital admissions	UCCK	Monthly total number of hospital admissions in the pediatric clinic at UCCK in 2019
Pulmonology visits	UCCK	Monthly total number of ambulatory pulmonology visits at UCCK in 2019
Pulmonology hospital admissions	UCCK	Monthly total number of respiratory-related admissions at UCCK in 2019

Air Pollution Data

Data	**Source**	**Description**
$PM_{2.5}$ Concentration Location 1	US EPA Air Now (station at US embassy)	Hourly $PM_{2.5}$ concentration for the year 2019

$PM_{2.5}$ Concentration Location 2	Kosovo Hydro-meteorological Institute (IHMK) Rilindje station (located in the center of Prishtina)	Hourly $PM_{2.5}$ concentration for the year 2019

Data from the two locations was averaged to obtain an approximation of the average level of $PM_{2.5}$ throughout Prishtina. The $PM_{2.5}$ concentration in Location 1 was almost always higher than the $PM_{2.5}$ concentration in Location 2. This is likely because air pollution can vary from location to location depending on geography and proximity to emission sources. The authors believe that averaging the two data sets gives a more accurate estimation of air pollution levels in Prishtina. The data from both locations was highly correlated (Spearman's rank correlation rho = 0.93; $p < .01$). See table below for detailed information from both data sets.

	$PM_{2.5}$ Concentration (ug/m3) Location 1 (US EPA)	$PM_{2.5}$ Concentration (ug/m3) Location 2 (IHMK)
Minimum	3	4
1st Quartile	12	8
Median	16	12
3rd Quartile	25	19
Maximum	179	103
Standard Deviation	21	14

SEASONALITY: WARMER AND COLDER MONTHS

Since high concentrations of $PM_{2.5}$ tend to be temperature related because of inversion, for some of our analysis we separated 2019 into "warmer months" and "colder months." Warmer months were March-September, and colder months were October-February.

INTERVIEWS

The team interviewed providers at MCFM and at UCCK. Interviewees were asked about how air pollution impacts their practices (see Appendix for interview guides). The team also interviewed a variety of stakeholders from the Institute of Public Health, the World Bank, IHMK, the World Health Organization, the Japanese International Cooperation Agency (JICA), and the University of Prishtina to better understand the issue.

In addition to formal interviews, the team spoke informally with a number of Kosovars to understand how air pollution impacts them and better understand the cultural barriers to addressing air pollution. The team spoke with approximately 30 men and women ages 20-35.

EXTRAPOLATION

Since Prishtina lacks a robust health information system, the team used incidence rates from other studies to estimate condition-specific disease burden in a number of scenarios. Details of each calculation are included in the findings section of the report.

LIMITATIONS

This analysis is subject to a number of limitations. Prishtina does not have a health information system, therefore, health data presented in this report is likely an underestimate of the true burden. Due to large population fluctuations during the week, there is no agreed upon population count of Prishtina, making it difficult to conduct rigorous statistical analyses. Additionally, there is limited data on vehicle types and the number of vehicles, making it difficult to estimate what impact traffic related policies may have.

The air pollution datasets have a few missing data points, but there was enough data to compute averages for most days (352/365) in 2019. Since air pollution concentrations vary throughout Prishtina, data was averaged from the IHMK Rilindje station (near the city center) and the United States Embassy to estimate daily $PM_{2.5}$ concentrations in Prishtina.

FINDINGS

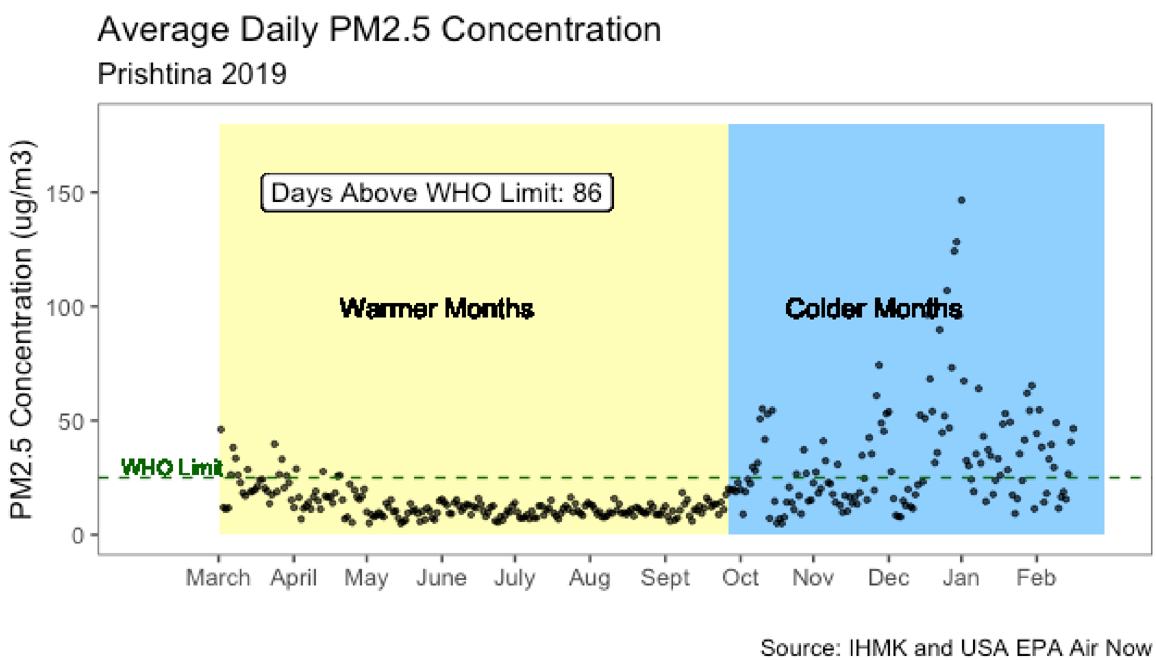
KEY FINDINGS

Frequently, months with high air pollution are correlated to months with more cardiopulmonary diagnoses, visits, and admissions, increasing the burden on the health care system. The full burden of air pollution related illness has not yet been realized in Prishtina because of the relatively young population. The problem will become worse as people age.

By implementing policies to reduce pollution, the Municipality can increase quality and length of life for citizens and save money. In the colder months in Prishtina there are 28 percent more respiratory and 15 percent more cardiology diagnoses per day at MCFM. The annual $PM_{2.5}$ concentration in the colder months is associated with a 14 percent increased risk of all-cause mortality as compared to a pollution-free scenario.

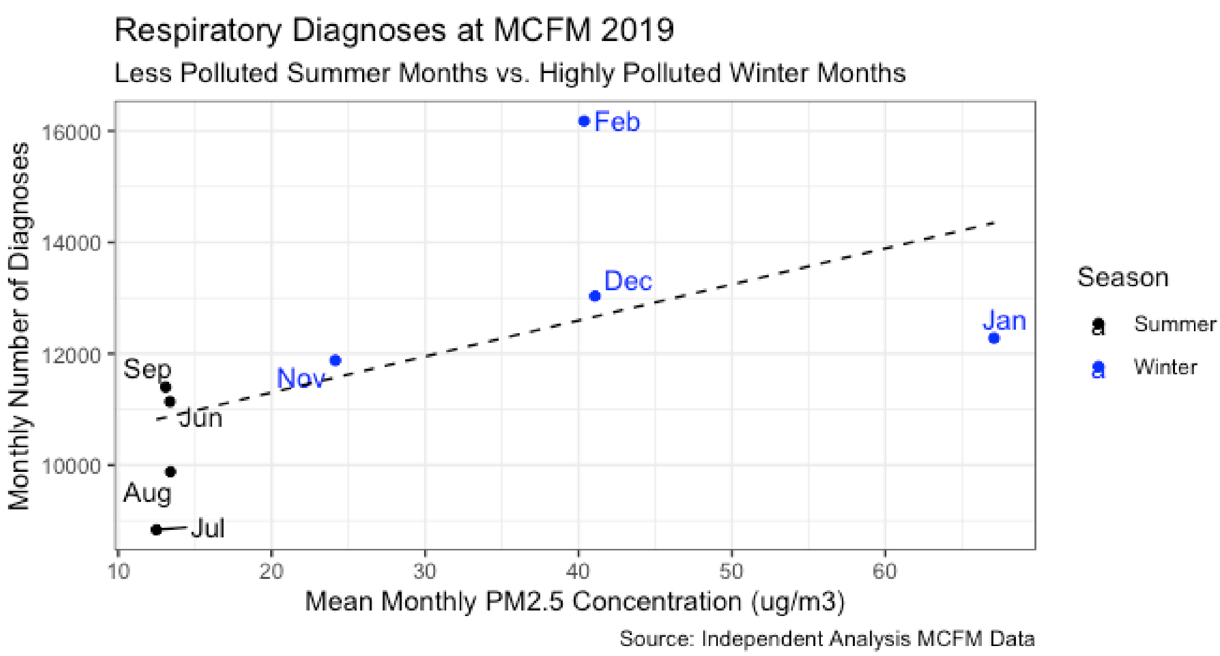
Since air pollution is worst during the winter months because of inversion and the addition of home heating emissions, the most effective policies will reduce winter levels of $PM_{2.5}$ concentration. A primary goal for the Municipality of Prishtina could be to reduce annual mean $PM_{2.5}$ concentration to 13 ug/m3 (the average in the warmer months).

HIGH PM2.5 CONCENTRATION



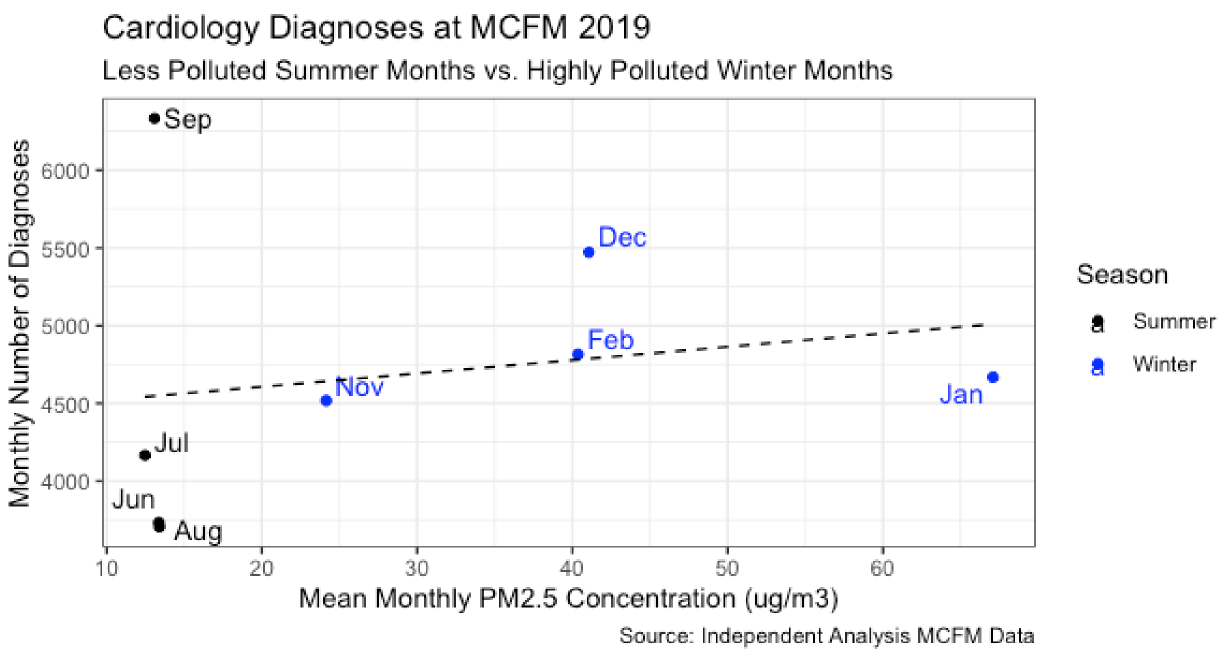
In 2019, the daily average $PM_{2.5}$ concentration frequently surpassed the WHO recommended 24-hour limit of 25 ug/m3. The highest $PM_{2.5}$ value recorded in 2019 was 147 ug/m3. The mean daily $PM_{2.5}$ concentration in warmer months (March-September) was 13 ug/m3. The mean daily $PM_{2.5}$ concentration in colder months (October-February) was 33 ug/m3, 20 ug/m3 than in the warmer months. The average annual $PM_{2.5}$ concentration was 21 ug/m3, double the WHO recommended annual limit of 10 ug/m3.

HEALTH SYSTEM BURDEN



At MCFM, there are more respiratory diagnoses in the highly polluted winter months than in the less polluted summer months.[121] According to the director of the medical center, high air pollution exacerbates respiratory illnesses that typically occur in the winter months, so patients are sicker for longer or have more severe symptoms.[122] On average, there are 28 percent more respiratory diagnoses per day at MCFM in the colder months than in the warmer months.[123] Since individual patient data is not available, it is not possible to know whether there are more patients coming in, or if there are more diagnoses being made per patient. Regardless, the colder months put a greater burden on physicians who must see more patients or spend more time with each patient to make multiple diagnoses.

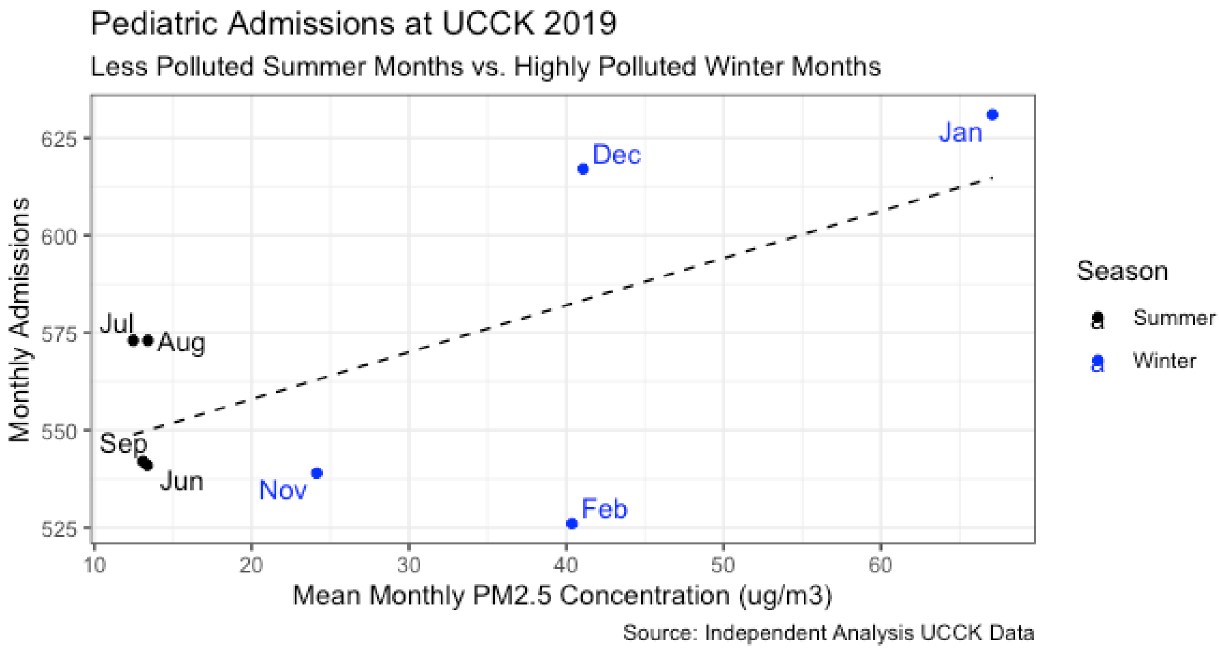
The data to create the figure came from MCFM, US EPA, and IHMK. MCFM provided the team with 2019 data that contained the total number of respiratory diagnoses (ICD 10 J0-J99) for each day in 2019. The team aggregated the data into the monthly number of diagnoses. The team then combined the MCFM dataset with the existing combined air pollution 2019 dataset (using data from both US EPA and the IHMK Rilindje station) to determine the average $PM_{2.5}$ concentration per month. Since $PM_{2.5}$ is attributable to respiratory diagnoses in the literature, the team wanted to see whether there was a correlation between $PM_{2.5}$ and respiratory diagnoses at MCFM.[124] Since $PM_{2.5}$ concentrations are greatest in Prishtina in the winter months of November, December, January, and February and lowest in the summer months of June, July, August, and September, the team isolated these months to see if there was a correlation between the mean monthly $PM_{2.5}$ concentration and the monthly number of visits. As the figure shows, the $PM_{2.5}$ concentration and the monthly number of respiratory visits are positively correlated. The correlation was not statistically significant.



The number of monthly cardiology diagnoses at MCFM is higher on average in the winter months than in the summer months (with the exception of September).[125] On average, there are 15 percent more cardiology diagnoses per day in the colder months than in the warmer months.[126] Since individual patient data is not available, it is not possible to know whether there are more patients coming in, or if there are more diagnoses being made per patient. Regardless, the winter months put a greater burden on physicians who must see more patients or spend more time with each patient to make multiple diagnoses.

The data to create the above figure came from MCFM, US EPA, and IHMK. MCFM provided the team with 2019 data that contained the total number of cardiovascular diagnoses (ICD 10 I0-I99) for each day in 2019. The team aggregated the data into the monthly number of diagnoses. The team then combined the MCFM dataset with the existing combined air pollution 2019 dataset (using data from both US EPA and the IHMK Rilindje station) to determine the average $PM_{2.5}$ concentration per month. Since $PM_{2.5}$ is attributable to respiratory diagnoses in the literature, the team wanted to see whether there was a correlation between $PM_{2.5}$ and cardiology diagnoses at MCFM. Since $PM_{2.5}$ concentrations are greatest in Prishtina in the winter months of November, December, January, and February and lowest in the summer months of June, July, August, and

September, the team isolated these months to see if there was a correlation between the mean monthly $PM_{2.5}$ concentration and the monthly number of visits. As the figure shows, the $PM_{2.5}$ concentration and the monthly number of cardiology visits are positively correlated. The correlation was not statistically significant.

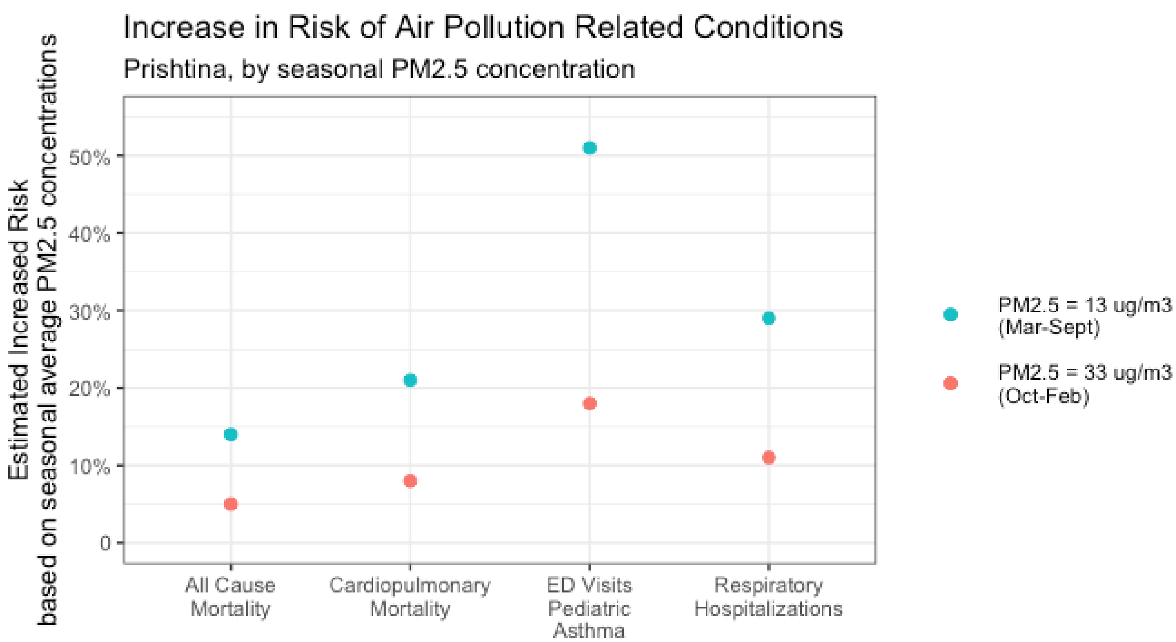


In the pediatric ward at UCCK there is an average of eight percent more visits in the winter months than the summer months.[127] Interviews with pediatric physicians at UCCK revealed that children are more likely to have respiratory infections in the winter than in the summer, creating a natural increase in burden. However, the physicians noted that air pollution tends to exacerbate children's illnesses and extend the time it takes for them to recover. One physician noted that this burden has become greater in recent years as air pollution has increased in Prishtina.[128] Sometimes two children must share the same bed at the hospital because there are so many cases. This reality overburdens providers and creates an unsafe healing environment for children.

The data to create the above figure came from UCCK, US EPA, and IHMK. UCCK provided the team with 2019 data that contained the monthly number of pediatric inpatient cases in 2019. The team combined the UCCK dataset with the existing combined air pollution 2019 dataset (using data from both US EPA and the IHMK Rilindje station). Since $PM_{2.5}$ exacerbates pediatric conditions, the team wanted to see whether there was a correlation between $PM_{2.5}$ and pediatric inpatient visits at UCCK.[129] Since $PM_{2.5}$ concentrations are greatest in Prishtina in the winter months of November, December, January, and February and lowest in the summer months of June, July, August, and September, the team isolated these months to see if there was a correlation between the mean monthly $PM_{2.5}$ concentration and the monthly number of visits. As the figure shows, the $PM_{2.5}$ concentration and the monthly number of pediatric hospital admissions are positively correlated. The correlation was not statistically significant.

The team also analyzed seasonal data from UCCK for monthly pulmonology diagnoses and admissions and cardiology admissions. Although the literature suggests that there should be seasonal, pollution-related increases for these metrics as well, the analysis with the UCCK 2019 data did not show this trend. This could be because data was not properly recorded or for a number of other reasons that were unrelated to air pollution.

INCREASED RISK OF DISEASE



Source: Independent analysis using estimates from Lii et al. 2002, Norris et al. 1999

Previous studies have shown that each 10 ug/m3 increase in $PM_{2.5}$ significantly increases a patient's risk of developing certain medical conditions. A 2002 study of 500,000 people living in metropolitan areas across the United States found that for each 10 ug/m3 increase in $PM_{2.5}$, the risk of all-cause mortality increases by four percent, the risk of cardiopulmonary mortality increases by six percent, and the risk of lung cancer mortality increases by eight percent.[130] The study controlled for age, sex, race, smoking status, and education level.[131] The team used the increase in mortality risk from this study to estimate the increased risk of mortality in Prishtina given the $PM_{2.5}$ concentration of 13ug/m3 in the warmer months and 33 ug/m3 in the colder months. A study in Seattle, Washington found that children living in inner city Seattle were more likely to go to the emergency room for asthma than children living in the less polluted suburbs. The authors of the study found that for each 11 ug/m3 increase in $PM_{2.5}$ the likelihood of an ED visit for pediatric asthma increased by 15 percent.[132]

The team used the following equation to estimate the increased risk, where IR = increased risk associated with an increase in $PM_{2.5}$, C = $PM_{2.5}$ concentration in Prishtina (calculated in winter and summer), and UI = unit increase in $PM_{2.5}$ from the study used.

$$\textit{Increased Risk} = ((IR/100) + 1)^{\wedge}(C/UI)$$

Due to the higher $PM_{2.5}$ concentrations in colder months, there is an increased risk of developing the selected pollution-related conditions. Reducing year-round $PM_{2.5}$ concentrations to the summer level of 13 ug/m3 could greatly reduce the burden on the health care system, resulting in financial savings and improved quality of life for Kosovars.

Pediatric emergency department visits for asthma are greatly exacerbated by pollution. Since UCCK does not currently have a functional pediatric emergency room, the health system is not equipped to handle this influx in pediatric asthma cases. As a result, they must either be admitted to the pediatric inpatient ward or be taken to the general emergency room. This places an unnecessary burden on already limited resources. By implementing policies to reduce air pollution, the Municipality could lower the $PM_{2.5}$ concentration, reducing the number of pediatric asthma cases and alleviating the strain on resources at UCCK.

CURRENT BURDEN ON SPECIFIC CONDITIONS

High average $PM_{2.5}$ concentrations in the colder months raise the overall annual mean to 21 ug/m3. The team used a 10-year study of 4.5 million veterans in the United States to estimate the excess burden of disease in Prishtina that can be attributed to air pollution. The study looked at health outcomes of people exposed to different levels of $PM_{2.5,}$ controlling for age, race, sex, and smoking status. The authors broke $PM_{2.5}$ concentrations into quartiles and aggregated the health outcomes at each quartile. Quartile 3 had a similar $PM_{2.5}$ concentration to Prishtina in the warmer months (11.3-13.8 ug/m3, Prishtina = 13 ug/m3) and Quartile 4 had a similar $PM_{2.5}$ concentration to Prishtina annually (13.9-20.1 ug/m3, Prishtina = 21 ug/m3). The team used the incidence rates of deaths in the study to calculate the relative risk of death from cardiovascular disease, cerebrovascular disease, and pneumonia.

The risk of mortality from cardiovascular disease for those exposed to higher annual $PM_{2.5}$ concentrations is three percent higher than for those exposed to summer concentrations (RR = 1.03, 95% CI = 0.27, 3.83). The risk of mortality from cerebrovascular disease for those exposed to Prishtina’s higher annual $PM_{2.5}$ concentrations is two percent higher than for those exposed to lower summer concentrations (RR = 1.02, 95% CI = 0.08, 13.05). The risk of mortality from pneumonia is seven percent higher for those exposed to higher annual $PM_{2.5}$ concentrations than if people were only exposed to summer concentrations year-round (RR = 1.07, 95% CI = 0.02, 68.32).

The estimates of the risk of mortality from air pollution exposure above are likely underestimates of the situation in Prishtina. The upper end of Quartile 4 is lower than the annual mean $PM_{2.5}$ concentration in Prishtina. The numbers calculated in the study are representative of a population exposed to less air pollution than the population of Prishtina. A meta-analysis showed that the most significant mortality risks associated with $PM_{2.5}$ are at concentrations below 10 ug/m3 and above 20 ug/m3, so the differences between Quartile 3 and Quartile 4 likely underestimate the impact of the higher annual exposure to $PM_{2.5}$ on mortality.[133] Since greater pollution exposure leads to an increased risk of mortality, it is likely that the risk in Prishtina is higher than the team's calculations show.

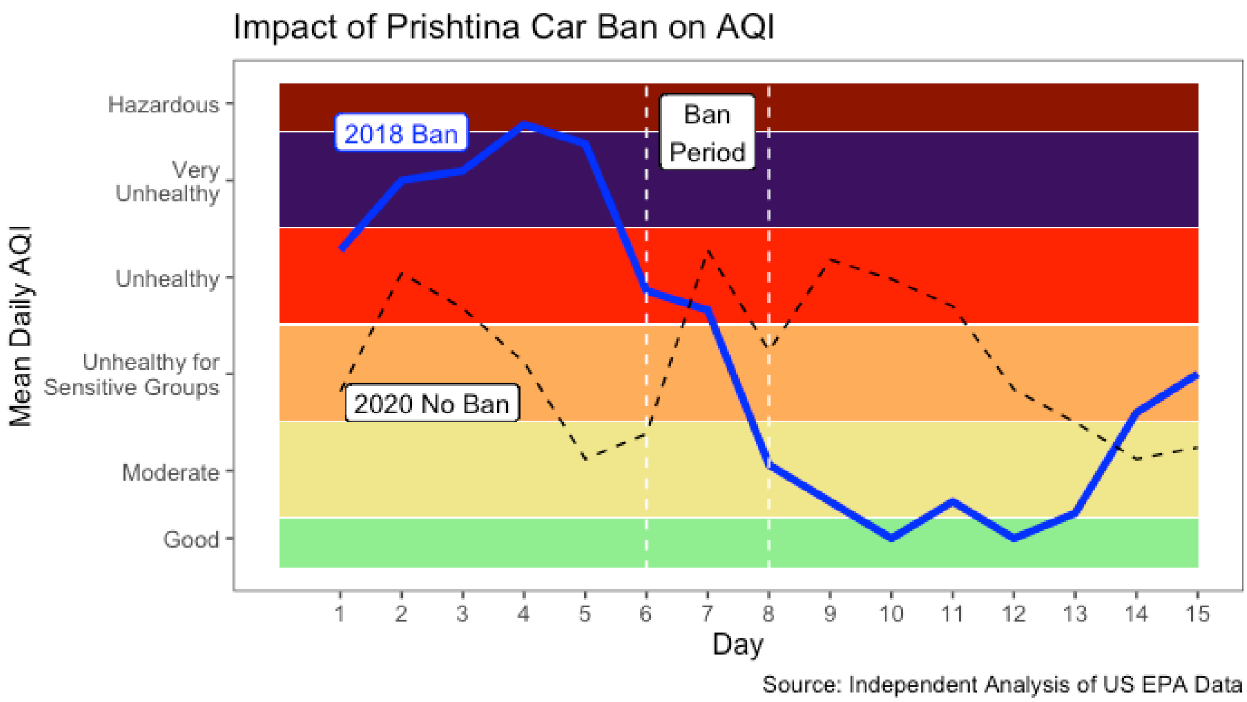
Since winter pollution levels greatly increase annual mean exposure levels, policies targeted at the winter months (i.e., low emissions zones or congestion pricing in the city center enforced in the winter or expanded central heating) will have the greatest impact in reducing overall annual $PM_{2.5}$ exposure. Reducing the annual exposure to the levels found in the warmer months is a productive first step to the goal of reaching the WHO annual recommended limit and reducing the burden on individuals and the health system.

PRISHTINA CAR BAN CASE STUDY

A **two-day vehicle ban** in Prishtina in the winter of 2018 r**educed the AQI from 228 ("Very Unhealthy") to 46 ("Good")**

On January 31, 2018, after a week of dangerously high Air Quality Index (AQI) levels, the Municipality of Prishtina enforced a two-day vehicle ban in the city center.[134] Only public transportation vehicles, taxis, and emergency vehicles were permitted in the center. During the same time-period the Municipality also banned the sale of coal, although the level of enforcement of this law is unknown. Thirty buses were designated to provide free transport during the ban.[135] The AQI average of five days directly prior to the ban's implementation was 228.4, placing it into the "Very Unhealthy" level.[136] Five days after the ban, the average AQI was 46.2, denoting it to the "Good" level of health concern.[137]

Since there was a temperature difference of 5.6 degrees Celsius before and after the ban, the team wanted to make sure that the car ban, and not a change in temperature resulting in decreased inversion, was the main reason for the improved air quality. The team used a period with similar temperatures in January 2020 as a control. The average temperature of -0.83 degrees was similar to 2018 pre-ban temperature levels during the period of January 17, 2020 to January 21, 2020. The average temperature level of 4.17 degrees during January 25, 2020 to January 29, 2020, similar to the calculated 2018 post-ban temperature averages (1.0 degrees pre-ban and 6.7 degrees post ban).[138] When AQI averages of the two control periods were calculated, there was not the same dramatic difference in AQI that was observed during the periods before and after the ban. The average AQI level of the first control period was 132.8, or "Unhealthy for Sensitive Groups."[139] The average AQI in the "post-ban" control period was 147, the same AQI category as the other control period ("Unhealthy for Sensitive Groups").[140]



The above figure shows the impact of the car ban on AQI levels (blue line). The control period in 2020 did not have the same rapid improvement in AQI when the temperature changed, demonstrating that the car ban had a major, positive impact on air pollution levels in Prishtina. Even when inversion is considered, it is clear that the car ban significantly improved air quality in Prishtina.

If Prishtina could implement an effective car ban during the winter months that had similar impacts on air pollution as the two day 2018 ban, there could be significant positive effects on health. In Prishtina, during the days before the ban, the mean $PM_{2.5}$ concentration was 149 ug/m3. During the two-day ban and the day after the ban ended, the average $PM_{2.5}$ concentration was 17 ug/m3. For the period five days after traffic returned to normal, the mean $PM_{2.5}$ concentration increased to 34 ug/m3.

Based on mortality and pollution data from small US cities, the team estimated the excess risk of mortality from $PM_{2.5}$ in Prishtina during the colder months with no car ban ($PM_{2.5}$ in study city = 30 ug/m3, slightly less than Prishtina average of 33 ug/m3) compared to the $PM_{2.5}$ concentration during the car ban ($PM_{2.5}$ in study city = 15 ug/m3, slightly less than Prishtina ban average of 17 ug/m3). The risk of mortality for those exposed to concentrations of $PM_{2.5}$ similar to those in Prishtina in colder months is 30 percent greater than for populations exposed to $PM_{2.5}$ concentrations similar to those following the ban (RR: 1.3, 95 percent CI = 0.62, 2.72). The higher level of exposure led to an excess of 3.7 deaths per 1,000 person-years. These estimates are not adjusted for age, sex, smoking status, race, or education level.

CONCLUSION

While the specific impacts of these policy interventions are not known in the Prishtina context, all evidence in this report shows that air pollution has a significant burden on the population health and healthcare system of Prishtina. Investing in these identified policies to reduce air pollution now will lead to long-term savings for the Municipality of Prishtina in the future. As the population ages, the health system burden of air pollution will only become more severe as people are more susceptible to its effects. However, it is not too late to implement policies that will reduce air pollution and improve health.

Since $PM_{2.5}$ concentrations spike during the winter months, the most effective interventions will be targeted at reducing $PM_{2.5}$ concentrations in October-February. Introducing low emissions zones or congestion pricing during the winter months only could be an effective way to reduce air pollution without completely restricting people's vehicle use. Expanding the district heating system offers a promising option to reduce both ambient and indoor $PM_{2.5}$ exposure in the winter. The most effective solution will likely be a combination of these policy options.

APPENDIX

INTERVIEW GUIDE

- What differences with your patients do you notice when air pollution is worse?
- What changes in patterns/volume (morbidity and mortality) do you see when pollution is worse?
- Do you notice that more patients come in with air pollution-exacerbated conditions (i.e. asthma, bronchitis, pneumonia, heart attack, stroke) in the winter months?
- Does pollution affect other things related to patient health? Can you please explain
- What kinds of measures are patients taking?
- What, if anything, do patients say about air pollution in relation to their symptoms?
- Can you describe any barriers to supporting patients who have a condition that is exacerbated by air pollution?

AQI TO PM2.5 CONVERSION

AQI Category[141]	Index Values	Breakpoints ($\mu g/m^3$, 24-hour average)
Good	0 - 50	0.0 – 12.0
Moderate	51 - 100	12.1 – 35.4
Unhealthy for Sensitive Groups	101 – 150	35.5 – 55.4
Unhealthy	151 – 200	55.5 – 150.4
Very Unhealthy	201 – 300	150.5 – 250.4
Hazardous	301 – 400	250.5 – 350.4
Extremely Hazardous	401 – 500	350.5 – 500

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