

# IMPACT OF AIR POLLUTION

ON HEALTH AND MEASURES TO REDUCE EXPOSURES IN KOSOVO

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All references to Kosovo shall be understood under UNSCR 1244

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## Acknowledgements

*This working document has been prepared to facilitate the exchange of knowledge and to stimulate discussion. The findings, interpretations and conclusions expressed are those of the authors and do not necessarily reflect the policies or views of UNICEF.*

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**ABBREVIATIONS AND ACRONYMS**

| | |
|---|---|
| ALRI | Acute lower respiratory infection |
| ASHRAE | American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| COPD | Chronic obstructive pulmonary disease |
| DALY | Disability-adjusted life year |
| GDP | Gross domestic product |
| HEPA | High-efficiency particulate air |
| HVAC | Heating, ventilation, and air conditioning |
| IAQ | Indoor air quality |
| IHD | Ischemic heart disease |
| OSHA | US Occupational Safety and Health Administration |
| PM2.5 | Particulate matter with an aerodynamic diameter of less than 2.5 µm at the fiftieth percentile cut-off |
| O3 | Tropospheric ozone formed by reaction of nitrogen oxides with volatile organic compounds in sunlight |
| NO2 | Nitrogen dioxide |
| SO2 | Sulphur dioxide |
| VOC | Volatile organic compounds |
| PAH | Polycyclic aromatic hydrocarbons |
| UNICEF | United Nations Children's Fund |
| WHO | World Health Organization |

# Executive Summary

Since the U.S. embassy started monitoring PM2.5 air pollution in Prishtinë in 2016 and made the data available on the internet, there have been growing concerns over the levels of air pollution that have led to citizen protests. For example $PM_{2.5}$ air pollution surpassed 600 $\mu g/m^3$ and 606 $\mu g/m^3$ on 28 and 29 January 2017 respectively, and wintertime concentrations substantially exceed levels determined by the WHO to protect health. Amid these citizen protests, in January 2018 Kosovo announced a 'task force' to plan short-term and mid-term measures to combat air pollution in Prishtinë. While the air pollution concentrations are a significant concern to residents of Prishtinë, there is a lack of information on the source sectors that contribute to the high air pollution concentrations, a lack of awareness of health impacts caused by air pollution, and the disease prevalence data that would allow health impacts to be routinely estimated. ***Development of a strategic roadmap to address air pollution in Prishtinë and wider Kosovo is therefore a key priority***.

Air pollution in Prishtinë has a number of sectoral contributors such as the coal-based thermal power plants outside Prishtinë, raw coal and wood used for domestic wintertime heating, industrial activity, and car exhaust combined with winter time thermal inversions that reduce the mixing height in the atmosphere. The amount that each sector contributes to the problem is not well known, which hampers control efforts. A lot of attention has been focused on the thermal power plants in Obiliq, with little attention to other sectors. For example the Kosovo Environmental Strategy 2013-2022 does not mention household emissions as a major contributor to the air pollution problem, although they report that 46% of energy consumption for the years 2003-2005 was in households[1]. Estimated annual emissions of particulate matter from the household sector in WHO scoping visits in 2013 were estimated to be nearly double those from powerplants Kosovo A and B, and more than 10 times those of transportation[2, 3].

While the thermal power plants contributed approximately 16 times more PM and 20 times more $SO_2$ than an average EU power plant in 2016[3], and total $SO_2$ and $PM_{2.5}$ emissions from the 16 coal power plants in the Western Balkans were almost as high as the combined emissions from the 250 existing coal plants in the EU, the other sectors are major contributors. Source apportionment of atmospheric PAH from an extensive passive sampling campaign in the Western Balkans revealed that biomass combustion contributed 35−65% in urban and industrialized areas, and in Prishtinë passive PAH samples indicated a biomass contribution of 35-40%[4].

Since the passive sampling was conducted between July and December 2004, when domestic heating was predominantly coal, and prior to 2018 policies to switch from coal to biomass domestically, the contribution of households to the air pollution problem are substantially greater, which highlights that household level sources are major contributors to the pollution problem and that biomass combustion processes should also be targeted for remedial action[4]. In order to understand the major contributors to the air pollution problem in Prishtinë, and develop policies to address the situation, ***a scoping study to understand contributions and model potential impacts of policy interventions is a key component of a strategic road map to address air pollution in Prishtinë***.

While there is a need to understand the source contributions, particularly for industrial and household sources which are not well quantified, development of strategies to eliminate domestic burning of coal and wood for space heating during winter months by replacement with technologies that are zero emission at the household level should be a priority. It is unlikely that WHO air quality guidelines can be achieved without major initiatives to address emissions from this sector. ***Economic modelling of pricing structures to connect homes to district heating networks combined with financial models to facilitate rapid expansion of heat pumps in more dispersed areas are a priority***.

Although it is well established that improved population health outcomes are achieved most effectively by societal control of emissions, there is an urgent need to protect at-risk populations from consistent air pollution exposures in excess of levels known to substantially increase risks of adverse health impacts. There is evidence to support individual actions to reduce exposures and health risks, with use of portable air filters in homes, particularly in high risk groups such as those exposed prenatally or during early childhood. Similarly measures to reduce indoor air pollution concentrations in day care centers, kindergartens and schools provide a mechanism to reduce exposures for substantial time periods during the day. ***Increasing awareness in the population of the health impacts posed by air pollution and strategies to mitigate exposures is a priority.***

Estimating current impacts of air pollution on health in Kosovo are hampered by a lack of systematic disease incidence data that would allow the attributable fraction of disease to air pollution to be estimated. While initiatives to disaggregate some of the disease endpoints reported to the Institute of Public Health are necessary, and use of survey based methods such as MICS provide detailed data on polluting activities, household structure and socioeconomic indicators, ***there is a critical need for ongoing systematic digital data collection of disease incidence from physicians trained in reporting ICD10/ICD11 codes as part of a health information system***. In addition recognition of the importance of disease burdens from air pollution and other environmental causes would be greatly facilitated if data from global burden of disease initiatives such as those by the Institute of Health Metrics and Evaluation (IHME) was reported separately for Kosovo, which would facilitate development of policies directed at reducing these disease burdens.

In rapidly growing urban environments like Prishtinë, growing populations compound the air pollution situation, combined with pressing demands for economic development. Given the need to reduce health impacts, ***a priority is to increase awareness of policy makers about the economic and social benefits of investing in intervention strategies quickly rather than more gradually, and of the burdens imposed by inaction on air pollution as a young population in Kosovo ages.*** Analyses of the benefits and costs of the US Clean Air Act in the period 1990-2020 indicate that although the United States spent 65 billion US dollars on the program, the benefits exceed the costs by a factor of 30 including averting 230,000 deaths which comprise about 85 percent of total estimated benefits, 200,000 cased of acute myocardial infarction, and 2.4 million cases of asthma exacerbation[5]. Air pollution can also result in significant economic impacts through avoided productivity, and reduction can result in significant savings through medications usage. In the US annual reductions in pharmaceutical purchases for asthma treatment and prevention and mortality are valued at about $800 million and $1.3 billion, respectively, suggesting that investments in prevention are over one-third of willingness-to-pay for reductions in NOx emissions[6].

An important consideration both for Kosovo and for the European Union is the impact of current exposures to air pollution throughout the Balkans on health burdens as young populations in Kosovo age. Current disease incidence likely underestimate disease impacts as the age structure of the population changes and the current population ages, as most disease endpoints from air pollution are expressed in elderly populations with associated treatment costs.

Although the direct impact of air pollution on disease outcomes in Prishtinë and Kosovo as a whole are less well known, global evidence indicates that at current wintertime concentrations, major impacts would be expected in the population. This report is intended to stimulate discussion on strategies to reduce exposures, identify gaps in information, and promote a strategic roadmap for Government and multilateral organizations in tackling the air pollution in Prishtinë. In addition this report provides a summary of global evidence for health impacts from exposure to air pollution particularly in relation prenatal and early life exposures, and where possible focusses on health impacts related to coal smoke exposures, as those best reflect the current situation in Prishtinë.

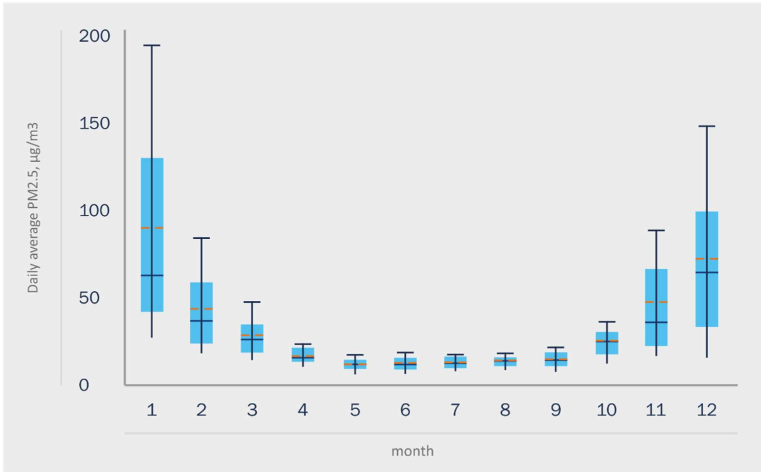
The recent recognition of cognitive impacts in children as a result of prenatal and early life exposure to air pollution gives added urgency to reduce exposures as these impacts affect children's brain development, memory, social interactions and future earning power starting children's lives already at a disadvantage. Addressing the air pollution in Prishtinë is therefore an urgent priority.

## 1. INTRODUCTION - AIR POLLUTION IN PRISHTINË

Figure 1 shows monthly distributions of daily average $PM_{2.5}$ for the time period April 2016 - March 2019. $PM_{2.5}$ concentrations during the wintertime heating seasons exceeded WHO Air Quality annual guideline of 10 $\mu g/m^3$ and 24 hour guideline of 25 $\mu g/m^3$ with concentrations approximately a factor 6 higher than the annual guideline in the coldest months, but close to the guideline during spring and summer periods April to September. While transportation and power plant emissions were relatively constant between seasons, there is a large fraction of domestic heating with solid fuels during the colder months.

Understanding the number of homes using solid fuels for space heating, the variety of heating stoves, and the cost implications for different socioeconomic groups is critical to development and modelling of economic incentives and financial structures to effectively replace solid fuel use with technologies clean at the household level. For 2013-2014 the most recent year the MICS survey was performed, 48.3 households in urban areas used solid fuels for cooking, with 84.6 used in rural areas. In the poorest quintile of the population 95.1% use solid fuels compared to 23.6% in the richest quintile. Use of solid fuels for space heating needs was not quantified which highlights the need for more nuanced questions on energy use in upcoming surveys.

***Figure 1 monthly distributions of daily-average $PM_{2.5}$ values measured at the US Embassy Kosovo***




Interior red line = mean; interior black line = median; boxes = 25th and 75th percentiles; whiskers = 10th and 90th percentiles

Although there is an increase in solid fuels used for space heating during winter months, the increases in air pollution cannot be directly attributed to this increase as there are differences in meteorology and mixing heights between seasons. Figure 2 shows how $PM_{2.5}$ concentrations vary depending on mixing height in the atmosphere with a strong linear relationship for days with precipitation less than 5 mm. Days with precipitation greater than 5mm are highlighted in blue due to their impact in reducing $PM_{2.5}$ concentrations in the atmosphere.

***Figure 2 PM2.5 Concentrations measured at the US Embassy Kosovo in relation to mixing height in the atmosphere***

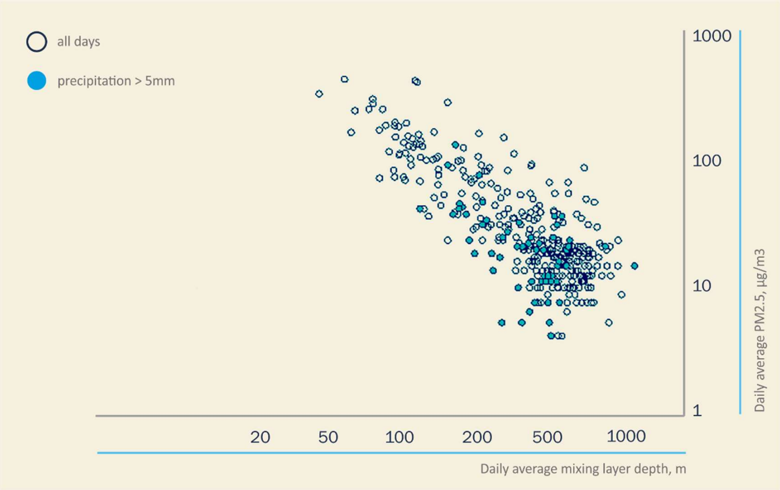



**Figure 3 shows the hourly profile of $PM_{2.5}$ concentrations during a 24 hour period for winter (a) and summer months (b). Although wintertime concentrations are much higher in winter compared to summer, the figures show elevated concentrations during commuting periods from 8-9am, and also a substantial night-time peak in concentrations as a result of space heating during the winter. During the winter cold months $PM_{2.5}$ concentrations during the night were substantially higher than the morning time commuting period and for a much longer duration, indicating the major contribution of domestic space heating emissions to the $PM_{2.5}$ air pollution problem in Prishtinë.**

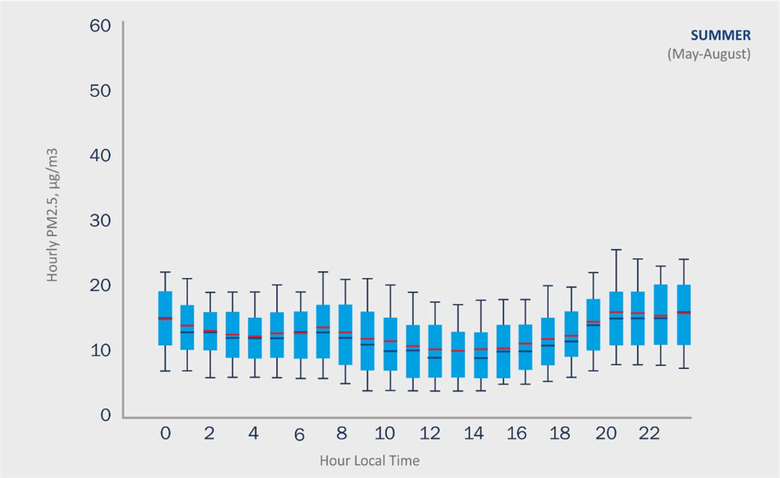
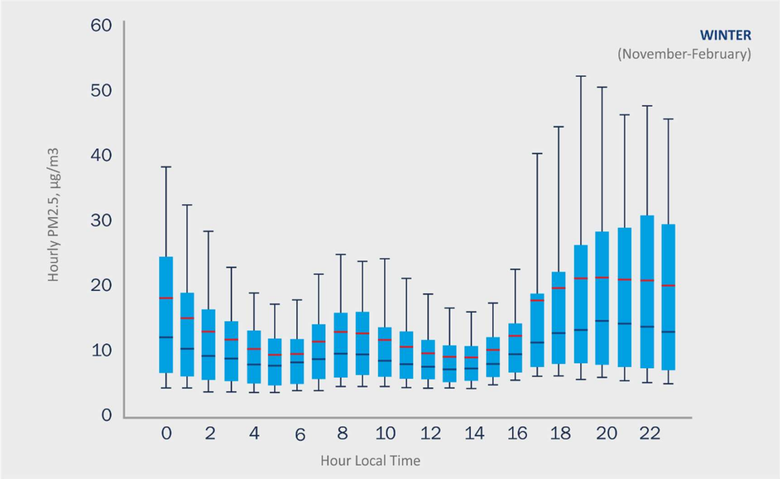





**Figure 3 Hourly $PM_{2.5}$ concentrations during a 24 hour period for summer (a) and winter months (b).**




Interior red line = mean; interior black line = median; boxes = 25th and 75th percentiles; whiskers = 10th and 90th percentiles

In summary figures 1-3 demonstrate that Prishtinë experiences wintertime air pollution that is substantially higher than levels known to cause major health impacts in affected populations. The elevated $PM_{2.5}$ concentrations are characterized by elevated night time concentrations during the cold winter months that are characteristic of domestic space heating emissions, which are not well quantified in Prishtinë, but other sources such as power plants, transportation, central heating boilers and industry identified in the Kosovo Environmental Strategy 2013-2022[1] also play a role.

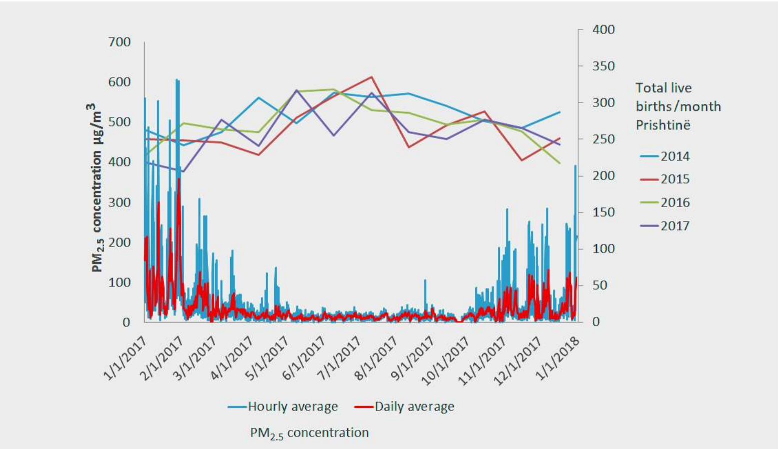
## 2. CHILDREN'S EXPOSURES TO AIR POLLUTION

Air pollution is a complex mixture of health-damaging pollutants. In Kosovo the primary indicator of health effects for combustion-related pollution would be $PM_{2.5}$, particles with a median aerodynamic diameter smaller than 2.5 µm that can penetrate deep into the lung. More information on the health effects of this pollutant exists than for any other, although it is recognized that for some diseases it may be an indicator of combustion pollution in general and that other pollutants may play roles in health effects. In single pollutant models $PM_{2.5}$, $O_3$, and $NO_2$ were associated with mortality in the 16 Years of Follow-Up in the Canadian Census Health and Environment Cohort, and exposure to $PM_{2.5}$ alone was not sufficient to fully characterize the toxicity of the atmospheric mix or to fully explain the risk of mortality associated with exposure to ambient pollution[7]. In Kosovo, however, wintertime pollution levels driven by nighttime space heating emissions are not accompanied by high ozone episodes, and $NO_2$ concentrations are relatively low compared to PM concentrations. Thus health impacts are likely to be dominated by $PM_{2.5}$ exposures.

Health impacts as a result of air pollution are driven not by pollution in any one place, but by people's exposure to pollution in all the places in which they spend time, combined with individual susceptibility to disease. A focus on exposure reflects the contributions of different indoor locations where people spent their time, and thus the health benefits of interventions in different locations. Expression of health effects in response to air pollution exposures are dependent on other intrinsic and extrinsic risk factors that interact with air pollution in the expression of disease. Reducing air pollution related disease resulting from exposures while children requires an integrated approach that targets both air pollution exposures, and modifiable risk factors that contribute to disease. Reduction of exposures requires policies targeted at all environments where children spend their time, especially those during critical windows of vulnerability, including the legal, regulatory and organizational frameworks that govern each location.

Understanding the vulnerabilities of different age children to air pollution related disease is important as the exposure environments change significantly during childhood. It is well recognized that time activity studies indicate that adults and children spend over 90% of their time in indoor environments. Although time indoors and outdoors was not directly assessed on the Millennium Challenge Corporation Kosovo labor force and time use study[8], combining time spent on sport and activities outdoors with time in transportation would be less than 5% of the day. Thus indoor environments dominate exposures to air pollution and resultant health impacts. Of particular concern are prenatal and early life exposures. Figure 4 shows $PM_{2.5}$ concentrations at the US embassy in Prishtinë for 2017 with birth rates for 2014-2017, which demonstrates that all children born in Prishtinë will be exposed prenatally to elevated wintertime air pollution levels. Health impacts are not limited to the last trimester, and thus adverse impacts would be expected in all ages. Children only exposed to elevated wintertime air pollution at very early stages of pregnancy, when impacts would be expected to be lower, would then experience high wintertime air pollution in the first few months of life with resultant impacts on brain and lungs growth and function.

**Figure 4. $PM_{2.5}$ concentrations at the US embassy in Prishtinë for 2017 with birth rates for 2014-2017.**






The residential indoor environment is particularly important for young infants susceptible to acute pneumonia infections, who spend nearly all the time in the residential home environment. Without good disease prevalence data for different ethnic groups in Kosovo, however, the impacts of lower respiratory infections in young children are hard to estimate, which highlights the need for systematic disease incidence data that would allow the attributable fraction as a result of exposures to air pollution to be estimated. Kindergarten children in Kosovo spend 8 hours during the day in the kindergarten which presents opportunities for reducing child exposures to air pollution.

Exposures of school age children depend on the time and mode of transit to school, the location of the school, the heating system used by the school, and the time of day when the children are attending school. Since the schools are in different locations to their home, with different neighborhood sources, building penetration rates, and have different heating sources, indoor environments at schools likely have different air pollution concentrations. The time of day is important since ambient air pollution concentrations vary widely over a 24 hour period due to diurnal patterns of fuel consumption and emissions combined with a raising of the mixing height in the atmosphere during the day.

## 3. Barriers

| Barriers: |
|---|
| • Lack of strategic roadmap to reduce health impacts of air pollution |
| • Awareness of burden of disease and health impacts of air pollution |
| • Awareness of sectoral contribution to air pollution problem |
| • Awareness of clean household energy intervention approaches |
| • Economic modelling of district heating connection pricing to increase penetration |
| • Low interest loans and other financial mechanisms to facilitate district heating connection |
| • Low interest loans and other financial incentives to overcome purchase price of heat pumps |
| • Modelling of policy trajectories to achieve desired health reductions |
| • Integration of approaches to reduce prenatal, early life, school age and adolescent exposures |
| • Coordination within and between government and multilateral organizations |
| • Policy coherence, and enforcement of regulations and standards |
| • Capacity of government and multilateral organizations |

The government of Kosovo has enacted several initiatives aimed at reducing air pollution in Prishtinë in cooperation with multilateral institutions such as the United Nations, the World Bank and the European Union, and through bilateral agreements with countries such as the United States, Switzerland, Luxemborg, Germany and Japan. These include significant investment in emission control technologies for Kosovo A in cooperation with the World Bank, Air monitoring at the US Embassy and replacement of the air pollution monitoring network in cooperation with the Millennium Challenge Corporation, refurbishment of Kosovo B and expansion of district heating in cooperation with the European Union, modelling of air pollution emissions in Prishtinë in cooperation with JAICA, and initiatives to start vehicle emission testing, and formation of an Environmental Health Committee, to name a few. Multilateral organizations including UNICEF, WHO, UNDP and the European Union have made investment to improve information on health through MICS surveys, improving health information and health registration for national insurance. In addition, although there have been major barriers to implementation, the Kosovo Government has passed major laws to regulate tobacco smoking, air pollution and emissions standards for air pollution sources including vehicles. In addition the Ministry of Environment and Spatial Planning developed the Kosovo Environmental Strategy 2013-2022, which identified shortcomings in implementation of air pollution laws and called for systematic development of plans for improving air quality[1]. In addition the strategy called for promoting the importance of air quality as a critical parameter for the health and welfare of the population[1].

While these initiatives are a step forward, unfortunately there are major gaps that prevent detailed evaluation of the causes of the problem and resultant health impacts in the population, and technical capacity, human resources and enforcement abilities have progressed more slowly. The Kosovo Environmental Strategy 2013-2022[1] identified a lack of co-ordination and harmonization of plans and programs which is still evident.

There is a need to develop a strategic road map of how to reduce air pollution to WHO air quality guidelines, with a national budget to achieve these goals. While this is generally acknowledged by the Government and international groups, there is still a lack of systematic evaluation of the costs of different approaches, and the timeframe over which the transition would occur.

A number of domestic heating technologies that are zero emission at the household level are available, which if promoted at scale would dramatically reduce air pollution in Prishtinë, principally district heating cogeneration from the thermal power plants to supply central urban areas and heat pumps installed in more dispersed communities surrounding Prishtinë (See Box 1).

There are a number of barriers that currently hamper distribution at scale related to lack of awareness of the importance of these technologies in addressing the air pollution problem, as the household sector is not seen as a major contributor to the issue, in contrast to the air pollution figures above that suggest a substantial contribution from this sector. In addition to the lack of awareness of these technologies in resolving the air pollution issue there is also a lack of awareness in the economic benefits of these technologies, and robust economic analyses of household expenditure in comparison to traditional heating options.

Furthermore there is a lack of financial incentives such as low interest loans or small scale financing options to overcome purchase barriers in poor urban communities, and a lack of awareness whether these technologies qualify for financial incentives currently available. For district heating these is a lack of economic modelling in relation to the connection pricing structure to maximize the number of residences connected to the network.

Replacing the one price connection fee with a tiered pricing system would allow a greater number of single residences to be connected, whilst maintaining revenue streams. Installation of metering to promote energy efficiency in the network, however, provides an important mechanism to increase the number of residences served and maximize the capacity of the system to reduce emissions from homes.



**BOX 1 HEAT PUMPS**

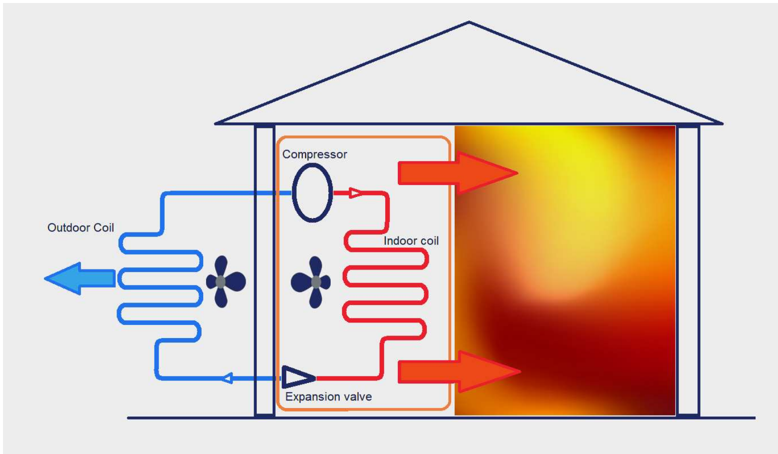
- Heat pumps are currently installed in some residential areas of Prishtinë
- A heat pump extracts heat from the outdoor environment and transfers it inside. Even if the outdoor environment is cold it still has heat that can be transferred.

Air source heat pumps move heat between the air inside a home and the air outside a home, while ground source heat pumps (known as geothermal heat pumps) transfer heat between the air inside a home and the ground outside a home. Heat pumps being installed around Prishtinë are air source heat pumps that are simpler to install and do not require excavation.

A heat pump conceptually compresses a refrigerant which causes it to heat up and this heat is released in indoor environments using a fan that blows room air over the warm coils. The refrigerant is then transferred to the outdoor environment, where the refrigerant is expanded, causing the refrigerant to cool.

Air from outside the house is blown by a second fan across the cold coils, causing heat energy to be absorbed by the refrigerant, even when the outdoor temperatures are cold during winter. In this way heat pumps do not generate heat – they absorb heat energy from the outside air (even in cold temperatures) and transfers it to the indoor air. In cold environments a double or triple compressor may be used.

- Conceptually it works in the same way as your fridge, except in reverse, where the heat is released to the interior
- When it's warm outside, it reverses directions and acts like an air conditioner, removing heat from your home.
- An advantage of a heat pump is that it transfers heat instead of generating heat, giving you more energy efficiency.



# 4. Strategic road map to address air pollution in Prishtinë, Kosovo and the Western Balkans

Reducing the health impacts of air pollution in urban areas is only successfully accomplished through political and social awareness of the health impacts imposed by air pollution combined with allocation of appropriate resources and coordinated action across sectors. To assist government, the private sector, civil society, multilateral and bilateral organizations in resolving the air pollution problem, a strategic plan would assist in coordinating actions and resources. In addition, greater political awareness of the economic and social benefits of investing in intervention strategies quickly rather than more gradually, and the burdens imposed by inaction, will assist policy makers in prioritizing air pollution.

Development of a strategic plan would be more credible with data driven recognition of sectoral contribution to the problem, economic modelling and piloting of clean technology alternatives, and modelling of impacts of policy trajectories. Key components of this approach are discussed below:

### 1. Improve information sources on sectoral contributions with source apportionment

Action to address air pollution requires a data driven knowledge of sectoral contributions to the air pollution problem to ensure that resources are prioritized on policies that result in the greatest reductions in air pollution concentrations in Prishtinë. For example although annually estimated to emit nearly double the amount of particulate matter than powerplants Kosovo A and B and more than 10 times those of transportation[2] , the household sector has received relatively little attention but likely plays a major role in air pollution concentrations. Furthermore reductions in the household sector may result in more cost effective allocation of resources. Identifying sectoral contributions to the air pollution problem would ideally be performed using detailed chemical speciation of ambient air samples over a winter heating season followed by apportionment of the source contributions.

While bottom up dispersion based air pollution models based on emissions data can be used to estimate contributions, they require *a priori* knowledge of the number and emissions from all sources in Prishtinë, which are not currently available, and frequently underestimate actual atmospheric concentrations in the atmosphere. As a result the top down chemical characterization approaches would produce more reliable information on source contributions and ideally would be performed by academic groups experienced in the chemical characterization and analysis required. A potential role for UNICEF would be to advocate for the need for such an analysis within government and donors in Kosovo, and provide guidance if necessary on groups that can conduct this analysis.

### 2. Improve information with systematic reporting of disease incidence data

A critical barrier to estimating the burden of disease from air pollution in Kosovo is the lack of systematic collection of disaggregated disease incidence data in a digital health information system. Collection of such data at the point of care would also greatly assist evaluating health impacts in many other areas, and is critical in determining the relative burdens of different



diseases and risk factors in Kosovo. While there has been a limited analysis air pollution and health impacts for the World Bank in 2013[9], estimation of health impacts of air pollution in a PhD thesis, and the World Bank has initiated a health registration system for national health insurance, these do not replace the need for ongoing systematic collection of disease incidence data in a health information system. Availability of this data is a key component in performing constraints to growth analyses as a prerequisite to Millennium Challenge Corporation compacts. In addition it is key to performing cost benefit evaluations of interventions, and modelling future health care expenditures. A potential role for UNICEF would be to advocate for the need for health information systems within government and donors to inform on the current status of disease burdens in Kosovo.

### 3. Rove information sources with number of homes using solid fuels for space heating, the variety of heating stoves, and the cost implications for different socioeconomic groups

In addition to improved disease incidence data, there is a need to improve other information sources on household expenditures, household fuel consumption and usage, and differences between different socioeconomic and ethnic groups in Kosovo. UNICEF MICS surveys already provide a well-accepted source of information on socioeconomic and household indicators and in 2019 provides a mechanism to increase this information; however the questions included in the 2019 survey are limited as they only ask about primary fuels used and currently do not ask about fuel quantities or expenditure. For more detailed fuel consumptions data and mixed heating stove use additional more detailed surveys may be necessary.

### 4. Model policy trajectories to achieve desired health reductions

Modelling of policy trajectories will ensure that reductions in air pollution and resultant health impacts are achieved prior to large investment of resources. In addition they allow for evaluation of cost effective allocation of resources by comparing policies in different sectors in relation to cost and reduction of air pollution concentrations to maximize overall impacts. Modelling trajectories however requires cross sectoral information, combined with technical capacity. A potential role for UNICEF is to collaborate with the Prime Minister’s to convene stakeholders and ensure that technical assistance is available to map trajectories. Collaboration with the WHO Urban Health Initiative which performs some of this scenario mapping and modelling in other countries would be an advantage.

### 5. Economic analysis of heat pumps and other clean household technologies in Kosovo

There is a lack of general awareness on the purchase and running costs of installing clean household technologies for space heating in comparison to costs of burning wood or coal in traditional stoves. Preliminary analysis of estimates suggests that wintertime heating costs using heat pumps would be comparable or better to use of coal or wood in traditional stoves. While initial purchase costs for those in the upper wealth quintiles would not be a critical barrier, small scale financial mechanisms and low interest loans would increase penetration in the lower wealth quintiles.

Given levels of air pollution in Prishtinë and likely impacts on health, the social and economic benefits of development of innovative pricing structures and low interest loans would likely exceed cost, however, detailed economic modelling of these initiatives would be required. A potential role for UNICEF would be to advocate for these analyses with the Millennium Challenge Corporation, the European Union or the World Bank, in collaboration with the Ministry of Economic Development.

**6. Economic modelling of pricing structure for district heat connection from street**

A critical barrier to increased penetration of district heating is the cost to connect to the network. Current costs do not differentiate between the size of building or number of residences being connected. Replacing the one price connection fee with a tiered pricing system would allow a greater number of single residences to be connected, whilst maintaining revenue streams, however economic modelling of the pricing structure is required. In addition for populations in the lower wealth quintiles, and in the rental markets, low interest loans and other innovative financing and incentive mechanisms to overcome the purchase barrier should be explored to maximize penetration of the network in central urban areas.

Current initiatives to install metering to promote energy efficiency in the network, however, provides an important mechanism to increase the number of residences served and maximize the capacity of the system to reduce emissions from homes. A potential role for UNICEF would be to advocate for these analyses with the Millennium Challenge Corporation, the European Union or the World Bank, in collaboration with the Ministry of Economic Development.

**7. Develop trusted information sources and increase awareness on air pollution**

With growing awareness and dissatisfaction with air pollution concentrations in Prishtinë there is a need to develop trusted information sources on health impacts based on the latest scientific evidence combined with information on interventions and individual actions that can be taken to reduce exposures. With exposure to a wide variety of commercial facemask and air filtration products, which have been shown to vary substantially in their effectiveness in reducing air pollution exposures, combined with wide access to social media messages on health, which may vary widely in accuracy, there is a need for broad active engagement on social media about air pollution combined with repositories of information on commercial products.

In addition training and education of nurses and primary healthcare physicians in health impacts of air pollution, combined with increased education in elementary and secondary schools will increase penetration of air pollution messages in less accessible communities. Identification of media personalities that can champion air pollution issues would also help to increase awareness in different social groups.

UNICEF has a track record of developing trusted information sources within different populations groups, and especially with adolescents. A potential role for UNICEF would be to collaborate with the Public health Institute to promote and host information on health impacts of air pollution through its activities and programs, identify champions, and increase education materials and activities with donor support.



# 8. Integrating air pollution with current UNICEF activities

*There are number of ways that tackling the air pollution situation in Prishtinë and wider Kosovo can be integrated into current UNICEF activities and programmatic areas.*

## 8.1. Improving MICS information

The upcoming scheduled 2019 MICS survey activities provide a unique opportunity to improve household information in relation to air pollution emissions that will have a wide utility. MICS has been widely used by different government and donor agencies and provides one of the few quantitative estimates of actual conditions in households in Kosovo. Current drafts of the 2019 MICS questionnaire include questions related to primary heating, cooking and lighting fuels, but are limited as they only ask about primary fuels used and currently do not ask about fuel quantities or expenditure. Additional information would be highly desirable in retrospective recall of costs associated with space heating in winter months, purchasing habits related to bulk purchase vs continuous expenditure, use of secondary heating fuels, changes in heating fuels, and any other cooking tasks performed on the stove. Since space heating during winter months is a key household contributor to the air pollution problem, prioritizing questions related to space heating over questions on cooking and lighting for example, could be considered when considering questionnaire length. MICS data will be very valuable in the next few years in understanding the affordability of different clean household heating options, suitability in Kosovo households, and in informing policy making. Similarly due to the large impacts of air pollution in the population, additional more detailed surveys may be necessary to collect more detailed information on fuel consumption, mixed heating stove use, perceptions and acceptability of different household heating options.

## 8.2. Awareness raising in adolescents

**UPSHIFT**

Upshift is a flagship UNICEF program designed to understand community challenges and design and build impactful solutions in the form of products or services.

Upshift activities on air pollution could be stimulated by the launch of a thematic workshop on air pollution. This could involve adolescents in the development of personal protection products for air pollution targeted to appeal to younger generations, such as:

•Development of air pollution mask designs fashionable for adolescents

•Development of low cost air filtration products for rooms and spaces – see https://smartairfilters.com/cn/en/

**START-UP**

Start-up is a second gate funding program to foster entrepreneurial culture and employment for adolescents and youth through finding commercial avenues to market products developed in Upshift. Start-up could be used to support air pollution related projects and services to commercial reality in Kosovo

**PODIUM**

Podium is a program to teach youth to advocate for the needs and rights of their communities through the power of social change and advocacy by cultivating campaign management and advocacy tactics. Podium could be instrumental in increasing adolescent awareness of air pollution health impacts that will be experienced later on in life, and in advocating for cleaner air. Podium could also be used to increase awareness through citizen science projects using low cost air pollution sensors to measure different city environments for air pollution, investigate most polluted areas, and increase advocacy for clean solutions. Finally use of low cost air pollution sensors could be used to increase awareness of and action for public place free from tobacco smoke.

**PONDER**

Ponder is a workshop to foster media literacy and critical approaches to information to judge the value, authenticity and authority of the information adolescents encounter. Ponder could play a role in assessing claims related to air pollution, and increasing awareness of health impacts

**U-REPORT**

U-report is a program to encourage reporting by adolescents on their environment and surroundings using app and web-based tools. U-report could fill in critical gaps in information from households on space heating practices, acceptability of different interventions, and other more specific data on relation to household's practices U-report could also be a valuable tool in dispelling myths related to air pollution health impacts and air pollution technologies by:

•Developing an app/forum for air pollution advocacy
•Identifying and connect groups active/concerned against air pollution
•Dissemination of air pollution health impact data
•Action on smoke free public spaces

### 8.3. Improving communication and awareness activities

A comprehensive response plan to drive down the incidence of air pollution-related disease in children requires a significant scaling up of communication and awareness to provide trusted sources of information on health impacts and measures to reduce exposure. Development of communication campaigns to raise awareness should include raising UNICEF profile of social media, developing content for primary medical centers and home visits, and also creating short documentary films of UNICEF activities to increase awareness of UNICEF activities with donors. As with other interventions to improve public health, a critical component of communication and advocacy strategies is evaluation of effectiveness in



reaching the target population, and impact on behavior. More format evaluation of communication effectiveness would be beneficial in evaluating strategies that work, and effective channels to reach different population segments. This means it will be important to set a solid baseline and assess impact after the campaign. These would include but not necessarily be limited to:

•Surveys on impact amongst pregnant women
•Internet and social media evaluation
•Coordination with planned surveys by international organizations

As part of the communication strategy there will be a need to develop new materials and also adapt UNICEF materials from other regions. For example, a priority should be adapting the Mongolia air pollution videos on cognitive and other health impacts in children to the Kosovo context, in preparation for the upcoming winter heating season.

### 8.4. Activities in schools, day-care centers and kindergartens

UNICEF activities in schools and daycare centers provide both an opportunity to intervene and reduce exposures for children in day care centers, and also to increase awareness and conduct investigations into air pollutions exposures children experience whilst at school. In addition, provision of education materials to assist teachers in fulfilling the environmental protection curriculum can directly improve awareness of the health impacts of air pollution in communities. A number of specific activities could be undertaken depending on available budgets, as follows:

**SCHOOLS**

•Art competition on air pollution and health with prizes – distribute results on social media platforms and utilize images for UNICEF publications, posters for awareness raising in public spaces, and framed images in UNICEF offices/Ministry of health etc

•Add air pollution health effects to environmental protection curriculum for $7^{th}$ to $8^{th}$ grade, and other grades where appropriate. Combine curriculum with portable air filters for classrooms to allow demonstration projects and awareness raising

•Provision of smart monitors to measure air pollution concentrations in their environment for science fair competitions with prizes – Distribute results and publicize event with social media

•Conduct a pilot study to demonstrate the effectiveness of portable air filters in classrooms to directly reduce children's exposures in schools

**DAY-CARE AND KINDERGARTENS**

•Conduct a pilot study to demonstrate the effectiveness of portable air filters in day care and kindergarten to directly reduce children's exposures



### 8.5. Activities in primary health care facilities and home visits

Primary health care centers and home visits provide a mechanism to access populations that are difficult to reach with information about the health impacts of air pollution, tobacco smoking and also protective measures that can be used to prevent exposures from metal working and other activities undertaken in these communities that lead to high exposure to air pollutants.

**PRIMARY HEALTH CARE FACILITIES**

•Incorporate health based programming on LCD screens installed in plot project by Swiss Development Corporation in waiting areas for maternal health visits. Expand LCD network to achieve greater coverage

•Develop programming specifically related to air pollution by first training and then filming physicians and nurses conveying air pollution messages

•Produce a documentary film of training physicians and nurses to convey air pollution messages to highlight novel approaches undertaken that can be duplicated in other districts for wider dissemination and fundraising

•Include programming for other UNICEF initiatives on breastfeeding, nutrition, immunization, tobacco smoke exposure etc.

•Supplement with large size posters for prenatal clinic waiting areas. Posters printed on 8.5" x 11" or A4 printer paper, such as messages found online and printed, have limited impact and tend to not be read. Large size (e.g. 1.5 meters by 1.2 meters) posters with infographics are needed

**HOME VISITS**

•Provide education materials for distribution on air pollution and tobacco smoking impacts during pregnancy

•Pilot of portable air filter loans during pregnancy and $1^{st}$ 6 months of life

## 9. DEVELOPMENT OF NEW PROGRAMMATIC AREAS TO ADDRESS AIR POLLUTION

Development of new programmatic areas to address air pollution should initially be to develop funding to expand current thematic elements. In addition communication products and demonstration of successful approaches in Prishtinë can be used as models to tackle air pollution in other communities in Kosovo and in the wider communities of the Western Balkans.

Convening a meeting with participation of internationally recognised experts on air pollution will assist in bringing together different stakeholders, increasing knowledge of direct health impacts, and in development of strategic plans to address the air pollution situation in Kosovo. While there are still significant information gaps, and international consultation will focus activities in directly addressing gaps in information, and also in developing consensus on domestic heating options that are clean at a household level.

There is a clear opportunity to act in establishing pilot programs to reduce exposures during pregnancy with loans of portable air filtration devices for the home. In addition, there are opportunities to establish pilot programs in school classrooms and day care centers with installation of portable air filtration to reduce exposures of children during the school day.

Monitoring of these initiatives with low cost particle sensors provides not only evidence for the impact of these measures, but also communication materials that can be used on social media to increase public awareness, and also in discussion with donors to raise the profile of UNICEF activities.

Develop media personalities that can champion air pollution issues to help increase awareness in different social groups, TV and radio.

# APPENDIX I

## HEALTH IMPACTS OF AIR POLLUTION

The following sections summarize health impacts as a result of exposure to air pollution and are drawn in large part directly from the UNICEF publication "Understanding and Addressing the Impact of Air Pollution on Children's Health in Mongolia." [10], and the ADB/UNICEF report "Reducing impacts of prenatal and early life exposures to air pollution"[11].

They are reproduced here as a reference for some of the compelling scientific evidence on consequences of prenatal and early life exposures to the high levels of air pollution currently experienced in Prishtinë. While not a formal systematic review of the evidence, the health impacts identified are also supported by the World Health Organization report "Air pollution and child health: prescribing clean air" [12].

### 1. AIR POLLUTION RELATED MORTALITY

The effects of long term exposure to air pollution on cardiovascular morbidity and mortality are well documented[13]. Exposure to $PM_{2.5}$ over a few hours to weeks can trigger cardiovascular disease–related mortality and nonfatal events; longer-term exposures increase the risk for cardiovascular mortality and reduce life expectancy within more highly exposed segments of the population by several months to a few years, with credible pathological mechanisms[13]. More importantly, reductions in PM levels show near immediate benefits with decreases in cardiovascular mortality within time frames as short as a few years[13].

Large cohort studies have investigated the relationship between long-term exposures to $PM_{2.5}$ and ozone and mortality[7, 14-16] including at concentrations lower than current US standards [17-20]. There is good evidence that major health impacts persist at levels lower than WHO air quality guidelines, which reinforces the need to reduce air pollution to very low levels to achieve major health benefits.

More recently, a nationwide cohort study involving all Medicare beneficiaries from 2000 through 2012, a population of 61 million, was investigated to provide information on the health effects of long-term exposure to low levels of $PM_{2.5}$ air pollution across the population, including among minorities or persons with low socioeconomic status in smaller cities and rural areas[21]. Increased risks in all-cause mortality of 7.3% (95% CI 7.1-7.5) in this nationwide cohort were associated with increases of 10 $\mu g/m^3$ in annual average ambient $PM_{2.5}$ concentrations, with increased risks when the population was constrained to those exposed to concentrations less than the US national standard of 12 $ug/m^3$.[21]

Both short and long term exposures to particulate matter are associated with increased risk for cardiovascular events and hospital admissions for pneumonia [22] [23], however exposure-response estimates for chronic health impacts of air pollution in global burden of disease estimates are based on long term averages of air pollution exposure. Although peak exposures may play a role in health impacts there is currently insufficient evidence to characterize these impacts.

## 2. Air pollution and lung function

Effects of air pollution on lung function in children can occur even at lower levels of exposure, as children's lungs are still maturing and therefore especially vulnerable to pollution. Compromised lung function in children is associated with long-lasting chronic conditions such as asthma and chronic obstructive pulmonary disease, and prenatal exposure to air pollution can predispose individuals to cardiovascular disease later in life[12]. In contrast, long-term improvements in air quality were associated with statistically and clinically significant positive effects on lung-function growth in children[24].

Exposure to air pollution in children results in a large direct burden of disease due to ALRI, which in turn may increase susceptibility to chronic air pollution related disease. For example, both non-severe and severe pneumonia increased the risk of at least one long-term major chronic condition, most commonly reduction in lung function, as a result[25]. In addition air pollution exposures and repeated incidence of pneumonia in children are both linked to increased incidence of chronic air pollution related disease later in life[26]. The time periods of vulnerability for these critical outcomes are different, however, with the vast majority of ALRI resulting from risk factors and exposures that act during the period from pre-pregnancy to 2 years old, with the most critical windows for air pollution and infection in the first 2-3 months of life. In contrast air pollution exposures that lead to later chronic respiratory disease may affect lung development throughout development, with critical periods of vulnerability reflecting time periods for organ development and maturity. Structure and function of the lungs are permanently altered in their design by factors operating during sensitive periods of fetal or early post-natal life [27]. Much of the lung development is prenatal and maternal prenatal smoking and passive maternal prenatal smoking have been extensively studied and are associated with irreversible alterations in lung growth [27, 28]. After birth infants and toddlers ventilate with flaccid ribcage with less effective ventilation, less effective diaphragm, and lowered functional residual capacity. Alveolar development is completed by age 3, after which growth occurs mainly by enlargement. There is a gradual increase in thoracic stiffness and lung compliance which continues during childhood resulting in an underdistension of the lungs below the age of 7-8 and an overdistension above this age[27]. The factors that adversely affect growth of the respiratory system has been covered elsewhere in much more detail e.g.[29], however of particular relevance is that development of children's lungs occurs throughout childhood and measures should be taken at all stages to reduce children's exposure to air pollution. Clearly a priority is to reduce exposure in residential environments during early development to reduce pneumonia and lung development impacts; however, measures should also be taken to reduce air pollution exposures in school age children to reduce impacts of air pollution related diseases later in life.

## 3. Air pollution and pneumonia

For children pneumonia as acute lower respiratory infections contributes the vast majority of the health burden from air pollution related disease in children. Exposures to air pollution in children, however, may contribute to the incidence of chronic air pollution related disease later in life. For example, structural remodeling as a result of respiratory disease that interferes with growth of air passages at crucial time periods may have long term effects on respiratory health, and there is little evidence of catch up afterward[30].

In 2017 22% of all deaths in children <5 years were estimated to be due to acute lower respiratory tract infections (ALRI), with 36% attributable to particulate matter pollution [31].



Causes of life-threatening invasive bacterial infections in the neonatal period are uncertain as infections might be environmentally acquired rather than perinatally acquired, however, in the late neonatal and postneonatal periods, Gram-positive cocci (primarily Streptococcus spp) cause about two of every three infections. As children grow older, the causes of clinical pneumonia are mainly respiratory syncytial virus, influenza virus, Streptococcus pneumoniae, and Haemophilus influenzae. Although 95% of all deaths from ALRIs occur in low- and middle-income countries[32], meta-analysis of ten European birth cohorts (ESCAPE study) found a significant association between air pollution and pneumonia [33]. 81% of the deaths from pneumonia occur in the first 2 years of life[34], and socioeconomic and environmental factors also contribute through air pollution, young maternal age, low maternal education, and environmental tobacco smoke exposure[32]. Recent exposure to second-hand cigarette smoke has been shown to be associated with increased severity of lower respiratory tract infections due to respiratory syncytial virus (RSV) in hospitalised children aged <1 year [35, 36]. Exposure to tobacco smoke increases Streptococcus pneumoniae nasopharyngeal carriage rates in children [37], which can act both as a disease precursor and mode of transmission between individuals. Furthermore compromised host immune responses in the nasopharynx following cigarette smoke exposure predispose individuals to invasive pneumococcal disease [38].

Respiratory syncytial virus (RSV) infection is the major global cause of ALRI. In South Africa, viral pathogens were found in 78% of children <5 years of age with ALRI[39], and 80% of children at 2 years of age have been infected with RSV, of whom one-third will have developed an ALRI, usually bronchiolitis (inflammation of the small airways in the lung) [40]. Major risk factors for severe RSV leading to hospitalization include lower gestational age, <3 months of age at onset of RSV season, and living with school age siblings. Lack of breast-feeding, and nutrition did not appear to increase the risk of severe RSV infection [41].

Important vaccine-preventable causes of severe pneumonia are S pneumoniae (which causes at least 18% of severe episodes and 33% of deaths worldwide), the influenza virus (7% of severe episodes and 11% of deaths), and H influenzae type b (4% of severe episodes and 16% of deaths)[34]. The effects of air pollution are more pronounced for bacterial causes of pneumonia compared to RSV[42], although there is evidence for a role of viral pathogens in bacterial pneumonia[43].

## 4. Health impacts from prenatal and early life exposures

### 4.1. Cognitive development

Brain development comprises an array of qualitatively different processes with overlapping timing: neural tube formation, cell proliferation and differentiation, migration, dendritic arborization, synaptogenesis, apoptosis, formation, and connectivity of cortical mini-columns, and myelination[44]. Neurogenesis takes place at an astonishing rate, averaging 250,000 new neurons per minute during gestation; the result is 100 billion neurons at birth [45]. Most of the growth is in the third trimester, when 40,000 synapses are formed per minute. This high growth rate is vulnerable to environmental insults and the prenatal and early postnatal periods are the most vulnerable window [46]. Long-term exposure to particulate air pollution levels typical of exposure in major cities around the globe can alter. Disorders of neurobehavioral development affect 10–15% of all US births[48]. Subclinical decrements in brain function are even more common than these neurobehavioral developmental disorders, which can have severe consequences for the welfare and productivity of entire societies[49]



Executive processes develop throughout childhood and adolescence, and play an important role in a child's cognitive functioning, behavior, emotional control, and social interaction. High cognitive executive functions essential for learning[50] develop significantly from 6 to 10 years of age [51]. Attentional control appears to emerge in infancy and develop rapidly in early childhood, whereas cognitive flexibility, goal setting, and information processing have a critical period of development between 7 and 9 years of age, and are relatively mature by 12 years of age. [51]

The neural systems responsible for executive functioning are numerous, complex and inter-related with the prefrontal cortex dependent on efferent and afferent connections with virtually all other brain regions including the brain stem, occipital, temporal, and parietal lobes, as well as limbic and subcortical regions [52]. Damage or loss of function at any level of one of these neural systems may result in cognitive and/or behavioral deficits[51]. Air pollution particles are not restricted to the lungs[53].

Nano-sized particulate matter has been observed in the human brain in highly exposed subjects confirming that air pollution components reach the brain [54, 55]. Inhaled ultra-fine particles (UFP) are efficiently deposited on the olfactory mucosa of the nasal region and will translocate along the olfactory nerve into the brain in rats[56], and evidence from a number of animal models that showed intranasally instilled solid UFP translocate along axons of the olfactory nerve into the brain [56]. In addition long term chronic exposure to air pollution may cause disruption of the blood brain barrier[54]. Once in the brain, particulate matter is pro inflammatory in microglia[57], which may result in chronic inflammation, oxidative stress, neurotoxicity, and cerebral vascular damage. In addition, some adsorbed compounds are soluble and may become a toxic stimulus independent of the particle itself [53].

Air pollution exposure results in developmental neurotoxicant effects in the brain of humans and animals[46]. In animals, inhalation of diesel exhaust and ultrafine particles results in elevated cytokine expression and oxidative stress in the brain [58, 59] and altered animal behavior [47, 60]. The prefrontal cortex and striatum, implicated in executive functions such as working memory and attention[61], have shown inflammatory responses after traffic-related air pollution exposure [58, 62]. In children, numerous studies have shown exposure to traffic-related air pollutants during pregnancy or infancy, when the brain neocortex rapidly develops, has been related to cognitive delays [63-70], even at low exposure levels[71], which can be modulated by antioxidant intake[67]. Children and dogs exposed to high concentrations of air pollution in Mexico city revealed structural damage in MRI analyses localized to the prefrontal cortex, which may be related to reduced cognitive function [72].

Children spend a large proportion of their day at school, including the period when daily traffic pollution peaks. Many schools are located in close proximity to busy roads, and may be heated in winter with heat only boilers that emit directly in the vicinity of the playground, which increases the concentrations of air pollution around and in schools. In a prospective cohort study of the association between traffic-related air pollution in schools and cognitive development in primary school children in 39 schools in Barcelona, Spain, Children from highly polluted schools had a smaller growth in cognitive development than children from the paired lower polluted schools[63]. children attending schools with higher levels of EC, NO2, and UFP both indoors and outdoors experienced substantially smaller growth in all the cognitive measurements: working memory (two-back detectability), superior working memory (three-back detectability), and inattentiveness (hit reaction time standard error) [63]. Moreover, increased air pollution increases school absenteeism[73], and decreases performance in examinations [74, 75].

In a Guatemala stove intervention trial CO exposure of pregnant mothers during their 3rd trimesters was associated with impaired child neuropsychological performance on 4 out of 11 neuropsychological tests including visuo-spatial integration, short-term memory recall, long-term memory recall, and fine motor performance[76]. Prenatal air pollution exposure could carry long-term consequences such as decreased performance in school, lower educational attainment, and reduced earnings[77]. In New York high prenatal exposure to Polycyclic aromatic hydrocarbons (PAHs) may adversely affect children's cognitive development at 3 years of age and odds of cognitive developmental delay[78], with implications for school performance. Numerous studies have shown in utero exposure to ambient air pollution increased risks of autism in children e.g. [79-84]

Thus pathways linking exposure to air pollution and brain damage include a systemic inflammatory response from particulate resulting in disruption of the nasal and olfactory barriers and the blood-brain barrier which serves to increase particulate matter uptake, combined with particulate matter uptake through olfactory neurons, cranial nerves such as the trigeminal and vagus, and the systemic circulation. Once in the brain, particulate matter exposure results in expression of inflammatory mediators at low levels and the formation of reactive oxygen species which result in altered neuronal development and damage.

### 4.2. Adverse birth effects

Maternal exposure to air pollution is associated with stillbirth, preterm birth, low birth weight and being small for gestational age[12]. Recent systematic reviews have found exposure to $PM_{2.5}$ was associated with preterm birth, low birth weight and being small for gestational age[85-87]. Further, there is increased likelihood of preterm birth among women exposed to PM2.5 during pregnancy with pre-existing diabetes 10.6%(95%CI:0.2–2.1%) compared to 3.8%(95%CI:2.2–5.4%) among women without this condition[88]. Similarly there is increased likelihood of preterm birth among women exposed to PM2.5 during pregnancy with pre-eclampsia (8.3%,95%CI:0.8–16.4%) compared to women without this condition (3.6%,95%CI:1.8–5.3%)[88]. In a prospective cohort study in China with concentrations more similar to Prishtinë there was a 3% (OR = 1.03; 95% CI: 1.02, 1.05) increase in risk of preterm birth with each 5-$\mu g/m^3$ increase in $PM_{2.5}$ with the strongest effect in the second trimester[89]. In a recent systematic review in China sulfur dioxide was more consistently associated with lower birth weight and preterm birth[90], reflecting the use of high sulfur coal for residential heating. In industrialized countries like Canada, which do not have residential coal smoke, traffic is an important predictors of adverse birth effects[91].

Effect estimates for decreased birth weight were generally largest for entire pregnancy exposure, with pooled estimates of decrease in birth weight from 10 $\mu g/m^3$ $PM_{2.5}$ exposure of -23.4g (-45.5, -1.4) , and pooled odds ratios of 1.05(0.99–1.12) per 10 $\mu g/m^3$ $PM_{2.5}$ based on entire pregnancy exposure[87]. In London only $PM_{2.5}$ traffic exhaust and $PM_{2.5}$ were consistently associated with increased risk of low birth weight after adjustment for each of the other air pollutants, and 3% of low birth weight cases were estimated to be directly attributable to residential exposure to $PM_{2.5}$>13.8 $\mu g/m^3$ during pregnancy[92].

There is also suggestive evidence of associations between exposure to AAP and the incidence of infertility and endometriosis[12]. In China which has coal smoke concentrations more similar to Prishtinë, there was also some evidence for congenital cardiovascular defects[90, 93].

### 5. AIR POLLUTION NEURODEGENERATIVE DISEASE

Inflammatory effects of air pollution may accumulate across an individual's lifespan resulting in neurodegenerative disease[62, 94]. Diffuse neuro inflammation, neurovascular damage, and production of autoantibodies to neural and tight-junction proteins seen in children chronically exposed to ozone and $PM_{2.5}$ air pollution, may constitute significant risk factors for the development of Alzheimer's disease later in life[95]. Acute and chronic low-level exposures to ozone (O3) and PM have also demonstrated neurotoxic effects in different

animal models [96-98]. Neuropathological evidence of accelerated brain aging has been described in the olfactory and respiratory nasal mucosae, olfactory bulb, and cortex of experimental dogs raised in Mexico City [72]. Furthermore air pollution may cause cardiovascular disease, which is also known to impact cognitive function in later years[99]. A study linking fifteen years of Medicare records for 6.9 million adults age 65 and older with cumulative residential exposure to $PM_{2.5}$ showed a 1 microgram-per-cubic-meter increase in average decadal exposure to $PM_{2.5}$ increases the probability of receiving a dementia diagnosis by 1.3 percentage points, and that the effect of $PM_{2.5}$ on dementia persists below current regulatory thresholds[100]. In a nationally representative longitudinal survey matched with air quality data in China, long-term exposure to air pollution impeded cognitive performance in verbal and math tests[101].

The effect of air pollution on verbal tests becomes more pronounced as people age, especially for men and the less educated. The damage on the aging brain by air pollution likely imposes substantial health and economic costs, considering that cognitive functioning is critical for the elderly for both running daily errands and making high-stake decisions[101]. In a population-based cohort of 2.2 million adults aged 55–85 years who resided in Ontario, Canada, residential proximity to major roadways was associated with a higher incidence of dementia[102].

Similarly, ambient traffic-related air pollution was associated with decreased cognitive function in older men on a battery of seven cognitive tests[103]. Lung function is also a predictor for cognitive decline in the elderly; however, air pollution and lung function are independent predictors of cognitive decline in the elderly[104].



# APPENDIX II

## PERSONAL PROTECTION MEASURES

The following sections summarize personal protective measure than can be implemented to reduce exposures to air pollution and mitigate health impacts when faced with air pollution concentrations that exceed levels known to cause health impacts in the population. The section is largely drawn from the ADB/UNICEF report "Reducing impacts of prenatal and early life exposures to air pollution"[11], and is reproduced here to provide scientific evidence supporting different measures and technical guidance on options for Prishtinë.

### 1. Air filtration units

High-efficiency particulate air (HEPA) filter air cleaners can effectively reduce indoor PM concentrations resulting from both indoor and outdoor sources. Studies suggest that air cleaners can provide some health benefits by reducing exposure to PM concurrently with biological responses associated with air pollutant exposure[105]. In a randomized, double-blind, crossover trial in Shanghai, China, in 2014, use of air filters in dormitories for 48 h resulted in a 57% reduction in $PM_{2.5}$ levels compared to sham filters (from 96.2 to 41.3 μg/m³), which was associated with reductions in circulating inflammatory and thrombogenic biomarkers, including 68.1% in interleukin-1β, 64.9% in soluble CD40 ligand, 32.8% in myeloperoxidase, and 17.5% in monocyte chemoattractant protein-1. Systolic and diastolic blood pressures and fractional exhaled nitrous oxide were significantly decreased demonstrating clear cardiopulmonary benefits of indoor air purification among young, healthy adults[106]. In a study measuring indoor, outdoor and personal exposure to $PM_{2.5}$ properly operating air cleaners in Beijing could significantly reduce indoor $PM_{2.5}$ concentrations to well below WHO guideline levels and significantly lower all major components of $PM_{2.5}$, including reactive oxygen species (ROS) activity, compared to sham air cleaners[107]. The utility of air cleaners in reducing overall personal exposure to $PM_{2.5}$ was marginal, however, due to short-term exposure contributions from environments with high $PM_{2.5}$ concentrations, including exposure to traffic related emissions[107], implying that this intervention should be coupled with face mask filtration for more effective exposure reduction. In one study of elderly persons living in close proximity (< 350 m) to major roads, the use of two portable HEPA filter air cleaners over a 48-hr period was shown to decrease the impact of outdoor-generated PM on microvascular function[108]. In a randomized crossover intervention study of endothelial function in 45 healthy adults in a wood smoke impacted community using a portable air cleaner, indoor $PM_{2.5}$ concentrations were reduced by 60% compared to a sham air cleaner with concurrent improved endothelial function and decreased concentrations of inflammatory biomarkers[109]. Filtration was associated with a 9.4% (95% confidence interval, 0.9–18%) increase in reactive hyperaemia index and a 32.6% (4.4–60.9%) decrease in C reactive protein[109].

Use of portable air cleaners has been associated with decreased symptoms relating to exposure to outdoor-generated smoke from the fifth largest US wildfire of 1999[110]. During the fires, the staff of the local medical centre and other tribal organizations implemented several interventions including filtering and non-filtering masks were distributed free of charge, public service announcements were released through local media outlets, and vouchers for free hotel services in nearby towns or portable high-efficiency particulate air (HEPA) cleaners were distributed to those had adverse health effects during the smoke or had been treated for pre-existing conditions. Increased duration of the use of high-efficiency particulate air cleaners and the recollection of public service announcements were associated with reduced odds of reporting adverse health effects of the lower respiratory tract. No protective effects were observed for duration of face mask use[110].

Air filtration has also been associated with decreased allergy and asthma symptoms. In a systematic review among patients with allergies and asthma, use of air filters was associated with fewer symptoms among adults and children [111] and cat allergy–related symptoms among adults [112] associated with indoor-generated pollution and allergens. In a double blind, placebo-controlled, cross-over study in which the effects of air cleaners placed in the living room and bedroom for 3 months were compared with the effects of sham air cleaners young asthmatic children sensitized and exposed to pets in the home showed a significant improvement in airway hyper responsiveness and a decrease in peak flow amplitude[113]. A number of historical studies did not find significant associations between air cleaner use and asthma related health effects[114-116], although some studies reported that the air cleaners reduced airborne levels in the rooms they were placed compared to sham cleaners [115, 116]. Weaknesses of study design limit generalizability including use of ionization air cleaners[114] now known not to be effective in reducing air concentrations, and in contrast to studies showing significant improvements placing air cleaners only in one room of the house, the living room[8] or the bedroom[9]. More recent systematic reviews have shown that mechanical filtration with HEPA air filters is effective in dropping indoor air concentrations of particulates[117]. Further, in apartment buildings in Ulaanbaatar Mongolia a randomized controlled trial to assess HEPA filter use and foetal growth showed 29% reduction in indoor PM2.5 concentrations[118, 119]. However filter care and maintenance is an important limitation as air cleaner effectiveness was reduced by > 50% after approximately 5 months of use[119].

Air cleaner effectiveness will differ within and between buildings depending on factors such as air exchange, the capacity of the air cleaner, and baseline pollutant levels[120]. It is important that an air cleaner capacity is matched to the room volume and air exchange, and that it delivers effective filtration without ozone generation. With a large variety of air filtration products available, central repositories of information on performance, such as that at the list of California certified air cleaners at the California Air Resources Board are important for making informed purchases[i] and comparing across brands using comparable methodologies as the choice of test aerosol will impact efficacy results[121]. However these are for California, and a central repository of information on air cleaners in Kosovo and the Western Balkans would be valuable to consumers in making informed decisions, similar to: https://thewirecutter.com/reviews/best-air-filter/

Finally, a range of other household activities and sources may reduce the effectiveness of the intervention in delivering health benefits. For example, in a randomized controlled clinical trial of home environmental interventions in Baltimore, USA, few of the 69% of the households with smokers in them changed smoking habits, which likely mitigated the effectiveness of the intervention in delivering symptom reduction[122]. However, air filters are also effective at reducing the effects of asthma in children that live in homes with cigarette smoke. In a double-blind, randomized trial of 225 eligible children 6 to 12 years of age, who had physician-diagnosed asthma and were exposed to>5 cigarettes per day there were 42 fewer unscheduled asthma visits among children in the intervention group (18.5% [95% confidence interval: 1.25%–82.75%]; P = .043), associated with a 25% reduction in particle levels, compared with those in the control group, demonstrating the effectiveness of HEPA filters as a control strategy[123]. There are also a range of advances in air purification technology that warrant continued evaluation of air filter efficacy.

[i] https://www.arb.ca.gov/research/indoor/aircleaners/certified.htm



**Air filter effectiveness**

The effectiveness with which an air filter can reduce air pollution levels in a room is dependent on room volume and air exchange. A clean-air delivery rate (CADR) is a measure of how much clean air a portable air filter can deliver to a room. Above 350 is excellent, and one below 100 is poor[ii]. Portable air filter units that rely on filters out-performed or matched most of the other types at their lowest and quietest settings, and thus there is no need to select other types[ii].

MERV - Minimum Efficiency Reporting Value (MERV) is a standard that rates the overall effectiveness of air filters. Higher value MERV rating equates to finer filtration, meaning fewer dust particles and other airborne contaminants can pass through the filter. MERV ratings are on a scale from 1-20, where the higher ratings indicate fewer dust particles and other contaminants can pass through. HEPA rated air filters have a MERV of 17-20. A HEPA filter is required to remove at least 99.97% of airborne particles down to 0.3um in size. MERV 13 and above provide effective filtration but may increase resistance for some HVAC systems. Table 1 shows effective filtration of MERV 13-16 by particle diameter size range.

**Table 1 Effective filtration with particle diameter for MERV ratings 13-16.**

| 0.3-1.0 microns | 1.0-3.0 microns | 3.0-10 microns |
|---|---|---|
| MERV 13 <75% | 90% or better | 85% or better |
| MERV 15 <75%-80% | 90% or better | 85% or better |
| MERV 16 <94% or better | 90% or better | 85% or better |

Providing a repository of information on portable air cleaners commercially available is helpful for consumers to make informed choices. For Example all portable indoor air cleaning devices sold in California must be certified by the California Air Resources Board (CARB).

To be certified, air cleaners must be tested for electrical safety and ozone emissions, and meet an ozone emission concentration limit of less than 0.050 parts per million. These and other requirements such as specific labeling language are required in Title 17, Sections 94800 - 94810, of the California Code of Regulations.

Potentially hazardous air cleaners that generate unhealthy ozone levels are listed on https://www.arb.ca.gov/research/indoor/o3g-list.htm

This list however is limited to those in California and does not include air cleaners sold in the Western Balkans. A fact sheet on ozone generating air filters is available at: https://www.arb.ca.gov/research/indoor/ozone_gen_fact_sheet-a.pdf

[ii] https://www.arb.ca.gov/research/indoor/cr-12-2007.pdf

## 2. Facemasks

### Facemasks and cardiovascular risks in adults

Air pollution exposure is an established risk factor for cardiovascular morbidity and mortality [13]. Exposure to $PM_{2.5}$ over a few hours to weeks is associated with the onset of myocardial infarction and has been proposed as a trigger for acute cardiovascular events [124, 125]. Longer-term chronic exposure over a few years increases the risk for cardiovascular mortality to an even greater extent than exposures over a few days and reduces life expectancy within more highly exposed segments of the population by several months to a few years[13].Both short term and long term exposure to PM can result in elevated blood pressure even at low concentrations [126]. In general the higher the blood pressure the greater the risk of myocardial infarction, heart failure, stroke and kidney disease, and small population-wide increases in blood pressure translate into serious public health burdens[127]. Reductions in PM levels are associated with decreases in cardiovascular mortality within a time frame as short as a few years[128]. Controlled exposure studies to diesel exhaust in animals and man demonstrate alterations in blood pressure, heart rate, vascular tone, endothelial function, myocardial perfusion, thrombosis, atherogenesis, and plaque stability through oxidative stress mechanisms[129].

Use of facemasks that effectively mitigate personal exposures therefore has the potential to confer significant health benefits in the general population and in those with a history of coronary heart disease. Although a couple of recent studies have demonstrated the potential for significant health benefits in adults without[130] and with a history of coronary heart disease[131], significant questions still remain about the use of facemask for sustained population level benefits. The time period wearing the facemask in these studies was very short (48 hours), and sustained benefits through extended use over weeks or months remains to be evaluated. Mandated use of facemasks in the general population in California in 1919 resulted in masks worn in public but laid aside indoors when the wearer was no longer subject to observation[132]. Evidence from China indicates nonlinear air pollution avoidance behavior, with significant increases of facemask purchases during extreme pollution episodes[133]. In spite of these limitations use of facemasks remains promising to reduce acute exposures.

### Adults without history of coronary heart disease

In a cross-over randomized controlled trial, 15 healthy volunteers (median age 28 years) walked on a predefined city center route in Beijing in the presence and absence of an efficient facemask. The facemask was a 3M Dust Respirator 8812 (3M, St. Paul, MN, USA) with filter efficacy of 97% reduction in particle number. The mask contains a lightweight polypropylene filter, which does not remove ambient gases. Cardiovascular effects were observed after estimated reductions in PM exposure from 89 µg/m³ and 43,900 particles/cm³ to approximately 2 µg/m³ and 1,200 particles/cm³ in the presence of the mask [130]. In order to maximize the difference in PM air pollution exposure, subjects wore the mask for 24 hr before the mask study day, in addition to wearing it during the 24 hr study day, and were given instructions to wear the mask at all times while outdoors and as much as possible when indoors.

Figure 6. 3M Dust Respirator 8812; https://www.safetysupplies.co.uk/trolleyed/products/3m-8812-dust-respirator-valved.htm

During the 2-hour city walk, systolic blood pressure was lower (114 ± 10 vs 121 ± 11 mmHg, $P < 0.01$) when subjects wore a facemask, although heart rate was similar (91 ± 11 vs 88 ± 11/min; $P > 0.05$). Over the 24-hour period heart rate variability increased (SDNN 65.6 ± 11.5 vs 61.2 ± 11.4 ms, $P < 0.05$; LF-power 919 ± 352 vs 816 ± 340 ms2, $P < 0.05$) when subjects wore the facemask. Thus, wearing a facemask appears mitigates the adverse effects of air pollution on blood pressure and heart rate variability, which has the potential to prevent cardiovascular events in cities during short term episodes with high concentrations of ambient air pollution[130].

### Adults with Coronary heart disease

In an open randomized crossover trial, 98 patients with coronary heart disease walked on a predefined route in central Beijing, China, under different conditions: once while using an efficient face mask, and once while not using the mask. The face mask was associated with decreased self-reported symptoms and reduced maximal ST segment depression (–142 vs. –156 µV, $p = 0.046$) over the 24-hr period. When the face mask was used during the prescribed walk, mean arterial pressure was lower (93 ± 10 vs. 96 ± 10 mmHg, $p = 0.025$) and heart rate variability increased (high-frequency power: 54 vs. 40 msec2, $p = 0.005$; high-frequency normalized power: 23.5 vs. 20.5 msec, $p = 0.001$; root mean square successive differences: 16.7 vs. 14.8 msec, $p = 0.007$). Reducing personal exposure to air pollution using a face mask improved a range of cardiovascular health measures in patients with coronary heart disease, which have the potential to reduce the incidence of cardiovascular events in this highly susceptible population[131].

### Facemasks and prenatal exposure

There is no evidence yet available that demonstrates use of a face mask reduces risks from prenatal exposure to air pollution. Recent studies on the cardiovascular benefits of wearing a facemask in adults without[130], and with[131] a history of cardiovascular disease in China, however, imply that a benefit may be possible through use of a facemask to reduce personal exposure to PM during pregnancy. Long term usage of facemasks would be required to confer benefits, however, as adverse effects on lung function in infants exposed prenatally to tobacco and are not limited to exposure in the last weeks of pregnancy[134]. Further usage of the facemask to prevent prenatal exposure would also likely include wearing a mask even in indoor settings, or in combination with mechanical filtration of indoor air with HEPA filters, as wearing a mask only during commuting periods would only confer a limited exposure reduction.

Overall, however, major questions remain about the efficacy and practicability of facemasks to prevent prenatal exposures compared to other approaches due to the lack of evidence for long term reductions in exposure beyond short term usage.

**Facemasks and exposure of infants and young children**

Since infants cannot wear face masks, potential benefits of this intervention would stop at birth and other intervention approaches that reduce the air concentrations of air pollutants would be required. For infants, intervention approaches that reduce personal exposures to PM in the home such as mechanical air filtration with HEPA filters would provide some benefits during critical windows of development and have the advantage of being effective over much longer periods during the day than are feasible through facemask use. Overall, however, major questions remain about the practicability of facemasks usage with young infants.

**Mask efficacy**

The earliest mandated use of facemasks in the general population most probably dates to an outbreak of influenza in 1919 in which many towns and cities adopted the measure, principally in California, which did not show any influence of the mask on the spread of influenza in those cities where it was compulsorily applied[135]. More recently limited success in finding ways to effectively mitigate the impacts of air pollution that affected the health of tens of millions of inhabitants during the rainforest fires in Indonesia in the summer of 1997 resulted in unprecedented and widespread distribution of face masks to the general public by a range of organizations including the United Nations[136]. Not all masks deliver the same degree of protection, however. A review of the evolution of the surgical mask[137] reveals that as early as 1920 Kellog and Macmillan demonstrated that leakage took place around the edges of surgical masks hampering their filtering capabilities[135]. More recently, leakage of inspired air around the periphery of tie on or moulded surgical masks circumvented the masks' ability to remove airborne spore particles, resulting in no difference compared to controls without masks[138]. Similarly, in tests of the efficacy of 3 facemasks in dental splatter tests a certified personal respirator resulted in an efficiency of 94 – 96% percent, compared with 90 - 92 % and 85 - 86 % for the moulded and tie-on surgical masks, respectively [139].

Choosing what type of facemask to wear to protect from air pollution is important. In tests of nine commercially available masks claiming protection against fine $PM_{2.5}$ from consumer outlets in Beijing, filtration performance varied widely from less than 1% to 29%, and the total inward leakage ranged from 3% to 68% in the sedentary tests and from 7% to 66% in active tests, primarily due to poor facial fit[140]. Similarly tests of 18 commercially available masks in Ulaanbaatar showed a wide range of efficiencies in fit tests, from approximately 35% to 99% with many failing to provide adequate protection[141]. Therefore, many available masks may not provide adequate protection, and evidence based testing and guidance to consumers is required[140]. In addition it it important to note that:

- Surgical masks and others that do not make a seal or have filtering material are not effective in reducing air pollution exposure
- Scarves are not effective in reducing air pollution exposure
- Masks do not protect infants and small children.
- Beards or other facial hair that interferes with the mask seal will reduce the effectiveness of the facemask in adults



**Mask Specifications**

With a wide variety of facemasks commercially available, there is a critical need for guidance on which will be effective for filtration of air pollution particles. There is a large literature on this topic, and US or European specifications should be followed. Table 2 shows US and European certification categories for facemasks. The US National Institute for Occupational Safety and Health (NIOSH) classification of face masks into nine categories (N95, N99, N100, R95, R99, R100, P95, P99, and P100). N (not resistant to oil) means that the respirators cannot be used in an oil droplet environment; R (somewhat resistant to oil) and P (strongly resistant to oil) mean that this respirator can be used for protection against non-oily and oily aerosols. For ambient air pollution particles in Kosovo N, R or P could be used as mask fit is likely to have greater impact on mask performance. The European Standard (EN 149:2001) classifies face masks into three classes: FFP1, FFP2, and FFP3. Surgical masks provide 12 to 16 times less protection than a NIOSH or FFP facemask to particle penetration[18].

**Table 2. US and European certification categories for facemasks and filtration ability.**

| Mask specification | | | Filtration ability |
|---|---|---|---|
| European standard | | FFP1<br>FFP2<br>FFP3 | 80% of particles at least 0.6 microns in diameter<br>94% of particles at least 0.6 microns in diameter<br>99% of particles at least 0.6 microns in diameter |
| US standard | N,R or P | 95<br>99<br>100 | 95% of particles at least 0.3 microns in diameter<br>99% of particles at least 0.3 microns in diameter<br>99.97% of particles at least 0.3 microns in diameter<br>HEPA quality filter |
| N-Not oil resistant, R-Resistant to oil, P-oil proof | | | |

## 3. Dietary modification and supplementation

**Antioxidants**

Based on evidence that oxidative stress may be a fundamental cause of some adverse health effects of air pollution, a number of pharmaceutical or chemo preventive interventions have been suggested to prevent air pollution related disease, such as antioxidant or antithrombotic agents[142] . The literature on dietary modification and supplementation on cardiovascular health is extensive, which lends support to the idea that these measures may mitigate some of the effects of air pollution. In addition, the literature on antioxidants on health in athletes also provides evidence of improved health outcomes. Elite athletes, particularly those engaged in endurance sports and those exposed chronically to airborne pollutants/irritants or allergens, are at increased risk for upper and lower airway dysfunction[143]. In placebo-controlled trials in cyclists' supplementation with the antioxidant vitamins C and E conferred partial protection against the acute effects of ozone on FEV1 and forced vital capacity [144, 145]. Vitamin C and E also conferred protection in patients with exercise induced asthma in randomized crossover design [146]. In a randomized, double-blinded, crossover design, higher plasma antioxidant concentrations were found in runners with Vitamin C and E supplementation and CC16 was higher post-exercise in the placebo group[147], suggesting short-term vitamin C and E supplementation might help to decrease the lung injury response of runners when exercising in polluted conditions[147]. A protective effect of lycopene[148] and β-carotene[149] have been observed in onset of exercise-induced asthma. Similarly, dietary fish oil supplementation suppressed exercise-induced bronchoconstriction in elite athletes, attributed to its anti-inflammatory properties[150], and undenatured whey protein, a cysteine donor that promotes production of a major lung antioxidant Glutathione, may augment pulmonary antioxidant capacity and be therapeutically beneficial in individuals exhibiting exercise-induced bronchoconstriction[151].

In non-athletes, dietary supplementation can reduce baseline risk for the development of cardiovascular disease and could thereby reduce susceptibility to air pollution. Long-term supplementation with antioxidant omega-3 fatty acids, found in oily fish such as mackerel and salmon and in flax seed oil, has been shown to reduce the likelihood of nonfatal myocardial infarctions and stroke, as well as the risk of all-cause, cardiovascular, and sudden deaths[152]. Reducing salt intake can also contribute to cardiovascular health; a 4–6 g/day reduction is associated with a reduction in systolic blood pressure of about 3.5 mmHg and 7 mmHg among normotensive and hypertensive (≥ 140/90 mmHg) individuals respectively, yielding a predicted avoidance of 240–362 cardiovascular events per 100,000 population over 10 years[153] Consuming a diet high in plant sterols, combining four groups of cholesterol-lowering components of plant origin (viscous fibres, soy protein, plant sterols, and almonds), was also shown to significantly reduce blood pressure in a longitudinal study of 66 hyperlipidaemic subjects[154].

Dietary modification or supplementation can also modulate the effects of air pollution. Intake of vitamins C and E can reduce the effects of ozone on lung function and nasal inflammatory cytokine production in both healthy and asthmatic populations e.g. [155-157]. Vitamin D is associated with lower risks of hypertension[126]. In a study of 52 older adults, daily supplementation with Omega-3 fatty acids in fish oil compared with soy oil reduced the effects of $PM_{2.5}$ on superoxide dismutase activity, plasma glutathione, and heart rate variability [158, 159]. In a randomized, controlled exposure study omega-3 fatty acid fish oil supplements offered protection against the adverse cardiac and lipid effects associated with exposure to concentrated ambient particulate matter [160]. Similarly, analysis of supplementation with vitamins B6 or B12 or methionine in 549 elderly men as part of the Normative Aging Study suggests an attenuation of the effects of $PM_{2.5}$ on heart rate variability [161]. Antioxidant-rich diets (leafy vegetables and fruits) might help to mitigate adverse impacts of air pollution by counteracting oxidative stress.

Antioxidant supplementation with vitamin C and E above the minimum dietary requirement led to attenuated nasal inflammation and partially restored antioxidant levels in asthmatic patients exposed to high levels of ozone[156]. N-acetylcysteine supplementation attenuated airway responsiveness by 42% in patients with airway hyper-responsiveness following inhalation of diesel exhaust compared with filtered air[162]. Animal models also suggest a protective role of antioxidants in asthma. In a murine model of allergic asthma, L-arginine reduced airway injury and restored mitochondrial dysfunction[163] and airway hyperresponsiveness [164].

While many health end points of $PM_{2.5}$ air pollution appear to be mediated through inflammation and reactive oxygen species (ROS), dietary supplements to mitigate health impacts of air pollution do not reduce exposure. Thus, the possibility of health impacts mediated via different pathways remains due to the wide variety and complexity of the effects of air pollution on body systems. In combination with other measures to reduce exposure, however, supplementation with antioxidants may confer protective benefits to the impacts of air pollution, especially in vulnerable groups such as infants[67].



### 4. Breastfeeding

Reduction in health impacts of air pollution related disease can be achieved through reduction in other child child-specific risk factors. Sub-optimal breastfeeding is a risk factor for pneumonia as exclusive breastfeeding allows maternal IgG antibodies against RSV to cross the placenta with sufficient levels help to protect the infant from severe infection. Exclusive breastfeeding has the single largest potential impact on child mortality of any preventive intervention feasible for delivery at high coverage in low-income settings, and is a primary intervention for the prevention of pneumonia[165]. Maternal IgG antibodies against RSV cross the placenta with sufficient levels help to protect the infant from severe infection.

### 5. Vaccination

Reduction in childhood diseases linked to air pollution exposures can also be achieved through PCV13 vaccination and to a lesser extent vaccination against influenza. A systematic assessment is needed to determine disease prevalence and whether PCV13 vaccination is warranted. Increased vaccination efforts against influenza would be warranted given population benefits of reduced seasonal impacts of influenza disease. These measures act to reduce underlying levels of disease in the population that are exacerbated by air pollution.

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