

Personal Interventions and Risk Communication on Air Pollution



Summary report of a WHO Expert Consultation,
12–14 February 2019, Geneva, Switzerland



World Health
Organization



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In memory of Prof Kirk Smith (1947-2020)

This is the last WHO publication co-authored by Professor Kirk Smith before passing away. The global public health community has lost a tireless mentor, advocate, leader and friend. We, as the authors, will deeply miss his leadership in advocating for strong evidence-based science and fighting for the most vulnerable population to air pollution.

Personal interventions and risk communication on air pollution

ISBN 978-92-4-000027-8

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Printed by the WHO Document Production Services, Geneva, Switzerland. Design and layout: atelier1203.ch, Geneva, Switzerland.

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Acknowledgements

This report was prepared and coordinated by Sophie Gummy (WHO), with inputs from Francesco Forastiere for its conceptualisation, draft findings and review and Pierpaolo Mudu (WHO) for technical contributions.

We thank all the participants in the meeting for their valuable contributions, as well as the authors of the abstracts and the external reviewers of the report for bringing the perspectives of academia, governmental bodies and agencies, nongovernmental organizations and various disciplines.

We thank especially Francesco Forastiere for his contribution in shaping the meeting as well as Michal Krzyzanowski, and also for their role as a Chairs, together with Lidia Morawska.

We are very grateful to the following external experts who reviewed the report and provided valuable comments, inputs and perspectives to this work:

- Kalpana Balakrishnan, Faculty of Public Health, Sri Ramachandra Institute of Higher Education and Research, Chennai, India
- Wayne E. Cascio, Center for Public Health and Environmental Assessment, Office of Research and Development, Environmental Protection Agency, Washington DC, United States of America
- Klea Katsouyanni, Medical School, National and Kapodistrian University of Athens, Greece and Environmental Research Group, King's College London, U.K.
- Yousef S. Khader, Department of Public Health, Faculty of Medicine, Jordan University of Science and Technology, Amman, Jordan
- Adetoun Mustapha, Nigerian Institute for Medical Research, Lagos, Nigeria and Imperial College London, United Kingdom.
- Dong Chun Shin, College of Medicine, Department of Prevention Medicine, Institute of Environmental Research, Yonsei University, Seoul, Republic of Korea.

Editorial assistance was provided by Elisabeth Heseltine.

We also acknowledge the Federal Ministry of Health, Germany, and the Norwegian Ministry of Foreign Affairs for their financial support.

" During major pollution episodes,
reducing exposure is often
recommended to reduce the risk of
acute harm ; however, the greatest
health benefit is likely to be
achieved with daily reductions in the
risk of chronic harm."

Acronyms and abbreviations

AQI air quality index

API air pollution index

COPD chronic obstructive pulmonary disease

PM particulate matter

PM_{2.5} particulate matter of a diameter $\leq 2.5 \mu\text{m}$

PM₁₀ particulate matter of a diameter $\leq 10 \mu\text{m}$

"While the problem of air pollution is increasingly being recognized and tackled by both governments and civil society, the action is too slow, especially in the most severely affected regions of the world. Most countries suffer from sustained unhealthy levels of air pollutants and regular acute peaks."

Preface

Clean air is a human right. Unfortunately, it is not a reality for a large proportion of the world's population. Worldwide, about 9 of 10 persons are exposed to air pollution at levels above the WHO air quality guidelines. As a result, about 7 million people die every year due to ambient or household air pollution. Although this number is impressive, it is only the tip of the iceberg, as there is also a huge burden of sickness, hospitalization, reduced life expectancy and the associated social and economic impacts of lost productivity and health care costs.

While the problem of air pollution is increasingly being recognized and tackled by both governments and civil society, the action is too slow, especially in the most severely affected regions of the world. Most countries suffer from sustained unhealthy levels of air pollutants and regular acute peaks.

Air pollution is complex, as it originates from various sources and depends on seasonal, meteorological and topographic factors. Solutions exist, but they require long-term planning and interventions; there is no quick, easy fix. They also require proper understanding of the sources, trust in the data, governance for coordination, multisectoral action and local, regional and international cooperation. These ingredients are essential to resolve the issue sustainably, and success is not yet in sight. Governments and the public health community attempt to provide relevant advice to affected population, especially during peaks of air pollution. The questions are how best to protect people's health, who to target as a priority and how to communicate the solutions.

WHO is committed to supporting Member States in addressing the health impacts of air pollution. As a normative agency, WHO's mandate is to provide evidence-based advice and recommendations. As a technical agency, WHO will continue to strengthen the health community with knowledge and tools for engaging with other sectors to lead discussions on air pollution and health and to include health in policy-making.

In order to provide the health sector with sound, reliable guidance on mitigating the risks of air pollution, WHO convened a group of experts to review the current scientific literature on individual interventions to reduce exposure to air pollution, such as use of respirators and air filters and modifying behaviour, such as avoiding exposure or staying indoor. They also discussed the best ways to communicate the guidance.

Individual interventions should complement – and certainly not substitute for – long-term planning and multisectoral interventions.

With all the experts from various disciplines and geographical regions who contributed to this report, we are confident that we can support Member States in protecting their populations' health. This report is a first step towards mitigating the adverse impacts of air pollution.

Dr Maria Neira

Director, Environment, Climate Change and Health
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World Health Organization



Background

The health effects of air pollution are well known, and efforts are being made worldwide to reduce emissions and decrease both peaks and long-term air pollution. Sustained high levels are, however, found in many parts of the world, and peaks of air pollution occur everywhere.

In implementing the “Road map for an enhanced global response to the adverse health effects of air pollution”, agreed by the World Health Assembly in 2016 (WHA69), WHO is addressing this urgent public health problem, including informing policy-makers and the public about the extent of population exposure and the health effects of poor air quality and strengthening the health sector with knowledge and tools to engage with other sectors in responding to air pollution. Evidence-based recommendations are needed on effective communication of potential risks to the public, to health care workers and to patients, with guidance on reducing exposure to air pollution.

In May 2018, the American Thoracic Society sponsored a workshop entitled “Personal Interventions to Reduce Exposure and Risk from Outdoor Air Pollution” in San Diego (CA), USA. The objectives of the workshop were to review and synthesize current knowledge and evidence on the effectiveness of personal interventions for reducing exposure to air pollution and the risks of adverse health effects, to identify gaps in knowledge and to assess evidence-based approaches to managing risk. A multidisciplinary committee of 20 experts in environmental epidemiology, engineering, personal protective equipment, communication, nursing and medicine considered evidence for individual susceptibility to air pollution and the effectiveness of staying indoors, reducing physical activity, filtering indoor air and using respirators to reduce exposure to ambient air pollution. The committee discussed ways of improving the usefulness of air quality indices and challenges in communicating risk, changing behaviour and promoting social equity. Participants included representatives from WHO and the European Respiratory Society. A report is to be published in the *Annals of the American Thoracic Society* (late 2020).

To build on the discussions at that workshop, WHO convened an expert consultation of an extended group of experts from various regions and from governments, nongovernmental organizations and academia. This report summarizes the results of the expert consultation.



Scope and purpose

The objectives of the consultation were to find consensus on the best ways to communicate potential risks related to air pollution to various audiences, including the public, health care professionals and patients, and to offer means of reducing exposure. While communication of the risks related to air pollution is a broad topic and covers a wide spectrum of stakeholders, the consultation was limited to those aspects of risk communication that are relevant for personal interventions and primarily for the public and for health care professionals who advise individuals and patients. The proposed elements of language and practical advice were directed to communication and feasible actions.

To formulate expert suggestions, the Consultation has :

- discussed communication about sources of air pollution and the related health impacts ;
- examined the evidence on use of the air pollution index (API) or the air quality index (AQI) and the limitations of current approaches to communicating air quality and health risks ;
- examined the literature to identify categories of risk and susceptible individuals and defined which individuals are most likely to benefit from interventions to reduce personal exposure to air pollution ;
- examined the evidence on the effectiveness for reducing exposure through avoiding places and times with high levels of air pollutants, and discussed practical advice ;
- examined the evidence for the discordance between the benefits of physical activity and the harms of air pollution, also in relation to population-specific characteristics, and discussed practical advice ;
- reviewed current use of air filters and evidence of their possible benefits and discussed practical advice ;
- reviewed current use of respirators and evidence of their possible benefits and discussed practical advice ;
- examined the various methods for communicating the risks of air pollution and discussed practical advice ;
- reviewed the equity of suggesting personal interventions ; and
- examined the role of medical societies and patient organizations in risk communication and clinical guidelines.

The outputs of the consultation were brief overviews of the published evidence for the above-mentioned topics, including identification of data gaps and research needs; for each topic, suggestions from experts on elements of guidance for specific, practical advice; and a road map of activities and reviews that could strengthen WHO's guidance on these topics in the near future.

The consultation comprised a number of sessions on specific questions. An important overarching issue was the wide variation in exposure to air pollution throughout the world, some areas having relatively low levels and others with constant, extremely high concentrations. The group also discussed the main sources of air pollution (combustion of fossil fuels, household fuels, transport, desert dust, waste, agriculture) and social and cultural resources. The wide variation precludes a "one solution fits all" approach; principles and advice must account for local variations and resources.

Although the meeting discussed emission control strategies, the main focus was on communication to population groups on personal interventions. They did not include all aspects of short- or long-term action plans, which involve different audiences and actors. The 3-day consultation included presentations of current evidence, methods and the experiences of the Member States in risk communication. Annex 1 contains extended abstracts of the scientific bases and relevant references in the scientific literature for the topics discussed, while Annex 2 lists the participants, reproduces the programme of the consultation.

The following is a summary of the original questions and the points and advice that emerged from the discussions.

"Although the meeting discussed emission control strategies, the main focus was on communication to population groups on personal interventions."



Session 1. Communication about sources of air pollution and related health impacts

The following questions were discussed :

What is the evidence for the main sources of air pollution and the related exposure in different regions of the world ?

Can source-specific exposure and health impacts be estimated ?

To what sources of air pollution should most effort be directed to protect population health ?

What communication approaches successfully reduce emissions from the main sources ?

- The most effective, efficient approach to protecting public health from the adverse effects of outdoor air pollution is to reduce ambient concentrations through emission controls in order to meet the WHO Air Quality Guidelines . Strategies for emission control should be guided by an evaluation of the contributions of different pollution sources in various locations. One of the most significant pollutants, particulate matter (PM) with an aerodynamic diameter $\leq 2.5 \mu\text{m}$ ($\text{PM}_{2.5}$), originates at any site from a wide range of sources that may be spread over several hundreds of kilometres around the site.
- Tools and data are available to estimate the source contributions in specific locations. Commonly, in densely populated areas, less than half (typically $< 40\%$ of the total concentrations of $\text{PM}_{2.5}$ in ambient air) originates from a nearby source, e.g. from within the same city. Thus, the conventional approach to managing urban air quality by addressing sources under the control of local authorities, may not significantly reduce ambient $\text{PM}_{2.5}$, and regional cooperation is necessary.
- While the main sources of population exposure differ from one location to another, measures are readily available to reduce emissions of $\text{PM}_{2.5}$ and precursor gases of secondary $\text{PM}_{2.5}$ from all anthropogenic sources. Population-weighted exposure, accounting for the spatial distribution of both pollution and the population, should be the indicator to guide interventions, and continuous outdoor air monitoring should be encouraged for regulatory purposes.
- Reliable source apportionment is lacking in many parts of the world, and programmes for air quality monitoring and emission inventories should be implemented rapidly to identify sources and their relative significance as determinants of population exposure.
- Emission control strategies have generally been applied in sectors such as industry, energy, transport and urban planning. Their implementation often faces political and social challenges, especially as effective approaches must include sectors that were not previously the focus of air quality management, such as solid fuel combustion in households for cooking and heating, waste management, livestock farming, manure management, fertilizer application and open burning of agricultural residues. They also include the lifestyles of the most privileged populations.

- Public acceptance of measures for pollution reduction requires clear understanding of their benefits, not only for a country or region but also for groups in society. Communications should reveal and highlight the important co-benefits for other policy and development priorities (e.g. climate) of many of the measures for lowering emissions of PM_{2.5} and its precursor gases.
- Successful communication to policy-makers and administrations should underline the importance of source apportionment, control of emission sources and population-weighted exposure in guidance for an intervention, the importance of both regional and local policies and the relevance of the co-benefits. The public should be informed about the complexity of the issue and of the relative importance of the sources.

ELEMENTS FOR CONSIDERATION IN THE WAY FORWARD

WHO

- A clear statement of the importance of identifying the sources of air pollution (with a call for source apportionment in air quality monitoring), both sectoral and spatial, which are context-specific.
- Avoidance of a “blame the other” strategy and emphasis on the importance of multi-sectoral, regionally coordinated approaches.
- Clear joint communication on the effects of air pollution.

Research / Academia

- In communicating about air pollution to the general public, avoidance of statements about “uncertainty” and “the need for more studies”, which may be misinterpreted. A strong argument for the fact that air pollution kills people and affects population health is critical for better, clearer communication.
- Source apportionment in epidemiological studies.
- Capacity and methods for source apportionment .

Medical community

- Clear joint communications on the effects of air pollution.
- Information on air pollution sources and impacts in medical and medical-related curricula.

"Successful communication to policy-makers and administrations should underline the importance of source apportionment, control of emission sources and population-weighted exposure in guidance for an intervention, the importance of both regional and local policies and the relevance of the co-benefits. The public should be informed about the complexity of the issue and of the relative importance of the sources. "



Session 2. Air pollution index or air quality index

In this session, the group reviewed the evidence on use of the air pollution index (API) or the air quality index (AQI) and the limitations of current approaches to communicating the status of the air and the health risks. The following questions were discussed:

What information about ambient air pollution is necessary to inform the population about short- and long-term health risks?

What health-based multi-pollutant indices are used in some countries and cities?

What are advantages and disadvantages of using AQI, API and health indices as compared with direct communication of air pollution levels?

- The provision of relevant information on air quality to the public should reduce the adverse impacts of outdoor air pollution by modifying individual behaviour to reduce exposure, while public authorities ensure timely reductions in emissions. Such interventions are used only sporadically; therefore, their effectiveness depends on whether individuals receive information that is applicable, reliable and understandable and whether relevant actions are feasible for them.
- The AQI or API is commonly used for reporting and communicating air quality or air pollution in cities and sometimes regions. AQI is also used as a basis for recommendations to reduce exposure to air pollution and to provide health advice to the general public and especially to vulnerable populations. This function is important during periods of high levels of air pollution.
- The intention of most indices of air pollution is for risk communication, although few were specifically designed for this purpose. Nearly all indices are ratios to predetermined thresholds based on regulatory or recommended levels. As these levels differ by country, AQI and API are not intrinsically useful for international comparisons and may be misleading.
- The expert group thus recommended that jurisdictions report the local AQI or API used, e.g. AQI-India or AQI-France, to prevent misleading cross-national comparisons by the public and the media.
- Even most indices derived from health research are based on long-term population-level risks, which are relatively well understood, and not on short-term risks, especially of vulnerable groups, such as infants and respiratory disease patients, which are less well characterized. Unfortunately, AQIs are often used for informing the public during short-term pollution episodes.
- To avoid the ambiguities inherent in AQI and API, the expert group recommended that all jurisdictions also report actual measured data in the units usually used for major pollutants (e.g. $\mu\text{g}/\text{m}^3$), including which pollutant is contributing the most, as people may be sensitive to different pollutants. This will facilitate comparisons among countries and cities and allow linkage to studies of health effects, which do not usually report indices, as they are so imprecise for health. The information should be readily available on local websites, with the local AQI.

- AQI and API are often reported every hour; however, the standards on which they are based are usually daily or annual means. Each local jurisdiction should state clearly on its website how hourly physical measurements are converted to hourly local AQIs, for example by assuming that the hourly level is maintained for a day or by fitting to a model of normal daily variations.
- There is no standard operating procedure for deriving a universal index that would be comparable among jurisdictions. The best solution is to indicate as specifically as possible how a local AQI has been tailored to local needs, which may differ according to local air quality, types of pollutants, geographical and climatic conditions and population characteristics.
- Health agencies and others responsible for information on air pollution should provide reliable information that is useful to individuals for modifying their behaviour on the basis of the physical levels at which they begin to experience adverse impacts, symptoms or discomfort, as is done, for example, in Canada.
- Although many health outcomes are associated with short-term increases in ambient air pollution, it is unclear which outcomes can be mitigated by disseminating information on pollution levels. The limited research available indicates that respiratory morbidity may be the most promising target for informed behaviour modification. Given the large number of people of all ages who are at risk of adverse health symptoms and their exacerbation, provision of an API that has no unintended consequences (i.e. discouraging outdoor physical activity) is justified, even if current AQIs have so far had a meaningful impact only on respiratory disease burden.

ELEMENTS FOR CONSIDERATION FOR THE WAY FORWARD

WHO

- Advocate for a health-based index.

Research / Academia

- Determine how efficient AQIs are in protecting health.
- Further validation.

Medical community

- Promote a “Know your numbers” approach.

" Health agencies and others responsible for information on air pollution should provide reliable information that is useful to individuals for modifying their behaviour on the basis of the physical levels at which they begin to experience adverse impacts, symptoms or discomfort (...)"



Session 3. Categories at risk

In this session, participants reviewed the evidence for categories of individuals at increased risk of adverse effects of air pollution and therefore more likely to benefit from personal interventions to reduce exposure. Evidence on factors such as age, socioeconomic status and pre-existing health conditions was considered. The questions discussed were:

What are the specific diseases, medical conditions or personal characteristics that increase the risk of adverse health effects associated with short- or long-term exposure to air pollution?

What is the relation between socioeconomic status and the risk associated with air pollution?

How can personal susceptibility to air pollution be prioritized in risk communication in view of its relative importance among other risk factors in susceptible groups?

- A distinction is often made between personal susceptibility (due to innate or acquired physical predisposition) and vulnerability (due to external factors that increase exposure to air pollutants or their dose). Here, we use the word “susceptibility” more broadly to indicate increased risk due to modification of associations between ambient air pollution and adverse health outcomes.
- Pre-existing conditions that may modify associations between exposure to air pollutants and the frequency and/or intensity of health outcomes include respiratory conditions such as asthma, chronic obstructive pulmonary disease (COPD), cystic fibrosis, interstitial lung disease (e.g. idiopathic pulmonary fibrosis), lung cancer and lung transplantation; cardiovascular conditions such as coronary artery disease (including prior myocardial infarction), heart failure and hypertension; endocrine or metabolic disorders such as diabetes, obesity and metabolic syndrome; life-stage factors such as pregnancy, childhood and older age; behaviour such as diet and physical activity; demographic factors such as sex, race, ethnicity and socioeconomic status; and genetic variation. Individuals who work outdoors are also at higher risk because of greater exposure.
- The strength of the evidence varies from robust associations between PM air pollution and exacerbation and increased mortality from COPD among older adults, to limited evidence that obesity modifies the associations between exposure to PM and cardiovascular mortality. Effect modification by socioeconomic status on air pollution-related health effects has been difficult to demonstrate, and the studies have mixed results. The lack of strong evidence for effect modification by complex factors such as socioeconomic status may reflect difficulty in measuring or obtaining individual data. Research should be conducted on susceptibility to other prevalent health conditions, such as some types of cancer and infectious diseases (e.g. tuberculosis, malaria, HIV infection, systemic inflammatory disease and neurological disease).
- The relative importance of susceptibility in the need for personal intervention should be estimated by comparing absolute changes in risk (attributable risk) with and without the modifying factor. Unintended risks of interventions, such as reducing the benefits of outdoor physical activity or adverse effects of respirators, should be carefully considered.

- When attributable risks can be estimated, values such as “number needed to treat” and “number needed to harm” may be useful for comparing and prioritizing the various courses of action that may be available for different populations. Rational prioritization of interventions also requires consideration of the feasibility and effectiveness of altering susceptibility factors or reducing the exposure of selected populations in the context of evidence, individual values and practitioner judgement.
- Studies of susceptibility and resulting inequity in exposure to and risk from air pollution have been conducted mainly in western Europe and North America, and the database should be extended. There is, however, sufficient evidence for children and adults with cardiorespiratory conditions to recommend that clinicians give them guidance on their potential health risks and their need for personal interventions to reduce exposure to outdoor air pollution. Prioritization of disease categories may include consideration of susceptibility to air pollution, the relative importance of air pollution and other risk factors and the feasibility and likelihood of successfully adopting personal interventions that effectively reduce exposure. Tools for quantitative risk stratification, such as the Framingham risk scores for cardiovascular disease, but that include consideration of susceptibility factors and levels of air pollution would be useful for guiding decisions about personal interventions.

ELEMENTS FOR CONSIDERATION FOR THE WAY FORWARD

WHO

- Clear definition of vulnerability and susceptibility.

Research / Academia

- More research on environmental inequalities and exposure in low- and middle-income countries.
- Relative susceptibility of different population groups.
- More research on other health conditions that may confer susceptibility.
- Tools for quantitative risk stratification to guide decisions on personal interventions.

Medical community

- Specific warnings for children and patients with cardiorespiratory conditions.
- Mention of air pollution as a risk factor in medical and allied medical field curricula for e.g. nurses, nurse practitioners, physician assistants and pharmacists and continuing education.
- Prioritization of interventions.
- Tools for quantitative risk stratification to guide decisions on personal interventions.

" Unintended risks of interventions,
such as reducing the benefits of
outdoor physical activity or adverse
effects of respirators, should
be carefully considered."



Session 4. Reducing exposure by avoiding polluted places

In this session, participants reviewed the evidence for reducing exposure by avoiding places and times with high levels of air pollution and discussed practical advice. The questions discussed were :

What is the main basis for recommendations such as “Stay indoors and/or reduce physical activity”?

Do these recommendations meet the needs of people at risk?

What variables influence exposure and the inhaled dose of air pollutants during transport according to the means of travel, proximity to sources (nearby vehicles), type and age of vehicles, operating mode (filtration and open or closed vents or windows) and level of physical activity (ventilation rate)?

How can communication material on avoiding “hot spots” be made effective?

- During major pollution episodes, reducing exposure is often recommended to reduce the risk of acute harm; however, the greatest health benefit is likely to be achieved with daily reductions in the risk of chronic harm. More studies should be conducted on which acute events (e.g. triggering a myocardial infarction) occur separately from chronic conditions.
- Staying indoors and/or reducing physical activity are classical public health precautions for reducing exposure when air pollution is elevated; however, these may not be possible or even advisable, according to individual circumstances. Modifying the location, timing and type of outdoor activity can, however, modify exposure to pollution, as the levels of air pollutants vary both spatially and temporally.
- For many people, exposure during commuting is responsible for a disproportionately large fraction of their total exposure to outdoor air pollution in relation to its relatively short duration. Many variables influence exposure and the inhaled dose of air pollutants during transport, including the mode of travel. Exposure in vehicles is often the highest; however, inhalation of polluted air is highest in proximity to vehicles, depending on their type and age, how vehicles are ventilated (filtration and open or closed vents or windows) and the level of physical activity and ventilation rate.
- As exposure in vehicles is usually higher than indoors or outdoors, people who spend a lot of time driving are vulnerable to greater health impacts, particularly in urban areas. Outdoor workers are also likely to have higher exposure than indoor office workers. Advice on reducing exposure should therefore be provided to people in vulnerable occupations.
- Recent improvements in air quality models and more accessible portable monitors allow measurement of exposure to air pollution in far greater spatial detail. Numerous studies have shown that exposure can be altered by changes in behaviour, such as walking down less-polluted streets, travelling at different times of day or changing the mode of transport.

- The magnitude of reduction of exposure depends on the pollutant. The primary traffic pollutants, such as black carbon and, to a lesser extent, NO₂, vary widely by route, whereas little can be done to avoid secondary PM. Public messaging about ozone is difficult, as the concentrations are usually lower along busy roads.
- Local authorities and public health organizations disseminate advice on avoiding air pollution at the same time as improving ambient air quality. The approach is, however, based almost entirely on evidence from studies in healthy populations, for whom it is assumed that a reduction in exposure will provide a health benefit. Evidence of a health impact, equity by socioeconomic status and the possibility of choice, particularly in vulnerable populations is, however, lacking.
- If avoidance is to be an effective public health intervention, its accessibility to all and its implications beyond exposure reduction must be considered. Like many public health interventions for individual behaviour change, they may have unintended consequences, such as reduced activity and social interaction and more energy use, which may negate or even reverse the intended benefits.
- The efficacy of staying indoors for avoiding air pollution depends on the level of indoor exposure. While many processes influence the concentrations of indoor particles, air exchange between indoor and outdoor environments – comprising infiltration efficiency, the fraction of the outdoor concentration that penetrates indoors and remains suspended and also natural and mechanical ventilation – is a key factor in controlling indoor air pollution. Many factors influence the infiltration of particles from outdoors to indoors and therefore particle concentrations, including ventilation habits according to season, climate and also housing.
- Often, the ability of individuals to reduce their own exposure to air pollution is linked to their wealth, i.e. location of residence, residential building quality, choice of cooking and heating fuel, natural ventilation or air conditioning, purchase of filtration equipment and flexibility in travel and transport choice. This creates socioeconomic vulnerability.
- During acute episodes of air pollution, emergency interventions may be applied by local authorities, including school closures and limitation of sports events, as part of risk management. The resulting reduction in exposure of populations and the health benefits of these interventions are not clear, however, and the potential benefits should be quantified.
- Potential exposure should be integrated into the planning of new facilities, particularly those designed for vulnerable populations (nurseries, schools, care facilities), including location, building design, ventilation methods, access routes and exercise areas. For example, considering variability of pollution around a building when the location of air intakes for ventilation systems in building plans should be encouraged.
- Research should be conducted to determine whether closing schools is an effective government response to exposure to air pollution episodes.

" Consideration of population exposure should be integrated into the planning phase of new facilities, particularly those designed for vulnerable populations (nurseries, schools, care facilities). This can include location, building design, ventilation methods, access routes, exercise areas."

ELEMENTS FOR CONSIDERATION FOR THE WAY FORWARD

WHO

- Provide guidance for transport, work and leisure microenvironments.
- Provide guidance on peaks of different pollutants, seasons and locations.
- Consider organizing a follow-up expert consultation on risk communication about acute events.

Research / Academia

- Investigate time–activity patterns.
- Provide more evidence on integration of indoor and outdoor air pollution, with separate assessments of the health effects of exposure to pollutants in ambient and indoor air.
- Conduct more research in low- and middle-income countries.
- Conduct an overall, comprehensive assessment of interventions during acute episodes (e.g. school closure), including population exposure, health assessments and social and economic implications.

Medical community

- Prevent consequences of exposure of groups at risk.



Session 5. Physical activity versus the harms of air pollution

In this session, participants reviewed the evidence for the benefits of physical activity (e.g. cycling to work, leisure or work with heavy exercise) as compared with the harm of possible extra exposure to air pollution and discussed practical advice. The questions discussed were :

What are the long-term benefits of physical activity?

Should activity be curtailed to reduce inhaled doses of air pollutants, and what are the possible net adverse effects on health?

What practical advice should be given to the general public, children and other at-risk groups, including outdoor workers?

- Regular physical activity reduces blood pressure, systemic inflammation and blood coagulation and enhances autonomic tone and endothelial function, all of which may reduce the risks of heart disease and stroke. Regular physical activity also reduces the risks of hypertension, coronary heart disease, stroke, diabetes, various types of cancer (including breast, lung and colon cancers), depression, falls and hip and vertebral fractures. Some of these health outcomes are also linked to air pollution. Physical activity improves muscular and cardiorespiratory fitness and bone and functional health. It is fundamental to energy balance and weight control.
- Physical activity increases breathing frequency and minute ventilation, influencing the uptake and deposit of air pollutants in the lungs and airways. Air pollutants have been associated with decreased lung and cardiovascular function, as shown in studies mostly of short-term exposure of healthy adults. The few studies that included patients with respiratory or cardiovascular disease indicate similar physiological effects and lack of improvement when physical activity was performed in highly polluted areas.
- Long-term studies on air pollution and physical activity suggest a small reduction in the protective effect of physical activity on mortality. These studies were also conducted mainly in adults in high-income countries.
- The limited evidence on the impact of air pollution on the short-term beneficial effects of physical activity indicate that these effects may be diminished, although not completely eliminated, in populations with diseases such as cardiovascular and respiratory conditions and also in healthy populations.
- At similar levels of air pollution, people with pre-existing conditions benefit less from physical activity than healthy individuals. The evidence also suggests that, in the presence of air pollution, patients on medication benefit more from physical activity than people without medication.

- In modelling studies of the health benefits of transport-related physical activity and the health risks of air pollution during commuting (mostly $PM_{2.5}$), the benefits outweighed the risks up to high levels of exposure, e.g. $100 \mu g/m^3$.
- Evidence on healthy adult populations in high-income countries supports continued promotion of regular physical activity, even if the air quality does not reach the levels recommended by WHO, as the health benefits of physical activity are maintained.
- Because of the lack of evidence on children, pregnant women, unhealthy populations and populations of low- and middle-income countries (where higher exposure to air pollution and different mixtures of pollutants may occur), no definite recommendation can be made. Furthermore, most of the evidence addresses $PM_{2.5}$ and long-term effects, and precise recommendations cannot be made for the short-term effects of multiple pollutants.
- The literature generally suggests that air pollution reduces people's engagement in physical activity. The global impact of air pollution on morbidity and mortality due to reduced physical activity should be estimated.
- Additional studies are needed to increase the evidence for low- and middle-income countries, populations other than healthy adults, pollutants other than $PM_{2.5}$, higher levels of $PM_{2.5}$ and unintended consequences of alerts about air pollution on overall physical activity.
- The following messages should be delivered
 - Each population (by age, sex and health status) should receive specific advice on modifying their physical activity according to their level of exposure to specific air pollutants.
 - In healthy adult populations, the long-term beneficial effects of regular physical activity in reducing mortality outweigh the adverse effects of air pollution at $< 100 \mu g/m^3 PM_{2.5}$.
 - With exposure to air pollution, the short-term beneficial effects of physical activity remain but are reduced.
 - In general, regular physical activity should be promoted even if the local air quality is not optimal.
 - The timing and location of physical activity should be adapted to reduce exposure to air pollution; the recommendation should include consideration of ozone and temperature levels, especially in warmer climates.
 - Patients who take medication should follow their physician's recommendations.
 - In accordance with the precautionary principle, populations at specific risk (due to their health status or occupation) should be advised about the best time and location for physical activity or for work (e.g. outdoors) and to reduce moderate-vigorous physical or work outdoors during air pollution episodes.

- Mass sports events such as football matches and marathons should be planned in locations and at times when the local authorities report or expect the lowest levels of air pollution.
- Local action to reduce daily background air pollution should be promoted in order to ensure physical activity under the best conditions for health.

ELEMENTS FOR CONSIDERATION FOR THE WAY FORWARD

WHO

- Ensure that air pollution is integrated into the new WHO global strategy on physical activity.

Research / Academia

- More research in low- and middle-income countries.
- More research on children, pregnant women and patients with various diseases.
- More research on different pollutants, places and times of day.
- Additional studies on the unintended consequences of alerting people about air pollution.
- Harmonization of the definition of physical activity and exposure assessment.
- More research on physical activity and indoor air pollution.

Medical community

- Carefully balanced messages for each group.
- Promote regular physical activity for healthy individuals, except during high air pollution episodes.
- Ensure adherence to treatment and medication.

" Evidence on healthy adult populations in high-income countries supports continued promotion of regular physical activity, even if the air quality does not reach the levels recommended by WHO, as the health benefits of physical activity are maintained."



Session 6. Air filters: evidence of possible benefits and practical advice

In this session, participants reviewed the evidence on the effectiveness of portable air filters and their possible benefits and provided practical advice. The questions discussed were :

What is the evidence that use of air filters reduces exposure to $PM_{2.5}$?

What is the evidence that use of air filters reduces the health effects of exposure to $PM_{2.5}$?

How should the evidence be reflected in communications, and what studies are needed?

- Indoor concentrations of air pollutants of outdoor origin range from < 10 % to close to 100 % of outdoor levels, depending on the pollutant, setting (home, office, school), rate of ventilation, removal (active filtration, deposition, reaction) and resuspension. Mechanically ventilated buildings equipped with heating, ventilation and air-conditioning systems sometimes have efficient air filters. Their efficiency in blocking pollutants from outdoors to indoors depends on the filter properties and the size of the filtered particles. It varies from 5–40 % for low-efficiency filters, such as dry media filters and panel and bag filters, to 60–90 % for electrostatic precipitators and to > 99 % for high-efficiency particulate air filters.
- Residential buildings do not often have heating, ventilation and air-conditioning systems but are naturally ventilated, typically by open windows. In naturally ventilated houses, the indoor concentrations of particles of outdoor origin might be similar to the outdoor concentrations when the ventilation rate is high but significantly lower if all windows are closed and the building envelope is tight. Particles can be removed actively from indoors by stand-alone air purifiers, the best of which are equipped with high-efficiency particulate air filters. The efficiency of an air purifier in reducing the concentration of particles indoors can range from low to very high and depends on the indoor volume, the setting (one or several interconnected rooms), the ventilation rate and whether the equipment is set to operate continuously or intermittently.
- A systematic review was conducted to assess publications on the efficacy of portable air filters in reducing indoor concentrations of air pollution and mitigation of health risks from exposure to air pollution in real-world situations. Twenty-three articles on indoor air filtration interventions were identified and reviewed systematically for both exposure reduction and to pool estimates of efficacy. The studies included randomized trials and observational studies (e.g. repeated measures panel study, cross-over study), with no limitation on the study population. The primary exposure measures were concentrations of indoor and outdoor $PM_{2.5}$. With the use of portable air purifiers in households, significant reductions in indoor $PM_{2.5}$ concentrations were observed, ranging from 40 % to 82 %. The studies were generally of efficacy and not of effectiveness in design, i.e. the devices were operated optimally for short periods and did not require long-term maintenance, such as changing filters.

- In the systematic review, the primary health outcomes assessed were cardiovascular and respiratory health indicators and biomarkers of systemic inflammation. Some improvements, including an overall reduction in systolic blood pressure, an increase in peak expiratory flow and some overall improvement in several cardiovascular and respiratory health indicators, were observed. The changes in health measurements were not, however, consistent across study populations in terms of the direction, magnitude and timing of response or the responses with which they were most strongly associated. The observed improvements in cardio-respiratory outcome measures were generally greater in healthy adults than among susceptible participants (e.g. older adults, patients with cardio-respiratory diseases).
- More high-quality clinical trials, rather than studies of biomarkers, with larger samples and longer follow-up in general and high-risk populations should be conducted to determine the efficacy of portable indoor air filters.
- Recommending the use of portable air filters from a public health point of view would be premature and should be tempered in view of the lack of information on their effectiveness in the real world despite their proven efficacy in experimental settings. As they are more efficacious when the space to be cleaned is isolated from outdoor air entry, if this sealing is overzealous, CO₂ concentrations may rise to problematic levels and indoor generated air pollutants. Furthermore, there are also possible environmental impacts, exposure to noise and cost of changing filters would be limiting factors. Also some electrostatic filters produce ozone. Use of portable air filters might be proposed for patients with e.g. COPD, heart failure or lung transplants, who should stay at home and be protected from exposure to air pollution; however, long-term studies on these populations are lacking.

ELEMENTS FOR CONSIDERATION FOR THE WAY FORWARD

WHO

- Clear definitions of indoor air filters and filtration capacity (by volume and pollutant).
- Organize a (web-based) expert consultation on air filtration technologies and their use to protect health.

Research / Academia

- Recommend an appropriate, standard study design to evaluate the usefulness of air filters.
- More long-term studies and randomized controlled trials.
- More studies on clinical outcomes with larger samples and longer follow-up in general and high-risk populations.

Medical community

- Consider prescribing air filtration for patients at risk and susceptible groups during air pollution episodes.

" Recommendations on use of portable air filters from a public health point of view would be premature and should be cautious in view of the lack of information on their effectiveness in the real world, as their use requires strict sealing of the environment and limitation of human activities.

Their possible environmental impact, exposure to noise and high cost of changing filters would be limiting factors."



Session 7. Technical aspects of respirators

What kinds of face masks are available on the market ?

What procedures should be used for fitting face masks ?

What are the recommendations and protocols for using these masks in different places ?

- Filtering facepiece respirators are the most common type of air-purifying particulate respirator recommended for use by the general public for protection from airborne particulates. Respirators are intended to provide respiratory protection for the wearer; however, a wide variety of respirators and face masks are sold that do not provide respiratory protection. Masks may cover all or part of the face but not provide respiratory protection. In this report, we use the term “respirator” and not “mask”. The general public should be cautious when purchasing or recommending products advertised online that have not been assessed for conformity by e.g. Chinese National Standards, European Conformity (CE), the Japanese Industrial Standard or the US National Institute for Occupational Safety and Health (NIOSH) standard.
- Respirators that are filtering 95% of airborne particle are called N95 (the most popular name) in the USA following the NIOSH Standard but are called KN95 in China following the Chinese National Standard, and FFP2 respirators in Europe following the European Conformity Standard. These terms (e.g. N95 etc), which refer to the particle removal efficiency of respirators, has not been patented or copyrighted and can be used by any maker of masks, even without proper testing. Packaging should be examined for certification or approval by a known national or international authority.
- The five factors that ensure that a respirator is effective are: putting it on correctly, ensuring that it fits properly, continuous use during exposure, replacement of the respirator or the filter when it becomes saturated and confirming that it has been approved to remove $\geq 95\%$ of particles. Because of facial anthropometric differences across the world, no one respirator can be guaranteed to fit all users. In general, for example, there appear to be no commercial respirators designed for children. *[as of February 2019]*
- Research should be undertaken on application of well-established occupational recommendations and protocols to respirator use by the public and who should be the responsible authority. When respirators are properly selected and used, they reduce exposure to inhalation hazards.
- Substantial research and operational experience support the health benefits of use of respirators in the workplace, but they are, however, generally healthy adult populations and do not represent the most vulnerable subgroups. Recommendations for use of respirators in the workplace could be adapted for use by the general public as interim guidance, in the absence of additional studies, with a special caution for people with respiratory disease since using a respirator can increase dead space and resistance. The International Society for Respiratory Protection has issued training modules that provide simple messaging tools for respiratory protection for the general public in areas of high air pollution.



Session 8. Respirators : efficacy in protection from air pollution

In this session, participants reviewed current use of respirators and the evidence of possible benefits and discussed practical advice. The questions discussed were :

What is the evidence that use of respirators reduces personal exposure to $PM_{2.5}$?

What is the evidence that use of respirators reduces the health effects of exposure to $PM_{2.5}$?

How should the evidence be reflected in communications, and what studies are necessary?

- A systematic review of studies on use of personal masks or respirators was conducted to assess their efficacy in reducing exposure to air pollution (i.e. PM) and thus mitigating health risks in real-world situations (i.e. not in a laboratory or occupational setting). Eleven articles were identified describing randomized trials and observational studies of cardiovascular and respiratory health indicators. While a respirator fit test may demonstrate the protection that users are expected to achieve by wearing a particular respirator, no measurement of personal exposure reduction during actual respirator use has been reported in studies of the general public.
- Some overall improvements in variations in heart rate (an indicator of cardiovascular outcomes) were observed during short-term interventions (usually a few hours to days) but on no other indicators of cardiovascular outcomes. The changes in health measurements were not consistent in different study populations in terms of direction, magnitude or timing of response. Most articles did not provide information on how well the respirators actually worked or fitted, which might have introduced exposure misclassification and biased the results. More high-quality studies with larger samples and longer follow-up in general and high-risk populations should be conducted to determine the efficacy of respirator use.
- More information is needed on the effectiveness of respirators in real conditions by both healthy and susceptible populations. In particular, more data should be provided on the effectiveness and tolerability of respirators. Given the limited evidence and evidence that a respirator with very high theoretical effectiveness often has limited or no effectiveness in real conditions of use by the general population, their use should not be recommended. Rather, the recommendation should be to continue and intensify action to reduce air pollutant emissions. Personal activities to reduce or limit daily exposure may be necessary. Use of respirators can be recommended in situations such as occupational exposure, or controlled, correct use may be necessary for short periods in situations such as wildfires, volcanic eruptions, desert dust episodes or clean-up after a disaster. Here again, a special caution for people with respiratory disease for which it may not be advisable to use a respirator due to increase dead space and resistance.
- Research should be conducted to design and test respirators that can be reliably used by children.

ELEMENTS FOR CONSIDERATION FOR THE WAY FORWARD

WHO

- Clear definitions of face mask and respirators.
- Position statement on the use of face masks for protection from air pollution.

Research / Academia

- Carefully designed studies with more power.
- More long-term studies on the health benefits of wearing respirators.
- More studies of high-risks population.
- More studies on the effectiveness and tolerability (including factors that improve or worsen adherence to use) of respirators.

Medical community

- Communication of a clear position of medical, public health and occupational health practitioners on use of masks for specific activities and by specific groups.

"The changes in health measurements were not consistent in different study populations in terms of direction, magnitude or timing of response. Most articles did not provide information on how well the respirators actually worked or fitted, which might have introduced exposure misclassification and biased the results."



Session 9. Communication and perceptions of air pollution

This session aimed at discussing the conflict between air pollution as a societal issue and as a problem of the individual. Perceptions about air pollution, actions and communication on different levels of society were discussed to address the following:

What is the perceived community or individual responsibility with regard to reducing the risks of air pollution?

How is the risk associated with air pollution perceived in different cultures and areas of the world?

How should risk communication be adapted to reflect the different ways people perceive their responsibility with regard to air pollution?

Communication of the risks related to air pollution often focuses on the objective consequences of exposure. A clear distinction should be made between raising awareness, communicating expert knowledge and suggesting or recommending interventions, and they should be integrated. Risk is often discussed in abstract statistical terms that cannot easily be communicated and do not motivate people to mitigate air pollution or its consequences. The main content, objectives and strategies that could overcome this problem are listed below.

- Use of “big numbers” and focusing on the number of victims of air pollution can numb people psychologically and undermine their motivation to change their behaviour. Descriptions of individuals who have experienced the effects of air pollution and their personal stories are more effective. Research on risk communication shows that describing individual victims of mass risks makes people more prone to change their behaviour.
- People are often environmental hyper-optimists and neglect local environmental risks. Therefore, they should be made aware of local environmental hazards. Focusing on the local consequences of environmental pollution makes it easier for people to understand the reality of environmental threats.
- People tend to neglect environmental hazards that cannot be directly perceived or sensed. Therefore, the direct sensory characteristics of air pollution should be emphasized.
- Communicate local, personal, feasible actions that can be undertaken by individuals to mitigate air pollution. People are motivated by a sense of self-efficacy and neglect hazards that they cannot reduce.
- One size does not fit all. Communication strategies should be tailored to the geography, economic conditions, culture, expectations and norms in each setting. Messages should be specific for the general public and for sensitive individuals. Help in adapting messages can be provided by social structures such as schools and associations such as those of mothers, cities, patients or cyclists.

- Communication must have a clear goal, objectives and target audience for the type of information and messages to be conveyed, with suitable vehicles for delivery.
- Trust in expert knowledge should be built by issuing publicly accessible facts, evidence and peer-reviewed data and results.
- To communicate the risk associated with air pollution, information should be available on how people perceive risk. The risk should be made more visible and detectable locally. People are motivated to control their environment and their fate, and this motivation should be strengthened.
- The most efficient way to motivate people to change their health behaviour is to send messages that evoke a strong negative emotion and then propose a solution. Evoking negative emotions such as fear and disgust is persuasive only when accompanied by possible solutions. It is also beneficial to emphasize the co-benefits of mitigating air pollution. A positive image of the effects of policies and interventions, such as pictures of healthy cities with pedestrian and cycling environments that have many benefits (physical activity, children playing in streets, enjoyable green spaces and increased resilience to climate change) is much easier to “sell” than air pollution reductions.

Creative communication strategies for each target audience require communications strategists and the necessary financial resources. Financial assistance for communication that is accessible to local authorities should be promoted.

ELEMENTS FOR CONSIDERATION FOR THE WAY FORWARD

WHO

- Technical communication with new vectors.
- Avoid big numbers and mortality rates, and use diseases and morbidity rates.

Research / Academia

- Experts should communicate more.
- Emphasize the benefits of exposure reduction.

Medical community

- Engage in localized, personalized, feasible actions that may be undertaken by individuals and patients.

"To communicate the risk associated with air pollution, information should be available on how people perceive risk. The risk should be made more visible and detectable locally. People are motivated to control their environment and their fate, and this motivation should be strengthened."



Session 10. Equity issues

The aim of this session was to discuss considerations of equity when recommending personal interventions. The questions discussed were :

How equitable is it to leave it to individuals to decide on personal interventions ?

What are the costs associated with personal interventions to reduce individual exposure and health risks from air pollution ?

How should the costs be distributed ?

- Personal interventions to reduce exposure to air pollution, such as avoiding places with high levels of air pollution, reducing physical activity when there are high levels of air pollution or using face masks or air filters, raise issues of equity, as the need for and access to appropriate interventions might be unequally distributed by individual, society or country.
- If the responsibility for interventions is left to individuals, each must define his or her needs. Such decisions depend on people's cultural and socioeconomic background, the information available to them to make an informed decision and their perceived risk of the harm of air pollution as compared with competing health risks. Provision of information that is readily accessible by all individuals, independent of their cultural and socioeconomic background, is therefore essential.
- A decision on need will also influence individuals' willingness to pay for personal interventions. Such decisions strongly depend on their perceived risk of harm in relation to their means and ability to pay for personal interventions such as face masks and air filters and also opportunity costs such as loss of wages and education or restricted activity.
- Authorities can ease the responsibility of individuals for reducing their exposure by providing subsidies to those in greatest need, in terms of both exposure to air pollution and limited resources, to implement the recommended interventions. The cost of such schemes, for example raised through taxes, could be shared among the emitters of air pollutants and the consumers of the goods that contribute to pollution.
- Uptake of any recommendations will depend on individuals' perceived risk, their knowledge about the harmful effects of exposure to air pollution, the accessibility of information and interventions, their affordability and the control that individuals have over their activities and exposure patterns.

ELEMENTS FOR CONSIDERATION FOR THE WAY FORWARD

WHO

- Equity should be ensured when recommending personal interventions.

Research / Academia

- Studies should be conducted on the equity of particular personal interventions.
- Experts should engage with various communities and socioeconomic groups in different parts of the world to better understand the issues of individual acceptance of personal interventions.

Medical community

- Engage in localized, personalized, feasible actions that may be undertaken by individuals and patients.

" Personal interventions to reduce exposure to air pollution (...) raise issues of equity, as the need for and access to appropriate interventions might be unequally distributed by individual, society or country "



Session 11. Clinical practice guidelines, role of medical societies and patient organizations

The aim of this session was to discuss the development of clinical practice guidelines and the roles of medical societies and patients' organizations. The questions addressed were :

Which patients' groups might require clinical guidelines ?

How should the guidelines be elaborated and distributed ?

What is the role of medical societies and patients' organizations ?

- Many populations around the world are affected by poor air quality, but there are few recommendations on handling the situation, especially for vulnerable subgroups. Moreover, conflicting messages sent through the media and even by medical professionals exacerbate the lack of knowledge, confusion and misconceptions about the role of air pollution in public health and individual well-being. Communication with the general public must be improved, and the health impacts of air pollution should be included in the curricula, residency training and continuing education of medical and allied medical students (e.g. nurses, nurse practitioners, physician assistants and pharmacists) and in clinical practice guidelines for medical professionals in their daily communication with patients.
- The biological pathways through which air pollution acts include pulmonary and systemic inflammation, enhanced coagulation and vasoconstriction and increased sympathetic tone in the autonomous nervous system. Susceptible patient groups include those with chronic respiratory or cardiovascular disease. People are more vulnerable to external disturbance if their tissues and organs are still developing or if their detoxification capacity is impaired, as for unborn and young children, older populations and people also exposed to other disadvantageous situations, such as low socioeconomic status and various sources of exposure.
- Clinical guidelines should be general and be designed to reduce the exposure of as many people as possible. They should include advice on reducing both short-term and long-term exposure. Patients with cardio-respiratory disease, who might benefit most from avoiding high short-term exposure, might require more specific advice on behavioural change.
- Medical societies can contribute to the development of guidelines because of their unique position in society. First, they have the scientific knowledge and expertise necessary to develop evidence-based guidelines, have networks for their development, distribution and implementation, enjoy general social and professional respect and have the appropriate authority to present new guidelines. Secondly, medical societies and patient organizations can reach and educate the users of guidelines (health care professionals) and patients and the general population. Networks of medical societies and their journals, websites and conferences ensure distribution of guidelines and the training of medical personnel in their use, and promotion through medical curricula, textbooks, professional training programmes and scientific meetings. Thirdly, medical societies and patient organizations can advocate

for patients' health in a healthy environment at all political and regulatory levels. Because of their respected role in society, they can effectively raise the topic of air pollution-related health effects at local, national and international levels. Fourthly, they must be aware of and prevent unintended effects, such as greater environmental injustice that might arise due to uneven access to personalized approaches to prevention.

- Clinical practice guidelines might have to be region-specific, as baseline and peak values and major sources of pollution differ widely globally. This will affect the options for avoidance and the usefulness of restrictions on activity in certain places at certain times. Guidelines should also be considered for increasing the expertise of affected populations, who have experience in individual reactions to exposure, through information systems such as the "Know your Number" air quality health index promoted in Canada. Guidelines should also be considered to differentiate between indoor and outdoor exposure. Several interventions and recommendations have been made by political and administrative authorities, often based on little evidence. The financial burden and possible reimbursement of protective equipment should be considered, and recommended use should be included in reimbursement policies, as for other medical devices, to prevent inequity.
- Groups developing guidelines should be aware of the difference between communication and awareness measures, such as personal monitors, and actual prevention or treatment.
- Medical societies and patients' organizations should continue and increase advocacy for clean air, beyond clinical guidelines, which may be transient emergency interventions in situations in which optimal air quality has not been achieved. Medical societies should be alert to unintended effects, such as environmental injustice, physiological effects of personal protective equipment such as increased breathing, frightening the public and discouraging physical activity. Medical societies must ensure in guideline development and advocacy that the responsibility for a healthy environment is retained at societal level and must prevent every attempt to reverse the responsibility and put it in the hands of individuals.

" Medical societies must ensure in guideline development and advocacy that the responsibility for a healthy environment is retained at societal level and must prevent every attempt to reverse the responsibility and put it in the hands of individuals. "

ELEMENTS FOR CONSIDERATION FOR THE WAY FORWARD

WHO

- Develop training material for health professionals.
- Develop simple fact sheets on health risks with the medical community.
- Develop simple checklists to map exposure with academia and the medical community.
- Map potential target societies and existing tools.

Research / Academia

- Develop simple checklists to map exposure with WHO and the medical community.

Medical community

- Ensure that the risks of air pollution are known and understood by clinicians.
- Develop simple fact sheets on health risks with WHO.
- Develop simple checklists to map exposure with academia and WHO.
- Medical societies should advocate at all levels of policy development and regulation and ensure that the responsibility for clean air is that of society.

Concluding remarks

This report summarizes the wide-ranging discussions and syntheses of evidence in each session. The objective was not to provide clear or region-specific recommendations, which would not have been possible, but to summarize the current global situation, reflect priorities for further action and plan the way forward regionally.

The priority is to lower ambient air pollution concentrations through emission control of the sources and public policies – the only way to ensure a healthy, sustainable, equitable environment for all. Medical, public health and associated sectors should therefore ensure, through education, guidelines and advocacy, that the responsibility for providing a healthy environment is that of society, and any attempt to put the responsibility onto individuals must be prevented. Individuals can play a role by staying informed or requesting information on air quality levels and the associated health effects and can pressure local and national governments and other decision-makers to take measures to mitigate the problem. Individuals can also contribute by lowering their own emissions whenever possible.

The most important step in guiding interventions is to identify the source of air pollution. Identification of sectors that are not addressed in traditional air quality management, such as household fuel use or agricultural practices, requires, first, advocacy for the development of cleaner alternatives that are available locally at affordable prices. Recent and ongoing wildfire emissions in various parts of the world (Australia, South and North America and Asia) are a growing source of PM. Management of land and fuel in forests is also not part of traditional air quality management. It is of great concern that natural sources such as wildfire emissions are becoming more dominant in some of the countries in which substantive progress has been made to reduce anthropogenic sources.

Although health is benefited by avoiding exposure, this may have unintended consequences. Maintaining regular physical activity is crucial for good health. Portable air filters can reduce indoor air pollutant concentrations, but it would be premature to recommend their wide use from a public health point of view for reasons that include the environment, finance and equity. Respirators and their use in controlled occupational settings have been well described; however, their use is often of limited or no effectiveness against air pollution in real conditions of use by the general population. Guidance and research are required to understand the application of well-established occupational recommendations and protocols to public respirator use and who should be responsible. The use of respirators can be recommended in some instances, such as in occupational settings, for specific sub-populations (e.g. patients) or controlled, correct use for a short time in situations such as wildfires, volcanic eruptions, desert dust episodes or clean-up after disasters, but some susceptible groups (e.g. those with respiratory conditions) might require extra recommendations

Clearly, additional evidence is required, and, while this report was being prepared, national agencies and scientists have initiated important activities in that direction. In the USA, the Environmental Protection Agency, the National Institute of Environmental Health Sciences, the National Heart Lung and Blood Institute and the Centres for Disease Control and Prevention recently co-sponsored workshop to discuss the rationale and timeliness of a controlled randomized clinical trial to test the efficacy of an intervention to reduce exposure to air pollution and to improve clinical outcomes. A short report of the workshop is available at : <https://www.nhlbi.nih.gov/events/2019/reducing-cardiopulmonary-impact-particulate-matter-air-pollution-high-risk-populations/>.

In the context of natural events or so-called air pollution disasters, the United States Environmental Protection Agency has revised its Wildfire Smoke Guide for Public Health Officials, which includes specific guidance for personal protection. On the research side, McDonald et al (International Journal of Disaster Risk Reduction 43 (2020) 101376) discussed the need for a framework integrating ethical aspects for the use of facemasks for community protection.

Annex I – Abstracts

1. Communication about sources of air pollution and related health impact

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KEY MESSAGES

- There are tools and data for assessing the impacts of different emission sources on population exposure. Although they are not perfect, they can provide important directions for effective policy interventions.
- Measures to reduce the precursor emissions from all relevant sources are readily available but should be tailored to the specific conditions. Effective action to reduce exposure requires regionally coordinated approaches.

Because of their small size and gravity, $PM_{2.5}$ particles remain in the atmosphere for up to a week before they are deposited, and they are transported by wind during this time over several hundreds of kilometres (Seinfeld & Pandis, 2012). Thus, $PM_{2.5}$ at a given site originates from a wide range, of sometimes distant, sources.

Tools and data are available to estimate the source contributions of specific locations (Karagulian et al., 2015). Typically, only a small fraction (10–40 % of the total concentration) originates from nearby sources, e.g. from within the same city. Thus, the conventional approach to managing urban air quality, and especially urban emission sources that are under the control of local authorities, is ineffective in significantly reducing ambient $PM_{2.5}$. Regional cooperation is indispensable (Amann et al., 2017).

While the key sources of population exposure differ by location, measures to reduce the precursor emissions of $PM_{2.5}$ are readily available for all anthropogenic sources. Their use, however, often faces political and social challenges, because effective approaches must include sectors that were not previously the focus of air quality management. These include solid fuel combustion in households for cooking and heating, husbandry, manure management, fertilizer application and open burning of agricultural residues (United Nations Environment Programme, 2019).

Public acceptance of counter-measures must be based on a clear understanding of their benefits, not only for the country but also for different groups in society. It will be critical to highlight the important co-benefits for other policy and development priorities associated with many of the measures that lower precursor emissions of $PM_{2.5}$.

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2. Risk communication with air pollution indices

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KEY MESSAGES

- Regardless of how an API is designed, the resulting index values must be associated with the health risks of the local population in order to function most effectively in risk communication.
- Indices that are predictive of population-level health risks may not have to be modified, even if they were not constructed with health-based approaches; however, if indices do not reflect local health risks, alternative approaches should be considered to inform people on which days they should modify their behaviour according to their sensitivity to outdoor air pollution.
- Respiratory morbidity is the health outcome that is most likely to benefit from individual behaviour modification based on a well-designed, effectively communicated AQI. Health-based indices based on mortality risks could perhaps be adapted by calibrating them to best represent respiratory morbidity.

Air quality indices such as the AQI and many similar variations are commonly used as an easy-to-understand format for reporting daily concentrations of outdoor air pollution to the public. The indices generally represent broad levels of pollution in outdoor air that are used to alert the public when the concentrations of pollutants are above regulatory limits or other recommended guidelines. While the original intent of these indices was to coordinate the reduction of emissions with a uniform index and to alert the general public to extreme pollution episodes, they are being used increasingly for communicating risk to the general public and especially those who are most vulnerable.

While reducing ambient concentrations of outdoor air pollution is the best strategy for mitigating health hazards, the provision of relevant information on air quality to the public could reduce the adverse impacts of outdoor air pollution by changing individual behaviour to reduce personal exposure. Individual behaviour modifications may include modifying the time, location or duration of outdoor activity; use of personal protective equipment; or modified use of medication. As such interventions are used only sporadically, their effectiveness depends on whether the information provided is applicable, reliable and understandable and if relevant actions are feasible for the affected population.

Studies of the use of AQIs to inform individual decisions on behaviour modification indicate that such action is still relatively infrequent, even when awareness of the local index is high (Wen et al., 2009). Furthermore, personal observations may be just as likely to drive behaviour modification as information on the local AQI (Borbet et al., 2018). There is thus probably room for improvement in reporting risks associated with air quality to the general public. A basic measure of the effectiveness of an AQI for communicating risk is that it is more effective in informing decisions on health-protection behaviour modification than personal observations.

Although many of the air pollution indices used around the world are intended for risk communication, few were designed specifically for this purpose. Most of those in current use are based on the general structure of the AQI and predetermined thresholds, with index values based on the pollutant present at the highest concentration relative to regulatory or recommended levels (Monteiro et al., 2017). The limitations of this approach for risk communication are well known. They include failure to account for the aggregated impacts of multiple pollutants (Perimutt & Cromar, 2019a), ineffective communication of health risks at concentrations below regulatory standards (Perimutt et al., 2017) and failure to include the epidemiology of the pollutants in the index. Because of these and other potential limitations, some countries use supplementary approaches to better communicate health risks, even when outdoor concentrations are below regulatory limits (Raun et al., 2019). AQI values can be modified for areas with relatively high pollution by adjusting them to the median concentrations in the area, thereby accounting for the typical exposure experience by individuals (Stergiopoulou et al., 2018).

The best-known modification to the traditional AQI is the “air quality health index” used in Canada, which has been copied by a number of cities (Stieb et al., 2008; Wong et al., 2013). The goal of these and similar approaches is to account for the health impacts of the many pollutants that occur in the ambient environment in calculating index values (Cairncross et al., 2007). Other quantitative approaches have been proposed, in which the health impacts of several pollutants are aggregated or are based on health outcomes (Kanchan et al., 2015). Most of these approaches have not been used in risk communication strategies.

Regardless of how an API is designed, the resulting index values must be associated with local, population-level health risks if it is to be used for risk communication. Validation of API values against local data on health, and not simply satisfying mathematical criteria as part of the design and construction of an API, is a critical step in providing information relevant to health. There has been insufficient work to validate the effectiveness of AQIs against local data, even in areas in which the most resources are committed to monitoring and communicating air quality. It is strongly recommended that local jurisdictions first assess whether the API used in their locality reflects population-level health risks. Once this is confirmed, the index can be undertaken, publicized and promoted. Once validation has been completed, index values generated from regulatory indices such as the AQI have been shown to be significantly associated with population-level health risks, particularly when the index values are dominated by a single pollutant (Thach et al., 2018). This is not, however, always the case, as regulatory indices are often less effective than health-based indices in reflecting population health risks in locations and during seasons in which there are high concentrations of many pollutants (Chen et al., 2013; Perimutt & Cromar, 2019b). Given the cost and difficulty of retraining the public in understanding a new API, existing index values should be evaluated to determine how well they represent public health risks in different seasons before any changes are made to the method of constructing an API.

Even though many health outcomes occur during short-term increases in ambient air pollution, it is unclear which outcomes could be mitigated by disseminating information on levels of outdoor pollution.

While there is limited research on the topic, respiratory morbidity is probably the most promising target for mitigation by informed decisions on behaviour modification. Adapting AQIs by weighting individual pollutants according mainly to respiratory morbidity will not mean that the index is not applicable to other types of health outcome; it could be used to directly target the large numbers of people of all ages who are at risk of adverse respiratory symptoms and their exacerbation.

Development of AQIs that are predictive of population health risks is just the first step in effective risk communication. Comparable work is required to design a communication strategy that can be readily accessed by the public and is understood. Additional information on specific types of behaviour modification might be helpful in communication on air quality (D'Antoni et al., 2019). Fixed messages based on predetermined pollution thresholds are difficult to justify, given the heterogeneity of individual responses to the same level of air pollution. Health agencies and others responsible for APIs should provide reliable information, so that individuals can tailor their behaviour modification according to the levels at which they start to experience adverse impacts, symptoms or discomfort. They should resist any demand by the general public to be told exactly what actions they should take for specific levels of outdoor air pollution.

The most important function of an API is reliable communication of day-to-day changes in the health risks of outdoor air pollution in a given location, rather than providing information to compare risks among geographical locations. Local index values are generated with widely different weighting factors and cut-off points, making them unsuitable for comparing local API values with global ones. As such comparisons are often made, however, it is recommended that actual air pollution concentrations and not just index values be reported. Alternatively, it may be advisable to state explicitly which index is being used (e.g. AQI-India, AQI-China, air quality health index-Canada) in order to indicate that direct comparison of index values is not possible without first converting pollution values to a common index.

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3. Evidence for assessing which individuals are most likely to benefit from communications and interventions to reduce exposure

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KEY MESSAGES

- Susceptibility to air pollution is biologically plausible, and there is robust evidence of effect modification by several combinations of air pollutants on individual factors and conditions.
- Personal communication and other interventions for people who may be at higher risk should be based on comparisons of individual attributable risks and the benefits of all opportunities to intervene.
- Research should be conducted to better characterize individual susceptibility to improve decisions about personal interventions, with the inclusion of prevalent but little-studied conditions such as some types of cancers and infectious diseases, and broader geographical, racial, ethnic and cultural representation.

A distinction is often made between susceptibility (due to innate or acquired physical predisposition) and vulnerability (due to external factors that increase exposure or dose) (World Health Organization, 2018). In this text, “susceptibility” is used broadly to indicate factors that modify associations between air pollutants and health outcomes to increase risk. With this definition, conditions that increase susceptibility should be evaluated by the strength of their effect modification, such as by evaluating relative effect modification or interaction terms in multiple linear regression analysis. Exceptions are cases in which the adverse outcome is specific to the modifying factor or condition, such as exacerbation of asthma in people with that condition or adverse pregnancy outcomes in pregnant women. In these cases, demonstration of increased risk with exposure to air pollution is sufficient to establish susceptibility.

Conditions that may modify associations between exposure to air pollutants and the frequency and/or intensity of health outcomes include respiratory conditions such as asthma, COPD, cystic fibrosis, idiopathic pulmonary fibrosis and lung transplantation; cardiovascular conditions such as coronary artery disease, prior myocardial infarction, congestive heart failure and hypertension; endocrine and metabolic disorders such as diabetes, obesity and metabolic syndrome; life-stage factors such as pregnancy, childhood and older age; behaviour such as diet and physical activity; demographic factors such as sex, race, ethnicity and socioeconomic status; and genetic and epigenetic variations.

Because of the limited length and general nature of this introduction to individual susceptibility to air pollution, only selected examples of air pollutant outcome modifiers are presented, with high-quality evidence in the form of systematic reviews and meta-analyses. The strength of evidence varies from robust associations between PM air pollution and COPD exacerbation and increased mortality among older than younger adults, to limited evidence that obesity modifies cardiovascular mortality outcomes associated with PM.

Foetuses, children and older adults, representing both ends of the continuum of life, are generally acknowledged to be at greater risk from air pollution than young adults.

The theoretical basis for such susceptibility includes differences in physiology, development, frequency of comorbid conditions, exposure to air pollution and adaptive behavioural responses. For example, asthma usually develops early in life, and a meta-analysis showed that exposure to black carbon was associated with an increased risk of asthma incidence among children (Khreis, 2017). An increased risk of pregnancy-induced hypertensive disorders, which can harm both mother and infant, has been associated with increased exposure to $PM_{2.5}$ and NO_2 (Pedersen, 2014). A large meta-analysis by Bell et al. (2013) showed that the risk of death associated with an incremental increase in PM_{10} was about twice as high in older than younger adults.

Increased risks of exacerbation, greater disease severity and total and cause-specific mortality have been reported among people with asthma, COPD, ischaemic heart disease and other conditions. For example, in a meta-analysis, Li et al. (2016a) found small but consistent increases in the relative risk of COPD exacerbation with short-term increases in ambient $PM_{2.5}$, NO_2 and ozone. Li et al. (2016b) found increased COPD mortality with short-term exposure to $PM_{2.5}$. Patients who have experienced a prior myocardial infarct have been reported to be at greater risk of mortality associated with elevated PM_{10} and $PM_{2.5}$ than other adults (e.g. Berglind et al., 2009).

Patients with prevalent endocrine and metabolic disorders such as diabetes, overweight and obesity have been studied for potential modification of the effects of air pollution on mortality and other outcomes. For example, Allesandrini et al. (2016) reported increased mortality associated with $PM_{2.5}$ in an analysis of 228 619 deaths among older adults with diabetes in 12 Italian cities. In a systematic review of effect modification by obesity, all of three large cohort studies reported stronger associations between $PM_{2.5}$ and cardiovascular mortality, and 11 of 14 panel studies reported stronger associations between $PM_{2.5}$ and acute changes in physiological variables among people in obese categories (Weichenthal et al., 2014).

People of lower socioeconomic status and /or social position are at higher risk of overall mortality, have higher incidence and mortality from many diseases and are often more highly exposed to air pollution, with fewer resources to cope with environmental stressors. For these and other reasons, modification of the health effects of air pollution by socioeconomic status is plausible. In a recent review, Fuller et al. (2017) identified 30 articles on modification of associations between short- and long-term exposure to air pollution and cardiovascular disease end-points. Eighteen articles identified at least one interaction between an air pollutant and a material resource indicator on a disease end-point, but 11 did not. The current lack of strong empirical evidence for effect modification by complex factors such as socioeconomic status may reflect difficulties in measuring the factor or obtaining individual data rather than the true absence of an important effect.

The relative importance of susceptibility in communicating the need for personal intervention should be based on a comparison of absolute changes in risk (attributable risk) estimated to occur with and without the modifying factor. Unintended risks of interventions, such as efforts to avoid air pollution that reduce the benefits of outdoor physical activity or adverse effects of use of respirators, should also be considered.

People who are more susceptible to air pollution may also be more susceptible to the adverse effects of some interventions, such as the increased psychological and physiological stress and increased cardiorespiratory demands of wearing a respirator. When attributable risks can be estimated, “number needed to treat” and “number needed to harm” can be useful statistical concepts for comparing and prioritizing the different courses of action that may be available to different categories of individuals. Rational prioritization of interventions also requires consideration of the feasibility and effectiveness of efforts to alter susceptibility factors or to reduce exposure in selected populations in the context of evidence, individual values and practitioner judgement.

Research should be conducted on susceptibility to other prevalent health conditions, such as some types of cancer and infectious diseases (e.g. tuberculosis, malaria, HIV infection). Studies of susceptibility and resulting inequity in exposure and risk from air pollution have been conducted mainly in western Europe and North America, and the database should be extended geographically and to other racial, ethnic and cultural groups. There is nevertheless sufficient evidence for children and people with cardiorespiratory conditions to recommend that clinicians provide guidance to these groups about the potential health risks and the need for personal interventions to reduce exposure to outdoor air pollution. Prioritization of disease categories may include consideration of susceptibility to air pollution, the relative importance of air pollution and of other risk factors and the likelihood of successful adoption of personal interventions that effectively reduce exposure. Tools for quantitative risk stratification, similar to the Framingham risk scores for cardiovascular disease, but which include consideration of susceptibility factors and levels of air pollution would be useful for guiding decisions about personal interventions for air pollution.

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4. Avoiding air pollution – a convenient distraction or a valid means of public health protection ?

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KEY MESSAGES

- Exposure reduction through behavioural change is often considered to be an alternative form of health protection to improving ambient air quality.
- Reducing exposure is often emphasized during major pollution episodes to reduce risks of acute harm; however, the greatest reduction in the risk of chronic harm is probably through daily reductions.
- Exposure reduction must be accessible to all, particularly vulnerable sections of the population, and the unintended consequences must be considered carefully.

Recent improvements in the resolution of air quality models, coupled with more accessible portable monitors, have allowed examination of exposure to air pollution in far greater spatial detail. Studies have shown that the exposure of individuals can be altered by changes in behaviour, such as walking on less-polluted streets, travelling at different times of day (Milà et al., 2018) or switching mode of transport (de Nazelle et al., 2017).

The magnitude of the reduction in exposure depends on the pollutant and the pollution climate. Primary traffic-related pollutants, such as black carbon, may vary by large increments among routes (Dons et al., 2013), whereas little can be done to avoid secondary pollutants. Often, the most visible acute pollution episodes, of the type experienced in Asian megacities, are dominated by regional secondary particulates, which cover large areas and are therefore difficult to “avoid”. Ozone presents a particular challenge in public messaging, as the concentrations are usually lower along busy roads.

Some civic authorities and public health organizations are advising the avoidance of air pollution as an additional means of health protection with the improvement of ambient air quality. With a few exceptions (Sinharay et al., 2018), however, this seemingly straightforward approach is based on evidence of studies in healthy populations. The assumption is that a reduction in exposure will result in a health benefit; however, there are significant gaps in the evidence of a health impact, equity among socioeconomic groups and the ability to choose, particularly in vulnerable populations. Similarly, the wider health benefits of emergency interventions introduced during acute air pollution episodes, including school closure and limitation of sport events, are not clear.

If avoidance is to be used as an effective public health intervention, its implications beyond exposure reduction must be considered. Like many public health interventions that involve individual behaviour, there is risk of unintended consequences, which may negate or even reverse the intended benefits. Examples include discouraging children from playing outside, reduced social interaction due to wearing masks and reluctance to leave home and increased energy use (e.g. for air purifiers, mechanical rather than natural ventilation).

Several factors affect the applicability, effectiveness and accessibility of interventions to reduce population exposure. Staying indoors and/or reducing physical activity are mainstays of current public health precautionary advice when the air pollution level is elevated; however, in many cases, only a small proportion of an affected population can choose where and when they travel. Preventive measures that are integrated into a daily routine are likely to be accessible to more people and have greater health benefits over time.

The effectiveness of staying indoors to avoid air pollution depends on the level of indoor exposure. Many factors influence infiltration of pollutants from outdoors to indoors, including ventilation habits, climate and building design (Allen et al., 2012). Furthermore, there are many indoor sources of pollutants, such as cooking, heating, smoking, cleaning and incense burning. Building designs that limit infiltration of outdoor air pollution indoors often limit ventilation of indoor air pollution outdoors. In households with strong sources of indoor pollutants, advice to stay at home may unintentionally lead to higher exposure.

Evidence mainly from high-income settings indicates that exposure during commuting is responsible for a disproportionately large fraction of total exposure to outdoor air pollution, given its relatively short duration. Many variables influence exposure and the inhaled dose of air pollutants during transport, including mode of travel, type and age of vehicles, vehicle ventilation mode (filtration and open or closed vents or windows), level of physical activity (ventilation rate) of individuals and proximity to sources (nearby vehicles). In urban settings, the perception that vehicles protect people from transport-related air pollution is often unfounded. Several studies have demonstrated that urban exposure to a range of pollutants in a vehicle is often the highest, followed by cycling and walking (Karanasiou et al., 2014).

Some sections of a population are more vulnerable than others to exposure to air pollution. This may reflect their age or health status (e.g. young children, people with chronic respiratory or cardiovascular disease, older people), ability to choose (often linked to income) or occupation. As in-vehicle exposure is typically higher than indoor or ambient exposure, people in driving occupations are potentially vulnerable to greater health impacts, particularly in urban areas. Outdoor workers are also likely to experience higher exposure than indoor office workers.

Often, people's ability to reduce their exposure is linked to their wealth. Examples include the quality of residential buildings, choice of cooking and heating fuel, natural ventilation rather than air conditioning, purchase of filtration equipment, flexibility in travel behaviour and transport choice. This creates socioeconomic vulnerability, which combines with other environmental and health inequalities to place the burden of health impacts of air pollution on people in lower wealth brackets.

Exposure reduction can be included in planning to promote and stimulate healthy urban spaces. Design considerations include location (e.g. away from busy roads or hot spots), building design, ventilation methods, access routes and accessibility of exercise and green areas. Such considerations are essential in buildings and neighbourhoods designed for vulnerable populations, such as nurseries, schools, hospitals and care facilities.

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5. Review of the evidence on the benefit of physical activity vs. the harms of air pollution

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KEY MESSAGES

- Each population (by age, sex or health status) possibly exposed to a specific air pollutant should receive specific recommendations about modifying (or not) their physical activity.
- Evidence suggests that the long-term beneficial effects on mortality of regular physical activity in the healthy adult population outweigh the adverse effects of air pollution.
- Evidence suggests that, with exposure to air pollution, the short-term benefits of physical activity may remain (but be smaller).
- In general, regular physical activity should be promoted, even if the local air quality is not optimal.
- The time and location of physical activity should be considered in order to reduce exposure to air pollution; any recommendations should include considerations of ozone and temperature, especially in warmer climates.
- Patients who require medication should continue to use it according to their physician's recommendations.
- In accordance with the precautionary principle, at-risk populations (on the basis of health status or occupational group) should be advised about the best time and location for physical activity or the best working regulation or schedule for outdoor work involving increased exposure and should be advised to reduce moderate–vigorous physical or working activity outdoors during air pollution episodes.
- Mass sports events should be held in locations and / or at times when local authorities report or expect reduced levels of air pollution.

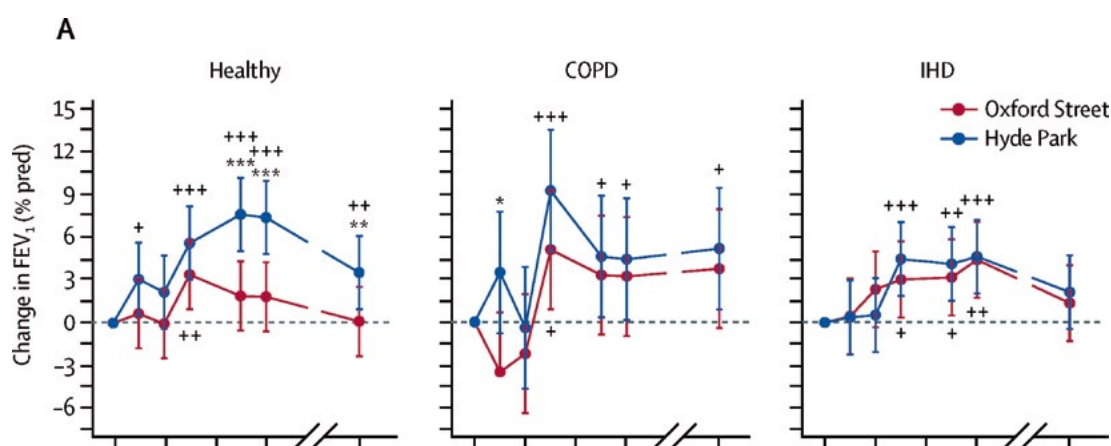
WHO defines physical activity as any bodily movement produced by skeletal muscles that requires energy expenditure (World Health Organization, 2018). Regular physical activity reduces blood pressure, systemic inflammation and blood coagulation and enhances autonomic tone and endothelial function, all of which may play a role in reducing the risks of heart disease and stroke. Regular physical activity reduces the risks of hypertension, coronary heart disease, stroke, diabetes, various types of cancer (including of the breast and colon), depression, falls and hip and vertebral fractures. Physical activity improves muscular and cardiorespiratory fitness and bone and functional health. It is fundamental to energy balance and weight control (World Health Organization, 2018).

Physical activity promotes the switch of breath from nasal to oral and increases breathing frequency and minute ventilation, influencing the uptake and deposit of air pollutants in the lungs and airways (Rundell, 2012; Giles & Koehle, 2014). Air pollutants have also been associated with

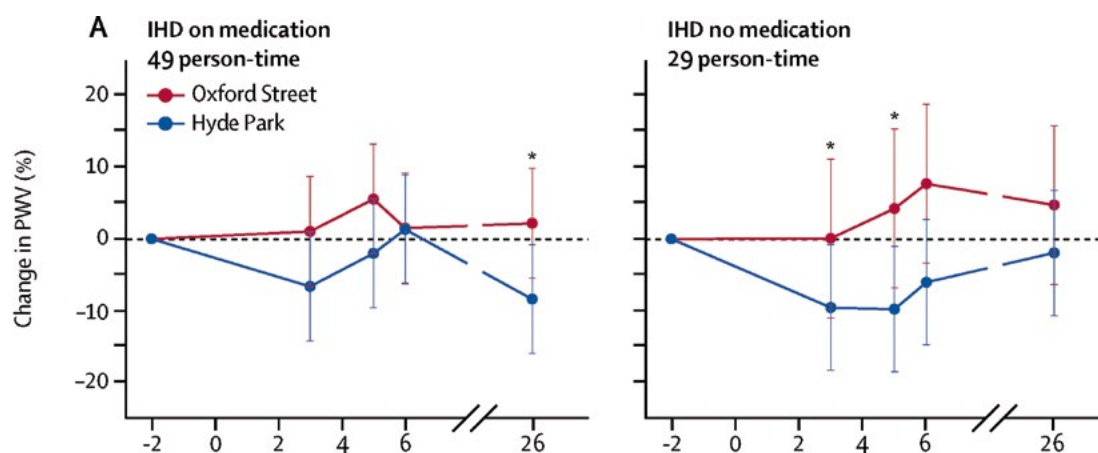
decreased lung and cardiovascular function, especially after short-term exposure (Rundell, 2012; Sinharay et al., 2018). Short-term effects have been studied mainly in healthy adult populations (Giles & Koehle, 2014), although some studies that included patients with respiratory or cardiovascular diseases indicated similar physiological effects and proposed that physical activity-related physiological improvements be avoided in highly polluted areas (Sinharay et al., 2018). In a study of short-term physical activity in high and low levels of air pollution in healthy and unhealthy adults, physical activity had less benefit in high levels of air pollution and less benefit in patients not taking medication (Fig. 1).

Fig. 1. Changes in (A) forced expiratory volume (1st sec) and (B) augmentation index, from baseline and hours after starting to walk in a highly polluted area (Oxford Street) and a less polluted area (Hyde Park) in London

(A) Forced expiratory volume, 1st s (FEV₁, 1st s) in 40 healthy people, 40 with COPD and 39 with ischaemic heart disease (IHD)



(B) Augmentation index (AI), a measure of systemic arterial stiffness derived from the ascending aortic pressure waveform



Modified from Sinharay et al. (2018)

Long-term exposure to air pollution has been suggested to cause a small reduction in the protective effect of physical activity on mortality in Table 1) (Andersen et al., 2015), although the study was conducted in adults in a high-income country.

Table 1. Association [HR (95% CI)] of total and cause-specific mortality with participation (yes/no) in physical activities among 52,061 participants in the Diet, Cancer, and Health cohort.

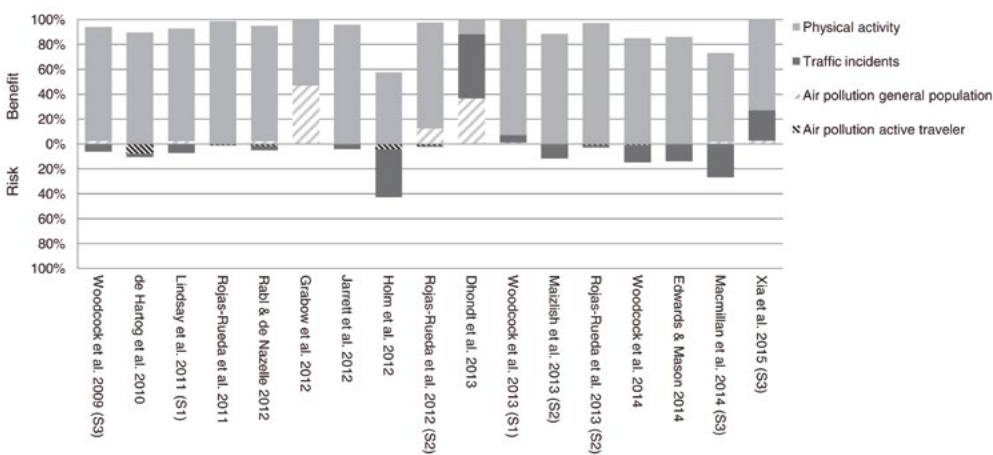
Physical activity	Main model		Interaction model, fully adjusted ^b		p-Value ^c
	Crude ^a model	Fully adjusted ^b model	Moderate/ low NO ₂ ($<19.0 \mu\text{g}/\text{m}^3$)	High NO ₂ ($\geq 19.0 \mu\text{g}/\text{m}^3$)	
Total mortality (n = 5,534)					
Sports	0.62 (0.59, 0.65)	0.78 (0.73, 0.82)	0.79 (0.74, 0.85)	0.75 (0.67, 0.83)	0.14
Cycling	0.77 (0.73, 0.81)	0.83 (0.78, 0.88)	0.83 (0.77, 0.88)	0.83 (0.75, 0.92)	0.81
Gardening	0.72 (0.68, 0.77)	0.84 (0.79, 0.89)	0.85 (0.78, 0.92)	0.83 (0.75, 0.91)	0.77
Walking	0.91 (0.83, 1.00)	0.97 (0.88, 1.06)	0.96 (0.86, 1.08)	0.95 (0.80, 1.14)	0.79
Cancer mortality (n = 2,864)					
Sports	0.66 (0.62, 0.72)	0.82 (0.76, 0.89)	0.84 (0.77, 0.92)	0.77 (0.67, 0.89)	0.12
Cycling	0.86 (0.80, 0.93)	0.93 (0.86, 1.01)	0.92 (0.84, 1.01)	0.95 (0.83, 1.10)	0.96
Gardening	0.87 (0.80, 0.94)	0.96 (0.88, 1.04)	1.00 (0.89, 1.11)	0.86 (0.77, 1.02)	0.27
Walking	1.00 (0.87, 1.15)	1.06 (0.93, 1.23)	1.00 (0.88, 1.22)	1.12 (0.85, 1.48)	0.79
Cardiovascular mortality (n = 1,285)					
Sports	0.61 (0.54, 0.69)	0.78 (0.69, 0.88)	0.76 (0.66, 0.88)	0.80 (0.65, 0.99)	0.88
Cycling	0.73 (0.66, 0.82)	0.78 (0.69, 0.88)	0.83 (0.72, 0.95)	0.70 (0.58, 0.85)	0.16
Gardening	0.85 (0.71, 1.03)	0.82 (0.72, 0.93)	0.85 (0.72, 1.00)	0.77 (0.63, 0.94)	0.55
Walking	0.85 (0.71, 1.03)	0.88 (0.73, 1.07)	0.86 (0.69, 1.00)	0.91 (0.64, 1.28)	0.95
Respiratory mortality (n = 354)					
Sports	0.40 (0.31, 0.50)	0.60 (0.47, 0.77)	0.65 (0.49, 0.88)	0.50 (0.32, 0.77)	0.70
Cycling	0.54 (0.43, 0.67)	0.62 (0.50, 0.77)	0.55 (0.42, 0.72)	0.77 (0.54, 1.11)	0.09
Gardening	0.50 (0.40, 0.63)	0.63 (0.50, 0.79)	0.55 (0.41, 0.73)	0.81 (0.55, 1.18)	0.02
Walking	0.63 (0.46, 0.86)	0.71 (0.51, 0.97)	0.67 (0.46, 0.97)	0.89 (0.47, 1.67)	0.40
Diabetes mortality (n = 122)					
Sports	0.28 (0.17, 0.44)	0.34 (0.21, 0.55)	0.41 (0.23, 0.73)	0.24 (0.10, 0.57)	0.22
Cycling	0.58 (0.40, 0.84)	0.61 (0.42, 0.89)	0.58 (0.36, 0.94)	0.66 (0.37, 1.15)	0.93
Gardening	0.33 (0.22, 0.48)	0.42 (0.28, 0.62)	0.44 (0.27, 0.74)	0.37 (0.20, 0.70)	0.79
Walking	0.74 (0.43, 1.28)	0.77 (0.44, 1.33)	0.82 (0.40, 1.67)	0.73 (0.30, 1.73)	0.74

^aAdjusted for NO₂, sex, calendar year, and mutually for other three physical activities. ^bAdjusted for NO₂, sex, calendar year, and mutually for other three physical activities, occupational physical activity, smoking status, smoking intensity, smoking duration, alcohol intake, environmental tobacco smoke, education, fruit and vegetable intake, fat intake, risk occupation, mean income in municipality, and stratified by marital status. ^cp-Value for interaction.

Modelling studies, such as health impact assessments, have been used to compare the long-term health benefits of transport-related physical activity with the health risk of air pollution (mainly PM_{2.5}) during commuting (Rojas-Rueda et al., 2011; Mueller et al., 2015). The results suggest that the benefits of physical activity outweigh the health risks of air pollution (Fig. 2). In these studies, the authors quantified the air pollution and physical activity levels at which the benefits of physical activity stopped increasing (tipping point) and the levels at which physical activity and air pollution started to have adverse health effects (break-even point) (Tainio et al., 2016).

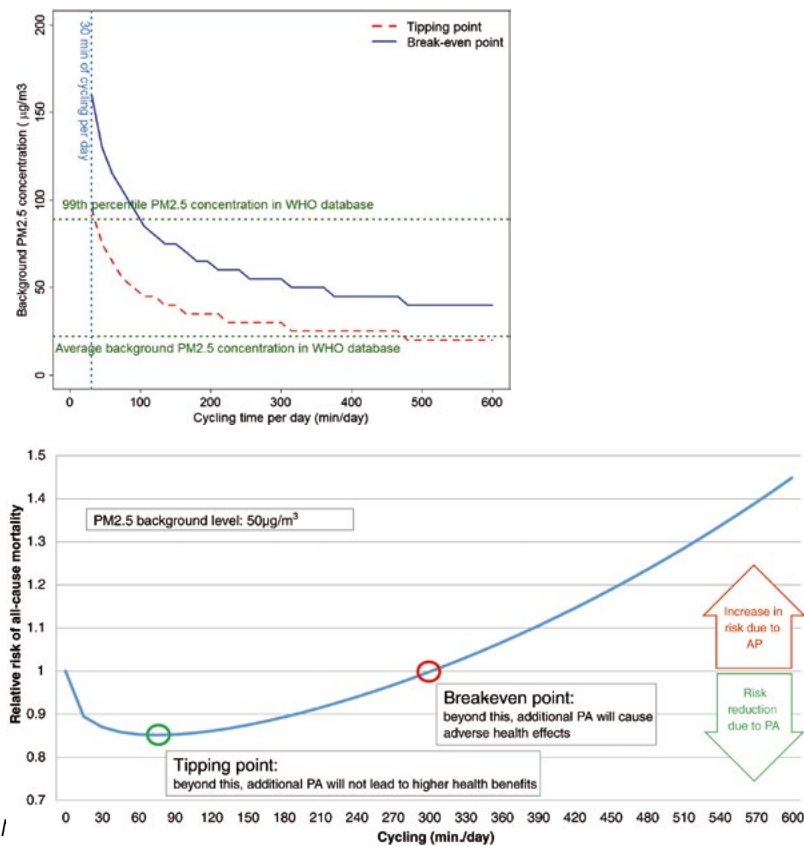
The calculations were made for all-cause mortality related to exposure to $PM_{2.5}$ and walking or cycling in several cities (Fig. 3). The results indicate that, for an average urban background $PM_{2.5}$ concentration of $22 \mu\text{g}/\text{m}^3$ (global average of cities [World Health Organization, 2014]), the benefits of physical activity far outweigh the risks associated with air pollution, even with the most extreme active travel. In areas with a $PM_{2.5}$ concentration of $100 \mu\text{g}/\text{m}^3$, the harm would exceed the benefits after 90 min of cycling or more than 10 h of walking per day.

Fig. 2. Health risk and benefits of active transport in health impact assessment studies.



From Mueller et al. (2015)

Figure 3. “Tipping points” and “break-even points” for physical activity and $PM_{2.5}$ levels and in a general curve and for walking and cycling



Recent studies have shown that air pollution may prevent people from engaging in outdoor physical activity (Saberian et al., 2017; An et al., 2018, 2019).

Because of lack of evidence, no definite recommendation can be made for children, pregnant women, unhealthy populations and populations in low-and middle-income countries. As most of the evidence is for the long-term effects of PM_{2.5}, it is also difficult to make precise recommendations about other pollutants and short-term effects. Studies should be conducted in low-and middle-income countries, populations other than healthy adults and pollutants other than PM_{2.5} and outdoor pollution. Studies should also include short-term impacts and types of physical activity other than that related to transport.

In accordance with the precautionary principle, populations at risk because of their health status or occupation should be advised about the best time and location for physical activity or working regulation or schedule for outdoor work involving high exposure and should be advised to reduce their moderate–vigorous physical or working activity in outdoor spaces during air pollution episodes.

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6. Review of current use of air filters, evidence of possible benefits and practical advice

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KEY MESSAGES

- Twenty-three articles on indoor air filtration were identified. Use of indoor air filtration units reduced indoor $PM_{2.5}$ concentrations by 18–82% during short-term interventions (from a few hours to weeks, with very few for months).
- After use of indoor air filtration units, some overall reductions in systolic blood pressure and increases in heart rate variation and peak expiratory flow were observed. Cardio-respiratory improvements were generally greater in healthy adults than in elderly and patients with cardio-respiratory diseases.

Objective

To assess the efficacy of air filters in reducing exposure to PM and to mitigate health risks from exposure to air pollution in real-world situations.

Methods

We identified 23 articles on indoor air filtration (see references) according to a predesigned search strategy and reviewed them systematically. The studies included randomized trials and observational studies (repeated measures panel study, cross-over study), with no limitation on study population. The primary exposure measures were concentrations of indoor and outdoor $PM_{2.5}$. The primary health outcomes were cardiovascular and respiratory health indicators and biomarkers of systemic inflammation.

Exposure was measured as the standardized weighted mean difference (SMD) for $PM_{2.5}$ after the intervention. Average pooled measurements of exposure showed substantial variation. The primary results for continuous health outcomes were usually reported as betas, percentage changes or mean differences. The SMD for health outcomes after interventions were also calculated because of the wide variation in average differences among measurements. To pool the reported estimates for the meta-analysis, the heterogeneity of study outcomes was assessed with Cochrane's Q statistic, with $P < 0.1$ considered statistically significant. Heterogeneity among studies was assessed with the I² statistic. A random-effect model instead of a fixed-effect model was used to estimate the pooled estimates because of the high heterogeneity among studies.

Results

The studies included small numbers of subjects, even when pooled. In most studies, the indoor air filtration intervention lasted from a few hours to days or weeks and very few for months. Significant reductions in indoor $PM_{2.5}$ concentrations were observed after short-term interventions, ranging from 18% to 82%, with an overall summary SMD of -1.69 (95% confidence interval (CI), -2.12 ; -1.26).

After short-term interventions for selected cardiovascular and respiratory health indicators, the overall summary reduction in systolic blood pressure was 1.74% (95% CI, -2.92; -0.55), and the increase in peak expiratory flow was 5.15% (95% CI, 1.20; 9.08). Some overall improvements in several cardiovascular and respiratory health indicators and reduced systemic inflammation were observed. The improvements in cardio-respiratory outcome measures were generally greater in healthy adults than in susceptible people such as elderly people and patients with cardiovascular disease or COPD; however, few studies included susceptible patients, which may account for the small effect.

Improvements in several cardiovascular health outcomes were not consistent among study populations in terms of the direction, magnitude or timing of response or the specific responses with which they were most strongly associated. The inconsistency may be partly due to the inherent limitations of panel studies and clinical trial designs for changes in health outcomes related to natural day-to-day variations in ambient air pollutants (e.g. residual confounding, differences in population characteristics, differences in PM composition and pollutant mixture) and to the differences among study subjects with regard to age, gender, health status, medication and time-activity pattern (Brauner et al., 2008; Li et al., 2017; Morishita et al., 2018). Lack of understanding of how “true” exposure can be reduced by air filtration may have introduced exposure misclassification of population groups that were not truly blinded or unblinded. Another limitation is variation in the methods and their quality for determining health outcomes, as few trials provided an a priori definition of primary outcome or statistical power to detect changes in outcomes (Noonan et al., 2017).

In summary, this review provides limited evidence of the potential health benefits of indoor air filtration. The partially effective interventions to reduce exposure to indoor air pollution and risk highlight the importance of reducing emissions of air pollutants at their source. To determine the global public health implications, trials with much larger samples general and high-risk populations and longer follow-up should be conducted to address the efficacy of indoor air filtration (Morishita et al., 2018).

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7. Technical Aspects of Respirators

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This article provides background information on respiratory protective devices and their value for reducing exposure of workers and the general public to air pollution when no other controls are available and hazardous exposure levels cannot be reduced.

PM_{2.5} particles, wildfire smoke and ash can irritate the eyes, nose, throat and lungs, cause coughing or wheeze and make it difficult to breathe. A respirator is a device (mask) that covers the nose and mouth and fits tightly to the face, which can filter out PM_{2.5} particles, smoke or ash particles before they are breathed in. NIOSH-approved (NIOSH, 2019) half-mask respirators (e.g. N95 or P100) and respirators that provide similar or greater protection (e.g. European EN FFP2 and FFP3, Chinese GB/T 2626 KN95 and KN100, Australian/New Zealand P2 and P3, Brazilian P2 and P3, Japanese DS2 and DS3 and Korean 1st and Special) protect workers exposed to harmful airborne PM. NIOSH-approved half mask respirators are effective when concentrations do not exceed 10 times the occupational exposure limit.

In the USA, no agency has the authority for non-occupational respirator use, while in many other countries, there is no restriction on use of respirators to occupational settings. Research should be conducted to make recommendations and set protocols for public use of respirators – with all the necessary precautionary statements for people with respiratory conditions - and to define the responsibility for their use by the general public. Recommendations for workplace use could be acceptably tailored for use by the general public and to provide interim guidance, in the absence of data.

Filtering facepiece air-purifying respirators

Respirators are intended to provide respiratory protection for the wearer. Masks are intended to cover all or part of the face but may not provide respiratory protection; therefore, the term “respirator” is used throughout this document.

Filtering facepiece respirators are types of protective device in which the entire respirator comprises filter material. They are the most common type of air-purifying particulate respirator and are those used by the general public to filter airborne particulates. They may be shaped like cups, flat or duck bills. The most common respirators used in many industries in the USA are N95. They are used widely in manufacturing to prevent exposure to particulates, such as metal fumes, silica, flour dust, wood dust and cement dust, and in health care establishments to protect against inhalation of infectious particles and other particulate hazards. Respirators rated “95” capture at least 95% of very small particles, while respirators rated “100” filter at least 99.97% (Hofacre et al., 2006; Krah et al., 2016). It is necessary to verify if the respirators have been certified and approved by official authorities.

People who stay indoors or spend limited time outdoors during high levels of PM_{2.5} pollution or wildfire emergencies may not require a respirator, as they are already protected from exposure; however, people who have to spend long periods time outside in such conditions may benefit from using a tight-fitting NIOSH-approved respirator (e.g. N95 or P100) or a certified respirator with equivalent or greater protection to reduce their exposure.

People whose health is affected by a polluted environment, even indoors, may also benefit from using a tightly fitting respirator to reduce their exposure. Those who wish to wear a respirator should learn to select and correctly use one to obtain the most protection.

Respirators can protect the lungs

N95 or P100 respirators can protect the lungs from pollution, if the manufacturer's instructions for use are followed. A user seal check (NIOSH, 2018a) should be made every time the respirator is worn to ensure that it is adequately sealed to the face.

Disposable particulate respirators are certified by NIOSH for filtering harmful particles, while paper masks and surgical masks are not certified by NIOSH and do not provide the same protection as respirators (NIOSH, 2018b). Commonly available one-strap paper dust masks are designed to keep larger particles out of the nose and mouth but offer little protection. Surgical masks are designed to filter the air from the wearer's mouth and do not provide a good seal to prevent inhalation.

Choosing the right respirator

Disposable particulate respirators, which are sold in many shops and pharmacies, filter only particles and do not filter gases or vapours or provide oxygen. US-approved respirators must be certified by NIOSH, with the words "NIOSH" and the designation "N95" or "P100" on the filter material. P100 respirators are more expensive than N95 respirators and have somewhat higher resistance to airflow. As the cost of P100 respirators may make people reluctant to change them when necessary, N95 respirators may be preferable in situations of high levels of PM_{2.5} pollution or wildfire smoke. Filtering facepiece respirators are approved in Australia and New Zealand (P2 and P3), Brazil (P2 and P3), China (GB/T 2626 KN95 and KN100), Europe (EN FFP2 and FFP3), Japan (DS2 and DS3) and the Republic of Korea (1st and Special).

The model or size of the respirator should fit over the nose and under the chin and seal tightly to the face. "Fit testing" with special equipment is the best way to determine if a respirator fits; however, even without fit testing, a respirator will provide some protection for most people. In many other countries, government-approved respirators include instructions on conducting a user seal check. As of February 2019, respirators were available in sizes that fit young children; however, NIOSH does not certify respirators for children.

How to use respirators

The three factors that ensure that a respirator is effective are: putting it on correctly, ensuring that it fits properly and confirming that it is approved to filter at least 95% of particles (Krah & Shaffer, 2016).

As facial characteristics differ around the world, no one respirator can fit all users.

- Place the respirator over the nose and under your chin, with one strap below the ears and one strap above. A hat should be worn over the straps.
- If the respirator has a nose clip, it should be pressed firmly over the nose and face with two hands.
- If the respirator includes instructions on conducting a user seal check (NIOSH, 2018a) or a fit check, it should be conducted every time the respirator is worn, before entering a polluted area.
- As facial hair may cause a respirator to leak, users should be clean-shaven, unless the facial hair does not lie along the sealing area of the respirator (Cichowicz et al., 2017).
- As effort is required to breathe through a respirator and it increases the risk of heat stress, people working outside while wearing a respirator should take frequent breaks, especially if they are working in heat or doing heavy work. A respirator with an exhalation valve may be preferable.
- A person who feels dizzy, lightheaded or nauseated should notify someone, go to a less polluted area, remove the respirator and seek medical attention.
- People with heart or lung disease should consult their doctor before using a respirator.
- A respirator should be discarded when it becomes more difficult to breathe through, if the inside becomes dirty or if it becomes damaged. If necessary, a fresh respirator should be used each day.
- Respirators should be kept clean and dry, and the manufacturer's recommendations on use and storage should be followed.
- People with a heart or lung problem should consult their doctor before using a respirator. Wearing a respirator when it is hot or during physical activity can increase the risk of heat-related illness.

Interim guidance in the absence of data for the general public

The US Government is collaborating with the International Society for Respiratory Protection to effectively translate the findings of studies on occupational exposure to address respiratory protection against pollution. Resources have been compiled by experts from NIOSH, the Environmental Protection Agency, the California Department of Public Health and the Food and Drug Administration, with input from respirator manufacturers. The Wildfire Smoke Resource (Environmental Protection Agency, 2018) provides useful recommendations applicable to air pollution. WHO could also collaborate with the International Society for Respiratory Protection, which has issued a series of simplified training modules and simple messaging tools for low- and middle-income countries to ensure respiratory protection for members of the general public in areas of high air pollution. In the absence of comprehensive data, lessons learnt from the recommendations for PM_{2.5} and wildfire smoke and ash could be used.

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8. Current use of respirators : evidence of possible benefits and practical advice

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KEY MESSAGES

- Eleven studies of interventions with respirators were identified and systematically reviewed. Some overall summary improvements in heart rate variation were observed during short-term interventions (mainly a few hours to days) but not on other cardiovascular outcomes.
- Most of the studies lacked information on how “true” exposures could be reduced with respirator use and how well the respirators actually worked or fitted, which might have introduced exposure misclassification in groups that were not truly blinded or were unblinded.

Objective

To assess the efficacy of mask use in reducing exposure to PM in real-world situations.

Methods

Few intervention studies of respirator use have been conducted, with few participants in each trial, and they have not previously been systematically reviewed. With a predesigned search strategy, 11 articles were identified and included in a systematic review (see reference list). The studies included randomized trials and observational studies (repeated measures panel study, cross-over study), with no limitation of the study population. Exposure to air pollution before and after respirator use could not be measured. The primary health outcomes were cardiovascular and respiratory health indicators.

The primary results for continuous health outcomes were usually reported as betas, percentage changes or mean differences. The SMDs for health outcomes after a respirator intervention were also calculated because of wide variation in the average differences among measurements. SMDs and 95% confidence intervals (CIs) for percentage changes in health outcome measurements were calculated. To pool the reported estimates in a meta-analysis, the heterogeneity of study outcomes was assessed in Cochrane’s Q statistic test, with a $P < 0.1$ considered statistically significant. The degree of heterogeneity between studies was assessed with the I² statistic. A random-effect model was selected for the pooled estimates because of high levels of heterogeneity among studies, which precluded use of a fixed-effect model.

Results

Some improvements in cardiovascular end-points were observed with the wearing of respirator in highly polluted areas. The overall summary SMD for systolic blood pressure was -0.15 (95% CI, -0.36 ; 0.06) with heterogeneity ($I^2 = 0.0\%$, $P = 0.517$, Q statistic (3) = 2.28). The overall summary SMD for diastolic blood pressure was -0.14 (95% CI, -0.34 ; 0.07) with heterogeneity ($I^2 = 0.0\%$, $P = 0.940$, Q statistic (3) = 0.04). The overall summary SMD for heart rate was 0.09 (95% CI, -0.27 ; 0.45) with substantial heterogeneity ($I^2 = 55.8\%$, $P = 0.079$, Q statistic (3) = 6.78). Even fewer studies examined respiratory end-points, and the potential benefit of masks could not be determined.

In summary, potential exposure reduction from respirator use could not be measured. Lack of information on how “true” exposure could be reduced by wearing a respirator and how well respirator can be fitted might have introduced exposure misclassification in groups that were not truly blinded or unblinded. Improvements in a suite of cardiovascular health indicators were not consistent among the study populations in terms of direction, magnitude or timing of the response with which they were most strongly associated. Differences in the characteristics of the study subjects (e.g. age, gender, health status, medication, time–activity pattern) might also have confounded effect estimates (Meng et al., 2009; Shi et al., 2017; Guan et al., 2018). Better-quality trials with larger samples and longer follow-up in general and high-risk populations should be conducted to determine the efficacy of respirator use. Recommendations should be made for the public on physical activity and behaviour adjustment that could affect mask use on high-pollution days (Laumbach, 2010). Potential medical complications resulting from partially effective respirator to reduce exposure or risk highlight the importance of reducing emissions of air pollutants at their sources.

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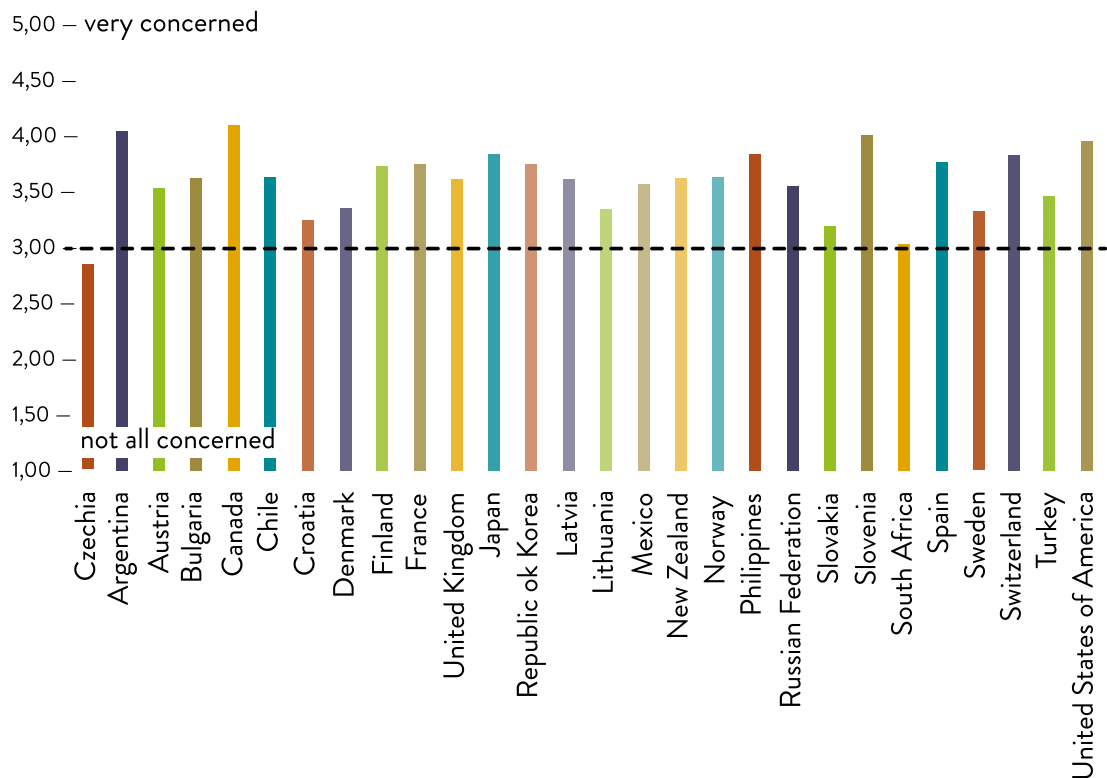
9. Communicating air pollution-related risk

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Cross-cultural perceptions of environmental risks

Although people recognize the seriousness of environmental risks, including air pollution, they do not prioritize them. Thus, generally speaking, environmental risks are perceived as less dangerous and less urgent than risks related to the economy or health. Fig. 1 illustrates the results of a survey in 28 countries in 2010 of concern about environmental risks (International Social Survey Programme Research Group, 2012).

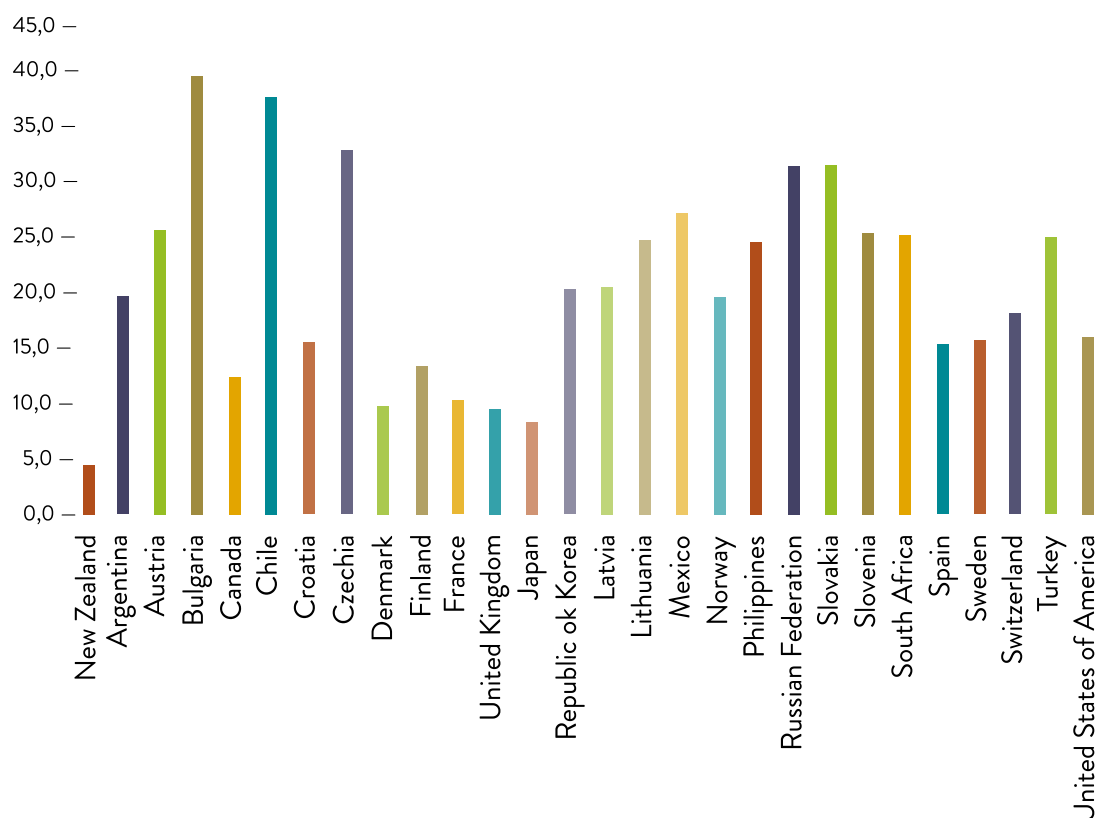
Figure 1. Perceptions of environmental risks according to the International Social Survey Programme, 2010.



Source: International Social Survey Programme Research Group (2012)

The data also indicated that the risk from air pollution was considered the most important environmental risk in about half of the countries, as compared with the risks associated with chemicals, pesticides, water shortage, water pollution, nuclear waste, domestic waste disposal, climate change, genetically modified foods and depletion of natural resources (Fig. 2). There was wide variation in the percentage of people who perceived air pollution as the most important environmental risk, from 4.6 in New Zealand to 39.7 in Bulgaria.

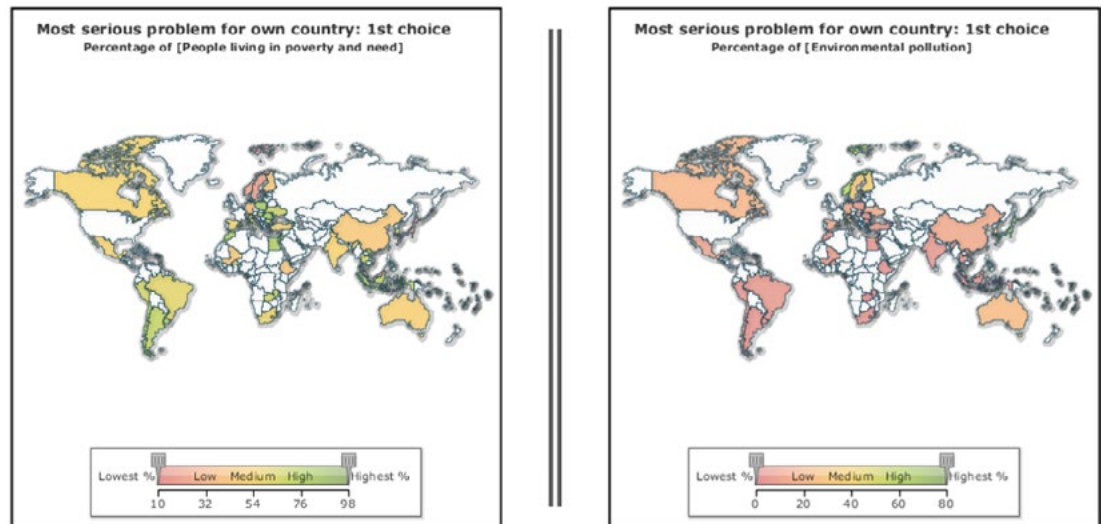
Fig. 2. Proportions of populations who perceived air pollution as the most important environmental risk.



Source: International Social Survey Programme Research Group (2012)

Even if people recognize the seriousness of air pollution-related risk, they may not necessarily perceive it as the most important issue in their country. In the World Values Study 2010–2014, respondents were asked which of the following five problems they considered the most serious: poverty and need, discrimination against girls and women, poor sanitation and infectious diseases, inadequate education, and environmental pollution. Poverty was considered the most important problem in most countries, and none named environmental pollution as the main concern (Fig. 3).

Fig. 3. Proportions of populations who considered that poverty or environmental pollution was the most important problem in their country.



Communicating risks related to air pollution

To understand how to communicate risks related to air pollution, the way in which risk is assessed and understood by lay people must be understood. In classical economic approaches, risk is the result of the probability of a negatively evaluated event and the possible consequences of that event (Loewenstein et al., 2001); however, non-expert risk assessment depends on the context, the form of the message and the emotions evoked by the message.

Persuasive arguments can be analysed in two ways. The “central route” is based on thoughtful, deliberative consideration of the arguments (Petty & Cacioppo, 1984, 1986; Kahneman, 2013), while, with peripheral cues, the message is analysed rapidly, automatically and intuitively.

People analyse problems by the central route only rarely, as, to process information deliberately, the person must be motivated, they must have the time to process the information with no distraction and they must be competent to assess the information properly. People therefore usually analyse information from peripheral cues, and environmental risks should therefore be communicated through peripheral cues. The main qualities that can influence the effectiveness of risk communication are numbers and emotions, the location of an environmental risk, sensory mechanisms and fear and self-efficacy.

Numbers and Emotions

Communication of risks related to air pollution often emphasizes the large numbers of victims of air pollution, such as 4.2 million deaths due to outdoor air pollution and 91% of the world's population living in places where the air quality exceeds the WHO limits (World Health Organization, 2019). Psychological research suggests, however, that focusing on mass victims leads to fading compassion and decreased willingness to engage in mitigating actions (Slovic, 2007; Markowitz et al., 2013). Naming individual victims of mass catastrophes may be more persuasive and efficient for engaging people in addressing risks (Butts et al., 2019).

The two main reasons for fading compassion are the difficulty of making a link with mass victims and weakening of the sense of self-efficacy, such that individuals assume that their actions will be simply “a drop in the bucket” and will not resolve the problem (Bartels & Burnett, 2011). Therefore, general communication about risks should be supplemented with personal stories of air pollution victims.

Location of environmental risks

People tend to perceive environmental problems as less threatening when they occur farther away (Uzzell, 2000). Such spatial bias leads to perceiving geographically close areas more positively (Gifford et al., 2009), whereby people tend to downplay the threat of air pollution in their closest neighbourhoods. Therefore, data on local air pollution should be used to convince people to engage in air pollution mitigation. Use of a dense network of air pollution sensors and GIS may be efficiently influential.

Disgust and Sensory Mechanisms

Psychological research suggests that people neglect threats they cannot see, feel or smell directly (van Vugt et al., 2014). Therefore, air pollution should be made sensorially detectable. One strategy is to evoke disgust, as this emotion has evolved to help people to avoid pathogens by avoiding physical contact with disgust-eliciting objects when they detect associated sensory cues (Rozin & Fallon, 1987). It has also been shown that disgust-oriented appeals are more persuasive than health-oriented appeals (Palomo-Vélez et al., 2018). Communication on air pollution might therefore include pictures of smog, of lungs after long-term inhalation of pollution and other disgust-provoking stimuli.

Fear and Self-Efficacy

Risk communication frequently includes fear-provoking information. Psychological research shows, however, that this strategy may backfire (Witte & Allen, 2000; Tannenbaum et al., 2015), as fear and negative emotions increase persuasiveness but also increase avoidance, resulting in a curvilinear relation between fear and persuasiveness. Research on health promotion campaigns indicates that the most effective way of making fear persuasive is to complement it by promoting self-efficacy (Heald, 2017). Messages that evoke fear must at the same time propose ways of mitigating and limiting the fear.

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10. Equity issues to be considered in recommending personal interventions

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KEY MESSAGES

- Placing the responsibility for reducing exposure to air pollution on individuals raises important issues of equity in terms of individuals' need and opportunities for implementing the recommendations.
- Recommendations should account for the individual cultural, educational and socioeconomic context, the resources available to effect choices, the information available to make an informed decision, people's perceived risk of harm from air pollution as compared with competing health risks and the basic human right to a sustainable livelihood.

Recently, there has been a steep rise in awareness of the impact of air pollution on health, especially among city dwellers. Consequently, clean air has begun to emerge as a desired good or lifestyle choice, especially in high-income countries but also more and more in low- and middle-income countries. People who can afford to “pay for clean air” are doing so, as evident from a global rise in the sales of air filters, respirators and face masks.

The fact that clean air is a luxury item, however, raises important questions of equity. Equity, in the philosophical sense, is the notion that people are treated proportional to their needs: society gives more to those who need more and less to those who need less. The “need” in this scenario is higher exposure to air pollution. Air pollution levels are not distributed equally across the world, countries, cities or neighbourhoods. It is often the most vulnerable and deprived populations, those who are less educated, and ethnic minorities who are exposed to the highest levels of air pollution. Regions in eastern and southern Europe where income and education levels are lower and unemployment rates higher have the highest exposure to PM (European Environment Agency, 2018). In England, ethnically diverse neighbourhoods have on average 14 $\mu\text{g}/\text{m}^3$ higher concentrations of NO_2 than predominantly white neighbourhoods (Fecht et al., 2015).

Recommendation of personal interventions to reduce exposure to air pollution therefore raises important questions with regard to equity. Individuals, societies and countries should have equal opportunity and resources to access appropriate interventions and recommendations to address a need. The opportunities and resources to, for example, avoid places with high levels of air pollution, reduce physical activity during air pollution episodes or use face masks or air filters might be unequally distributed.

Use of personal interventions should be determined solely by personal choice and motivation and be independent of status, social setting, cultural tradition and economic constraints. The reality is far from this ideal. Disparity is seen across socioeconomic, ethnic, gender and age groups, particularly in low- and middle-income countries and in countries with deep inequity.

For example, an indigent family is unlikely to prioritize spending resources on protection from poor air quality over securing food for their children. A woman in a low- or middle-income country is much more likely to be exposed to high levels of household air pollution from unclean fuel sources than a man because of the socio-cultural context, which is beyond her individual choice.

If the responsibility for interventions is left to individuals, everyone must define their own needs. The decision process will be influenced by individuals' cultural and socioeconomic contexts, the information available to them to make an informed decision and their perceived risk of harm from air pollution as compared with competing health risks. Providing targeted, timely, easily accessible information that is understandable to all individuals, independently of their cultural and socioeconomic context is therefore essential. The provision of affordable, appropriate interventions for each subgroup is another critical element for ensuring equity. For example, respirators for children are not readily available and the cost is usually higher during air pollution episodes. Without proper control by authorities, market forces will determine the price of personal interventions, which will reduce equity.

Decisions about their needs influence individuals' willingness to pay for personal interventions, and their decision depends strongly on their perceived risk of harm in relation to their means and opportunities to pay. This applies to interventions that might be paid for directly by individuals, such as face masks or air filters, but also opportunity costs such as loss of wages due to absence from work or education or restricted activities.

Actions by authorities could ease the pressure on individuals to reduce their own exposure. The actions include subsidies to individuals in the greatest need, in terms of both exposure to air pollution and limited resources, to implement the recommended interventions. The cost of such schemes could be raised through taxes or shared between the emitters of air pollutants and the consumers of the goods that emit. For example, in Delhi, India, vehicles that do not comply with the prescribed standards are charged an "environment compensation charge" or "green tax" if they enter the city, and the money is used to improve public transport, including a rapid transport system.

Ultimately, uptake of a recommendation depends on individuals' perceived risk, their knowledge about the harmful effects of exposure to air pollution, the accessibility of information and interventions, the affordability of actions and the control individuals' have over their own activities and associated exposures.

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11. Development of clinical practice guidelines: role of medical societies and patients' organizations

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KEY MESSAGES

- Everybody should reduce their exposure to polluted air. Reduction of short-term exposure is particularly important for young and old people and patients with cardiovascular, cerebrovascular or respiratory disease, and reduction in long-term exposure is important for everybody.
- Medical societies could play a central role in educating the public about the health effects of air pollution and in developing and distributing clinical guidelines, which might have to be region-specific. Inequity should be considered.
- In guideline development and advocacy, medical societies should ensure that the responsibility for providing a healthy environment is that of society, and every attempt to place the responsibility on the individual must be prevented.

Outdoor and indoor air pollution has substantial impacts on cardiovascular, respiratory, metabolic, mental and child health worldwide (World Health Organization, 2006), with increasing risks for cardiovascular and cerebrovascular events, lung cancer, diabetes mellitus, impaired prenatal growth and child lung development and exacerbation of cardiac and lung diseases and health inequality (World Health Organization, 2013; International Agency for Research on Cancer, 2016). Despite substantial improvements during past decades, the concentrations of air pollution throughout the world remain above the WHO guideline, particularly in urban areas (World Health Organization, 2016).

Some population subgroups are particularly susceptible to the short-term effects of air pollution (Thurston et al., 2017). These include very young and old people, whose defence mechanisms are not yet fully developed or are impaired, and patients with chronic conditions such as cardiovascular, cerebrovascular and respiratory disease. Everyone is more or less at risk of air pollution-related chronic disease due to long-term exposure, depending on their age life, lifestyle, external circumstances and known and unknown further susceptibility factors.

Medical societies can contribute to guideline development because of their unique position in society. First, they have the scientific knowledge and expertise necessary for developing evidence-based guidelines. They have networks for their distribution and implementation, enjoy general societal and professional respect and have the appropriate authority to set new guidelines. Secondly, medical societies and patient organizations can reach and educate the users of guidelines (health care providers), patients and the general population. The networks of medical societies and their outlets (journals, websites, conferences) ensure distribution of guidelines and training of medical personnel in their implementation, including promotion of the contents in medical curricula, textbooks, professional training programmes and scientific meetings. Thirdly, medical societies can advocate at all political and regulatory levels for a healthy environment for their patients' health. Because of their respected role in society, they can effectively raise the topic of air pollution-related health effects at local, national and international levels.

Lastly, they must be aware of and prevent unintended effects, such as greater environmental injustice due to unequal access to personalized approaches to prevention.

Specific considerations for the development of clinical practice guidelines are that the advice might have to be region-specific, as baseline and peak values and major sources differ widely globally, which also determine the options for avoidance and the efficacy of restricting activity in certain places and at certain times. Guidelines should also recognize the increasing personal expertise of affected populations, who have experience in reacting to exposure by using information systems, such as the “Know your number” air quality health index promoted in Canada. Guidelines should differentiate between indoor and outdoor exposure and address existing interventions and recommendations by political or administrative authorities, for many of which there is little evidence. The financial burden and possibilities for reimbursement of protective equipment should also be considered. Recommended equipment must be included in reimbursement policies, like other medical devices, to prevent inequity.

Medical societies should continue and increase advocacy for clean air, beyond clinical guidelines, which are primarily transient emergency interventions when optimal air quality has not been achieved. Medical societies should be alert to unintended effects, such as environmental injustice, physiological effects on breathing of personal protective equipment and frightening the public. Most importantly, medical societies should ensure in guideline development and advocacy that the responsibility for providing a healthy environment is that of society, and any attempt to place the responsibility on the individual must be prevented.

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