

training toolkit on air pollution and health for health workers



Air pollution and cardiovascular diseases

Learning objectives

1. Describe the global burden of cardiovascular disease (CVD) attributable to air pollution;
2. Explain the current paradigm shift from individual to environmental risk factors for CVD;
3. List the mechanisms of pollution-attributable CVD;
4. Recognize patients at elevated risk of pollution-attributable CVD; and
5. Apply community- and individual-level interventions.



Acronyms

ALRI	acute lower respiratory infection
CO	carbon monoxide
COPD	chronic obstructive pulmonary disease
CVD	cardiovascular disease
DM	diabetes mellitus
HAP	household air pollution
HLD	hyperlipidaemia
HTN	hypertension
ICD	International Classification of Diseases
IHD	ischaemic heart disease
LMICs	low- and middle-income countries
LPG	liquified petroleum gas
MI	myocardial infarction
NCD	noncommunicable disease
NO ₂	nitrogen dioxide
PM	particulate matter
SO ₂	sulfur dioxide
WHO	World Health Organization

Module outline

1. Cardiovascular burden of disease from particulate matter:
 - 📎 air pollution exposure;
 - 📎 global burden of CVD attributable to air pollution; and
 - 📎 fraction of NCD deaths attributable to selected risk factors.
2. Mechanisms of disease:
 - 📎 general evidence-based mechanisms;
 - 📎 ischaemic heart disease;
 - 📎 stroke;
 - 📎 heart failure and atrial fibrillation;
 - 📎 hypertension, atherosclerosis, diabetes; and
 - 📎 other CVDs.
3. Risk assessment:
 - 📎 identify populations at risk; and
 - 📎 individual risk assessment.
4. Interventions:
 - 📎 guiding principles;
 - 📎 intervention for individuals; and
 - 📎 interventions for communities.

Main target of this module:

CLINICIANS (caregivers)

Clinicians include physicians (family doctors, general practitioners and specialists) as well as other primary health care workers such as nurses, midwives, community health workers and other health professionals who are caregivers to patients. The term also includes medical students and other future health care professionals.



WHO / Christopher Black



WHO / Atul Loke

Clinicians are essential



WHO / Maheder Haileselassie

- Individualized interventions can reduce exposure to air pollution and associated cardiovascular risks.
- Clinicians can be advocates for clean air policies.
- **Clinicians therefore play an essential role** in reducing the global burden of CVD attributed to air pollution.

Clinical case study

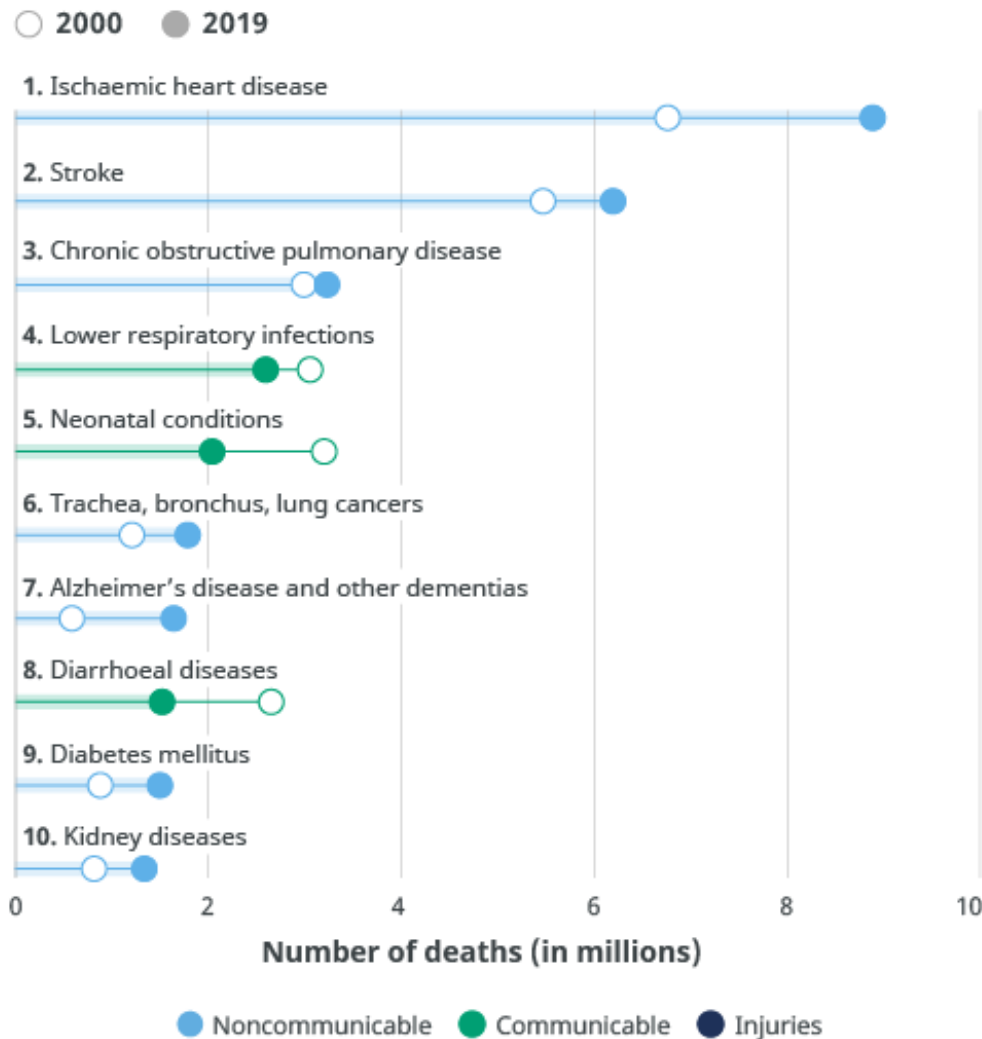


Mrs Mutai is a 72-year-old woman with a history of hypertension and diabetes mellitus who visits Dr Chebet in Nairobi for a regular health check-up. The doctor is testing a new approach for screening and protecting patients from the harmful cardiovascular effects of air pollution. Mrs Mutai is identified as a patient at elevated risk of pollution-related cardiovascular events given her age and multiple cardiac risk factors. A brief risk assessment is performed. Mrs Mutai cooks her meals using an indoor wood-burning stove and commutes across town on a public bus. Dr Chebet locates Mrs Mutai's home on a publicly available pollution map and learns that average daily outdoor pollutant concentrations in her neighbourhood are $61 \mu\text{g}/\text{m}^3$. Dr Chebet calculates that these various exposures impart an elevated risk of ischaemic heart disease and stroke.

1.

CARDIOVASCULAR BURDEN OF DISEASE FROM PARTICULATE MATTER

Leading causes of death globally



Cardiovascular events represent the most important cause of death globally, followed by chronic obstructive pulmonary disease, lower respiratory infections and neonatal conditions.

All these health outcomes are linked to exposure to air pollution.

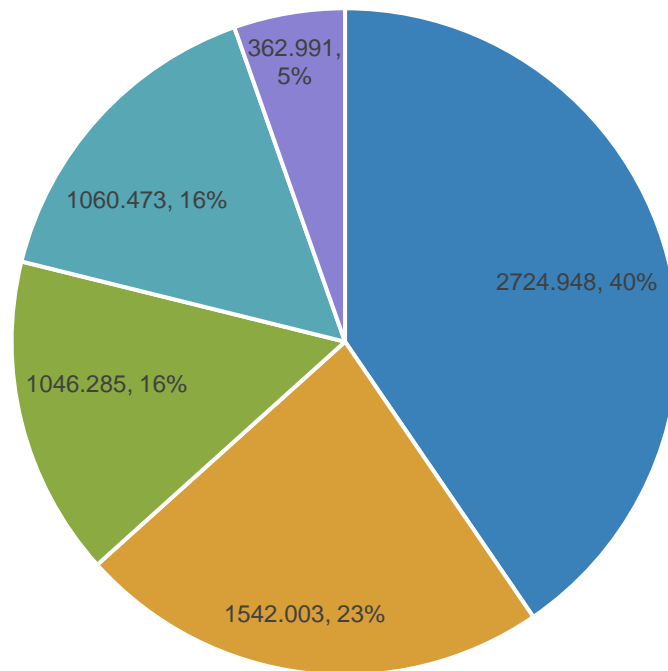
Global burden of CVD attributed to air pollution



- Air pollution is now **one of the five major risk factors for noncommunicable diseases** (along with tobacco use, harmful alcohol consumption, poor diet and physical inactivity).
- This represents a **paradigm shift** in focus from individual risk factors to environmental risk factors for CVD.

Global burden of CVD attributed to air pollution

Globally, more people die from CVD attributed to air pollution than from respiratory disease attributed to air pollution. In fact, most air pollution deaths are the result of CVD (IHD and stroke).



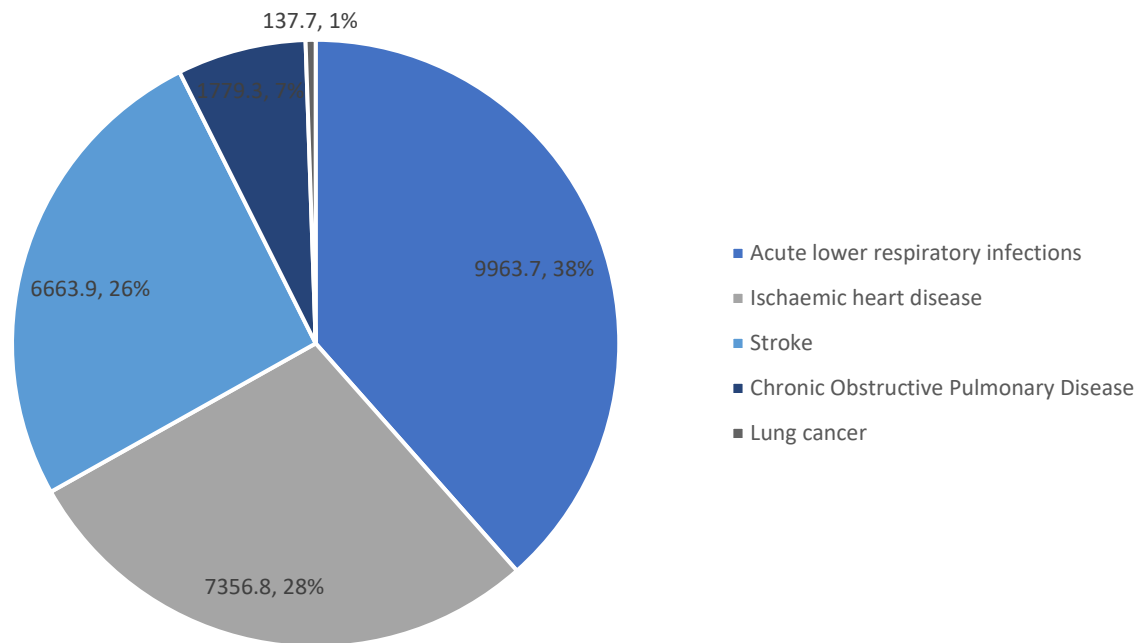
Deaths ('000) from joint effects from air pollution, 2019 (WHO)

- Ischaemic heart disease
- Stroke
- Acute lower respiratory infections
- Chronic Obstructive Pulmonary Disease
- Lung cancer

The case of Ghana

In Ghana, the greatest proportion of deaths from the joint effects of air pollution are the result of acute lower respiratory infections, followed by IHD and stroke.

Ghana deaths from joint effects from air pollution, 2019 (WHO, preliminary data)

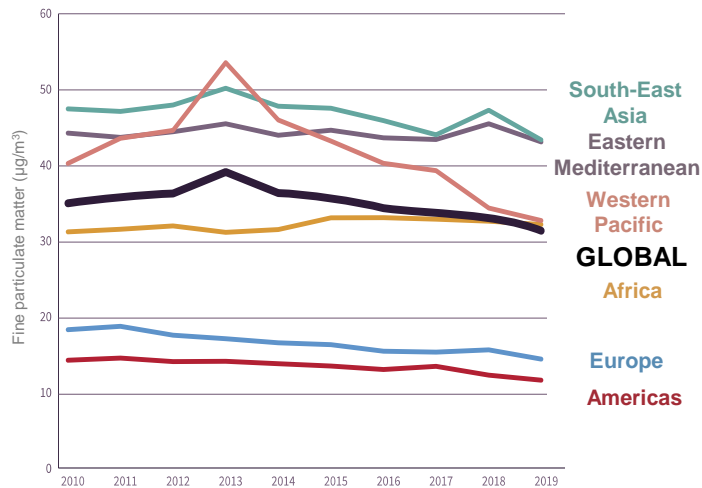


Trends in air pollution and CVD by region



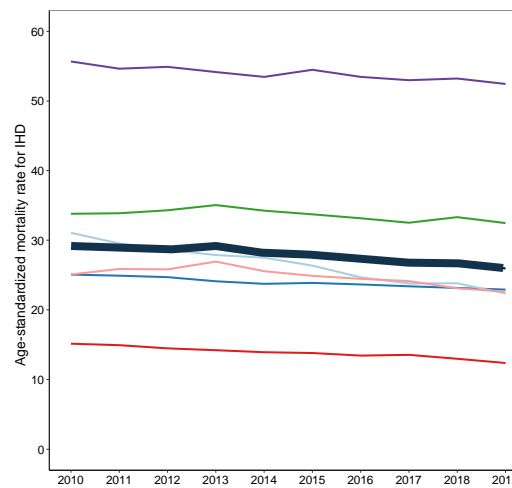
- World Heart Federation (WHF) World Heart Report 2019
- Using 2019 WHO data from 2019: focus on PM_{2.5}
- CVD burden: Ischaemic Heart Disease (IHD) and stroke

Trends in fine particulate matter (PM_{2.5}) between 2010 and 2019



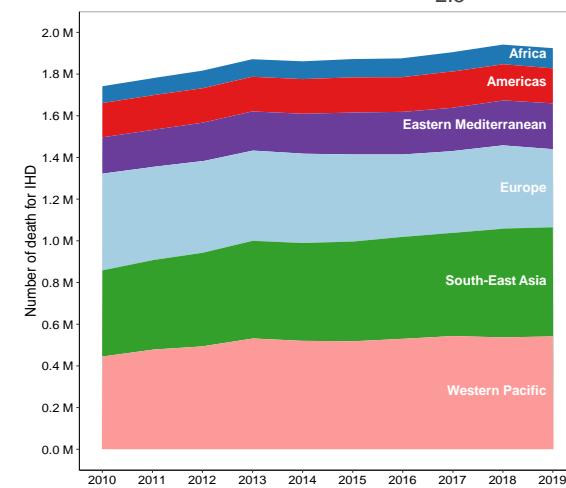
Global levels of PM_{2.5} are decreasing...
...but by just 1% between 2010 – 2019

Age standardized IHD mortality (per 100,000 people) attributed to PM_{2.5}



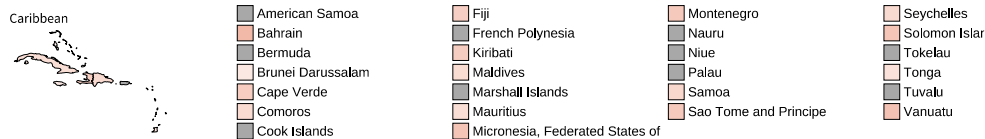
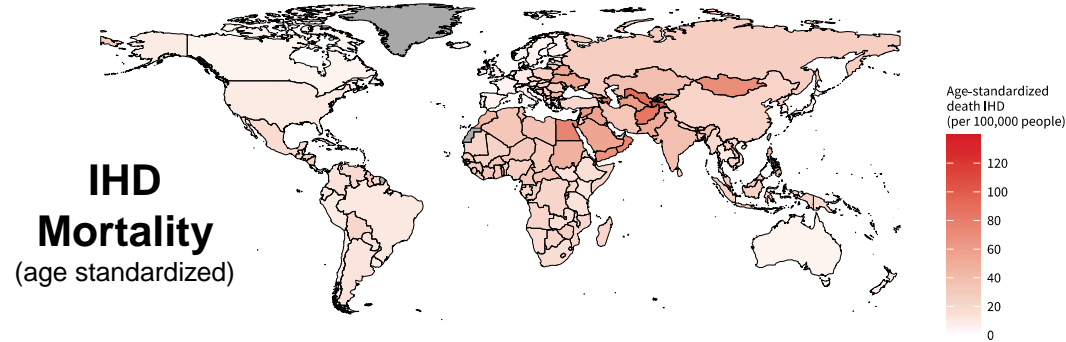
Age-standardized
IHD mortality is decreasing

Number of IHD deaths attributed to PM_{2.5}



The actual numbers of
IHD deaths are increasing

Global burden of PM_{2.5} related IHD and stroke



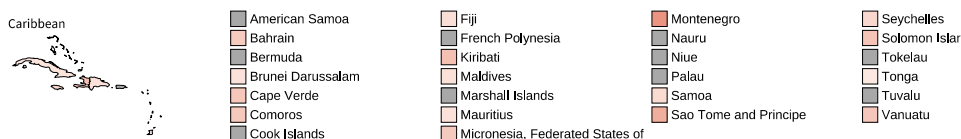
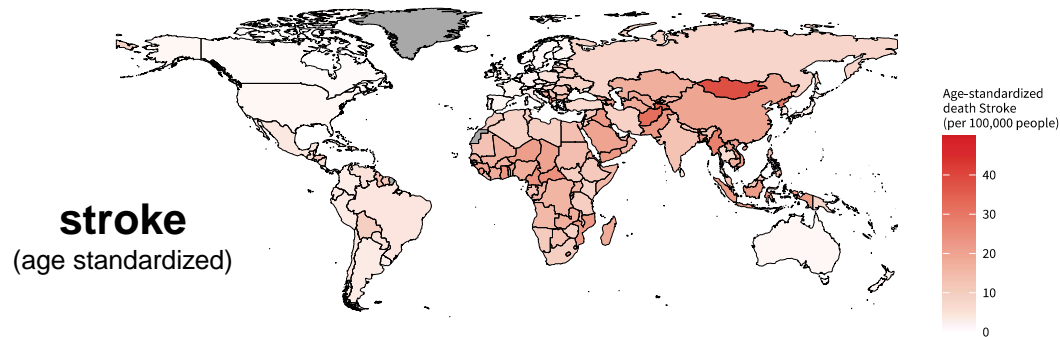
In 2019, PM_{2.5} contributed to:

1.9 million premature deaths from IHD

900,000 premature deaths from stroke

Air pollution is linked to most major CVDs

Therefore, these values are likely to be underestimates

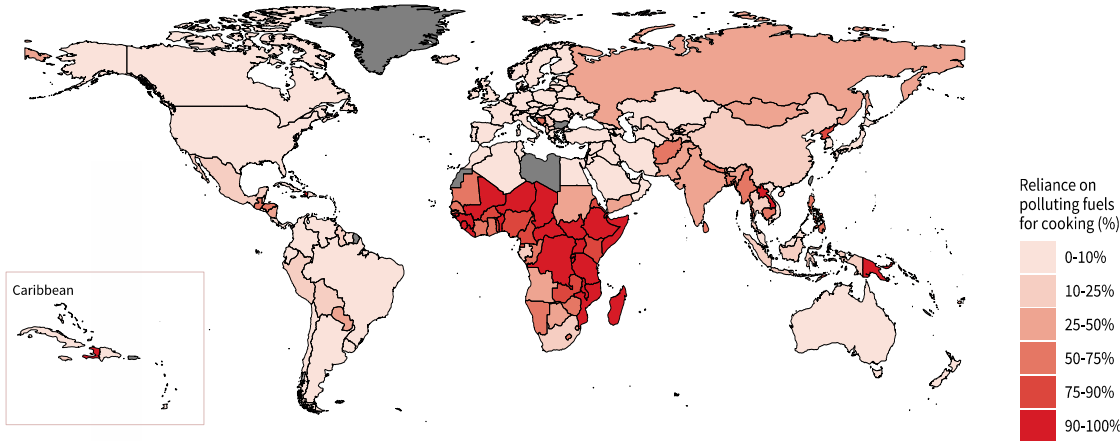


There are notable regional differences in air pollution-related CVD

The burden is greatest in LMICs

Household/indoor air pollution and CVD

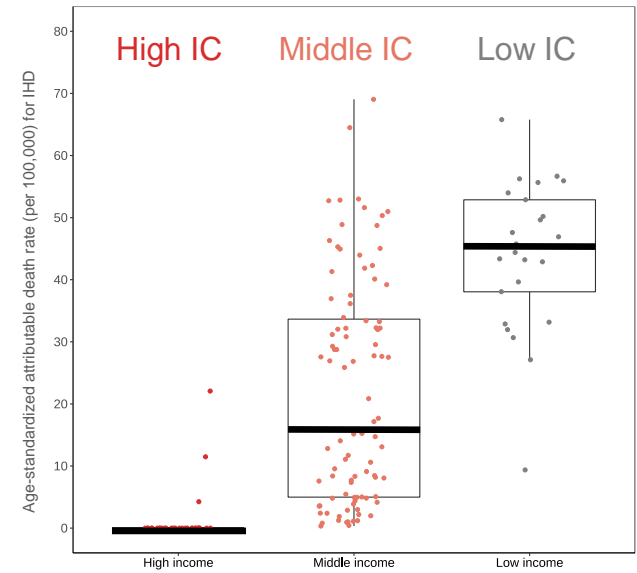
Solid-fuel use in different regions



Polluting solid fuel use remains prevalent in many nations, especially in sub-Saharan Africa

Household air pollution causes more than **1 million IHD** and **700,000 stroke** deaths every year

IHD mortality linked to solid fuel use

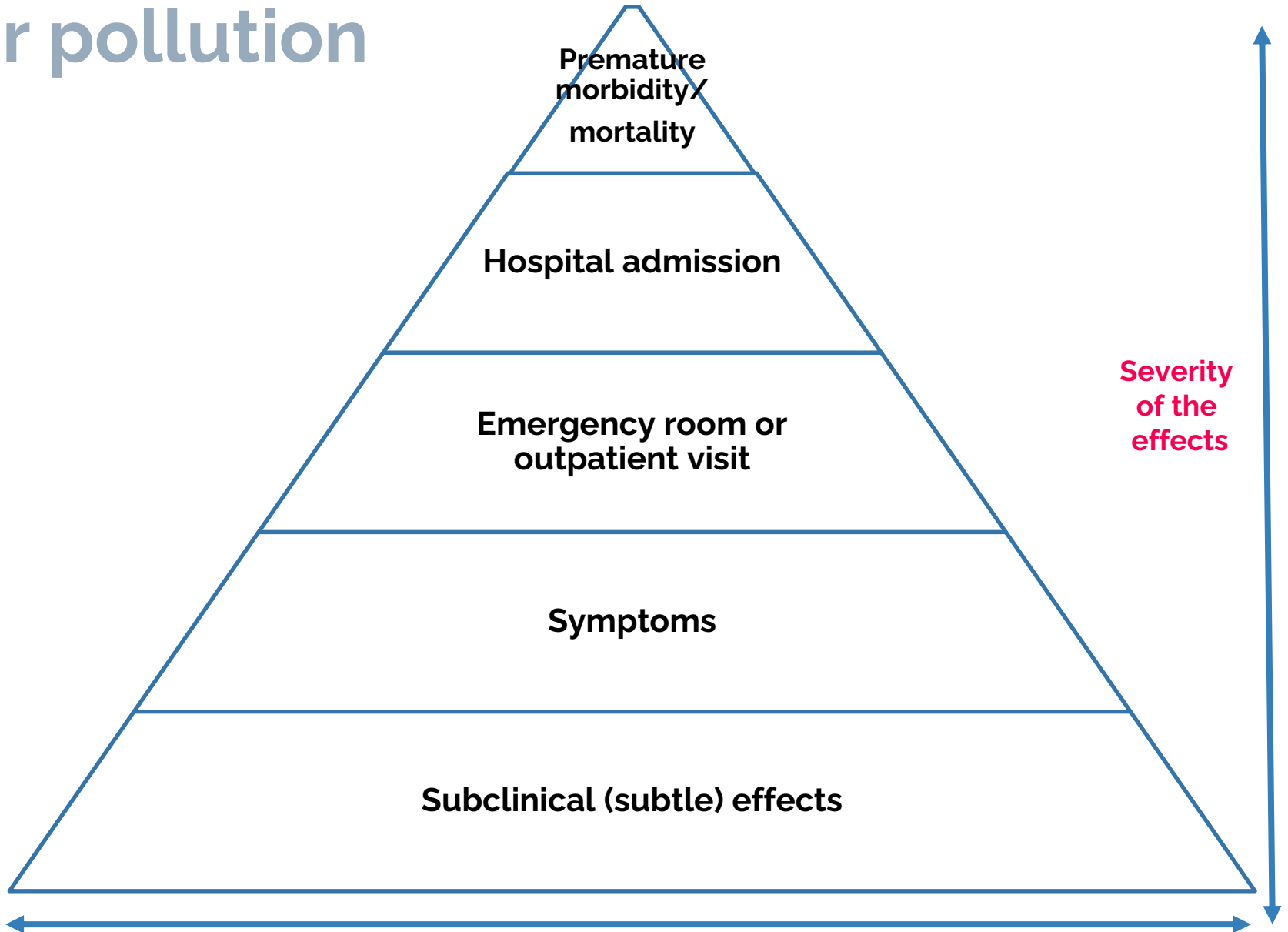


IHD and stroke attributed to household air pollution is greater in LMICs

2.

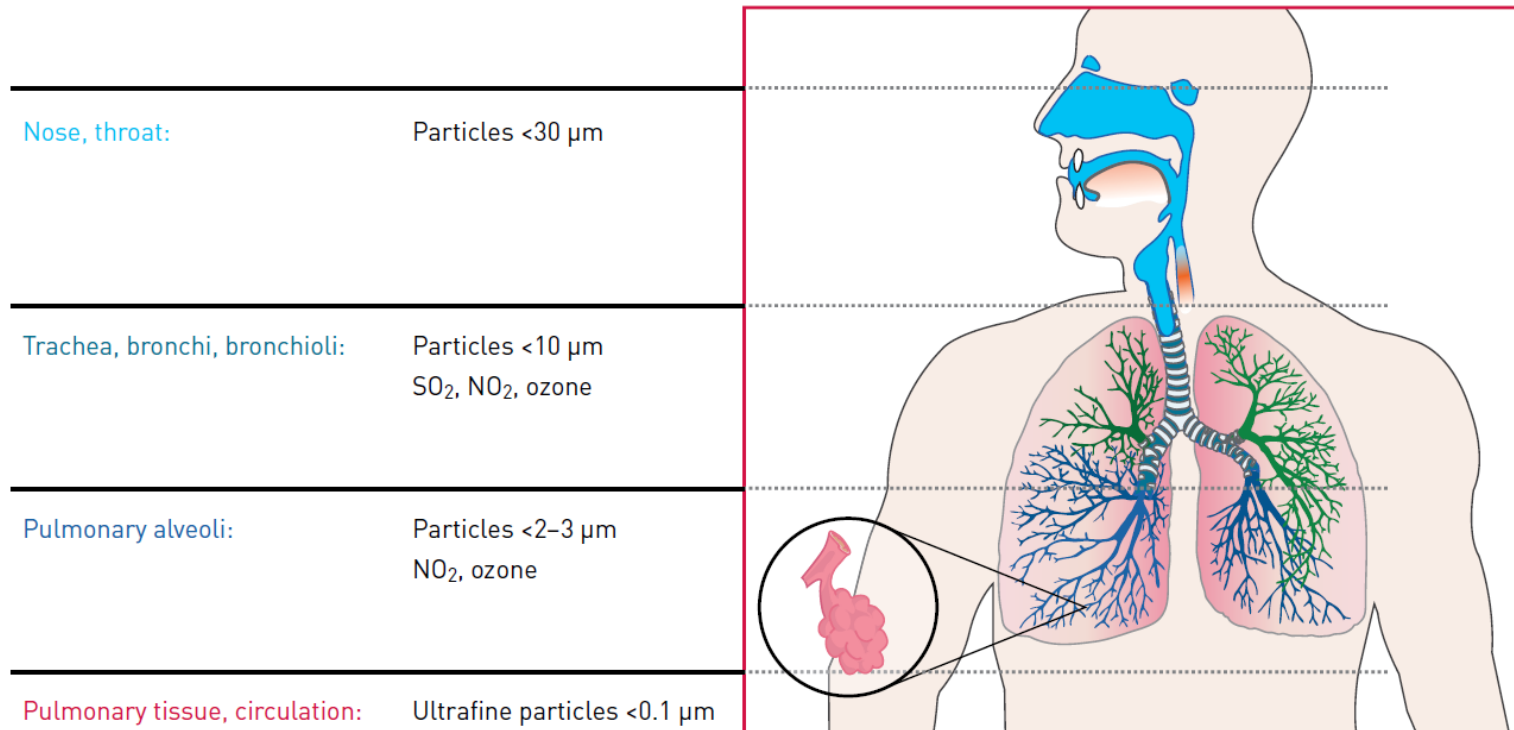
MECHANISMS OF DISEASE

Pyramid of health effects of air pollution



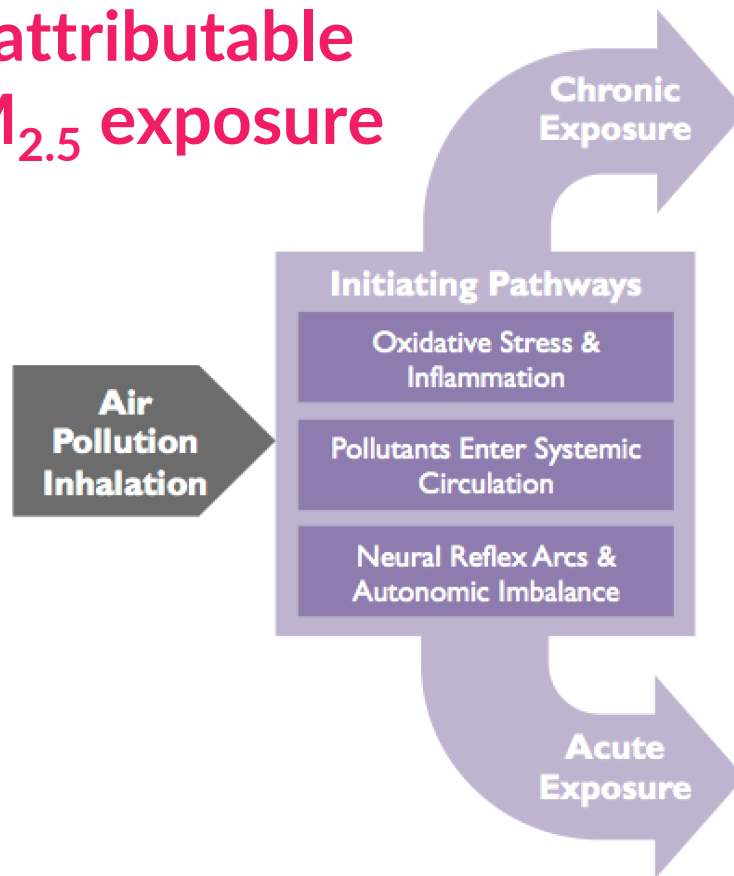
How pollutants enter the body: routes of exposure

The main pathway is through the respiratory tract. Other routes of exposure include dermal absorption and ocular exposure, as well as ingestion.

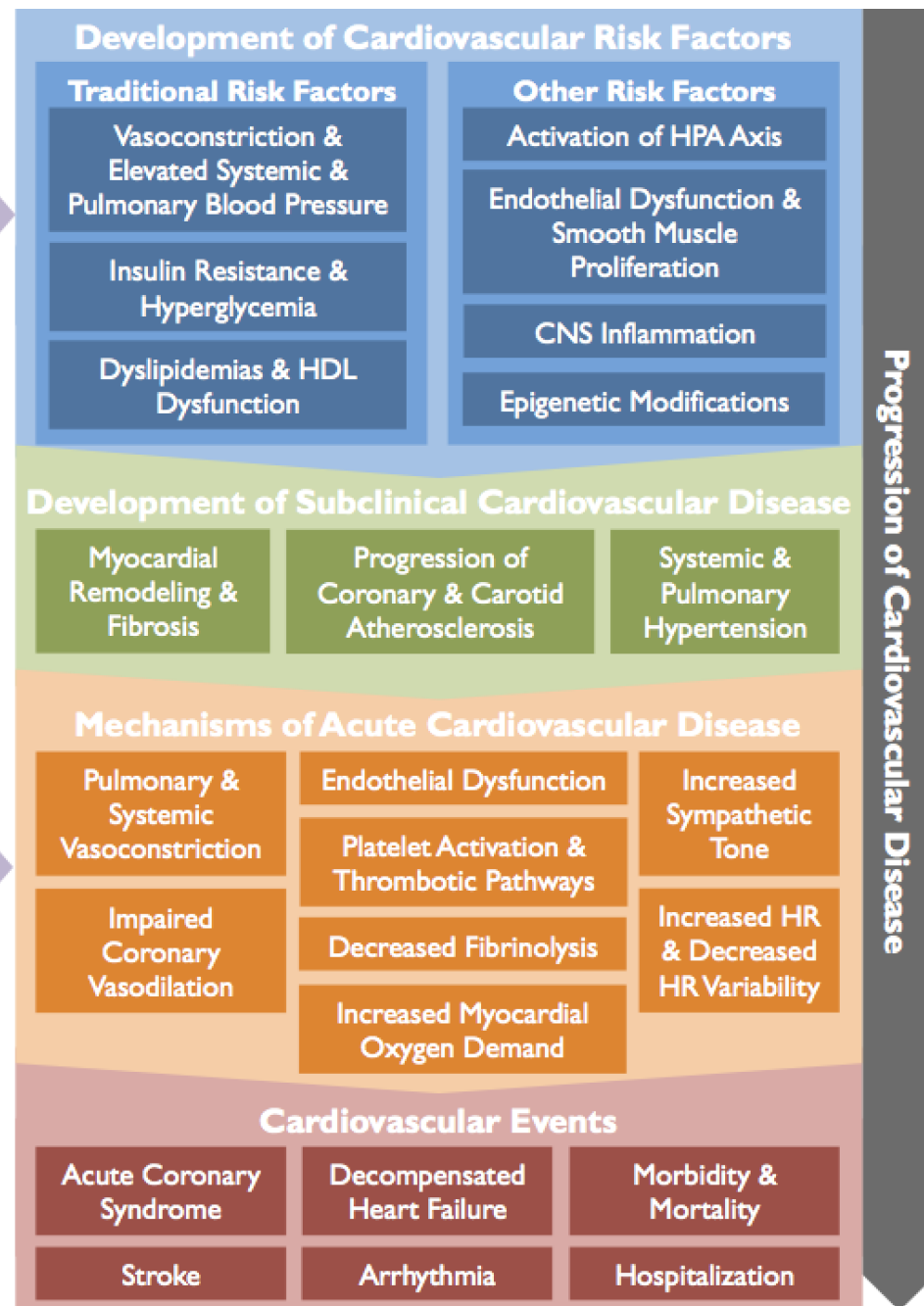


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Mechanisms of CVD attributable to PM_{2.5} exposure



Overall, there are many interrelated mechanisms underlying the development and progression of CVD attributable to exposure to air pollution.



Epidemiological evidence base

There is substantial evidence that exposure to air pollution precipitates the following.

Disease outcome	ICD-10	ICD-11
Ischaemic heart disease*	ICD10:I24.9	ICD11:BA4
Stroke*	ICD10:I63	ICD11:8B20
Heart failure	ICD10:I50	ICD11:BD10,BD11
Atrial fibrillation	ICD10:I48	ICD11:BC81.3
Hypertension	ICD10:I10	ICD11:BA00
Diabetes	ICD10:E11	ICD11:5A11

* Fatal and non-fatal





Evidence: ischaemic heart disease

PM_{2.5}, NO₂, SO₂ and CO are each associated with increased risk of myocardial infarction (MI), principally in individuals with evidence of coronary artery disease.

PM_{2.5} maintains the strongest evidence base, for example:

- a meta-analysis found that short-term exposure increases relative risk of MI;
- the ESCAPE study found that long-term PM_{2.5} exposure increases relative risk of non-fatal acute coronary events;
- a large cohort study found that exposure increases hazard ratio for IHD mortality;
- the Women's Health Initiative found exposure increased combined fatal and non-fatal coronary artery disease; and
- cohort studies found survival following MI is reduced by exposure.

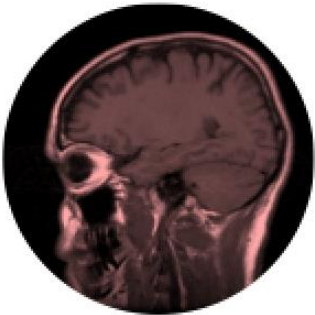
Place holder visual

Evidence: (ischaemic) stroke

$PM_{2.5}$, PM_{10} , CO and NO_2 have all been associated with stroke in China.

$PM_{2.5}$ maintains the strongest evidence base, for example:

- a meta-analysis found an increase in relative risk of stroke mortality or related hospital admission with increased exposure;
- the ESCAPE cohort found increased risk of stroke with increased exposure, with higher risk seen in never-smokers and subjects aged 60 years and older; and
- the Women's Health Initiative study found increased risk of stroke and increased risk of cerebrovascular disease with increased exposure.



Place holder visual



Evidence: heart failure

In a systematic review and meta-analysis, short-term increases in $PM_{2.5}$, PM_{10} and gaseous pollutants were associated with an increased risk of heart failure hospitalization or death.

- Subjects with pre-existing hypertension, arrhythmias, and chronic heart failure were at highest risk.
- There are no studies on long-term exposure to air pollution and the incidence of chronic heart failure.

Place holder visual



Evidence: atrial fibrillation

A meta-analysis found that exposure to higher levels of PM_{2.5} was associated with increased risk of atrial fibrillation.

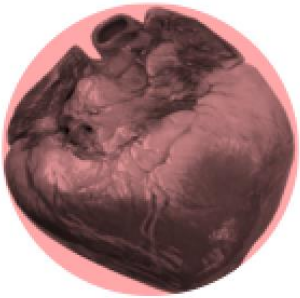
Place holder visual

Evidence: hypertension



- Meta-analyses have found that a **short-term** increase in exposure to $\text{PM}_{2.5}$ is associated with elevations in systolic and diastolic blood pressure.
- **Long-term** exposures to $\text{PM}_{2.5}$ are linked to chronic elevations in blood pressure.

Place holder visual



Evidence: atherosclerosis

- Exposure to $PM_{2.5}$ is associated with increased coronary artery calcium score, aortic calcification, carotid intima-media thickness, and plaque inflammation and vulnerability.

Place holder visual

Evidence: diabetes



- A meta-analysis demonstrated that relative risk of diabetes increases with $PM_{2.5}$ exposure.
- A different meta-analysis demonstrated that NO_2 increases the risk of diabetes with hazard ratio of 1.08.

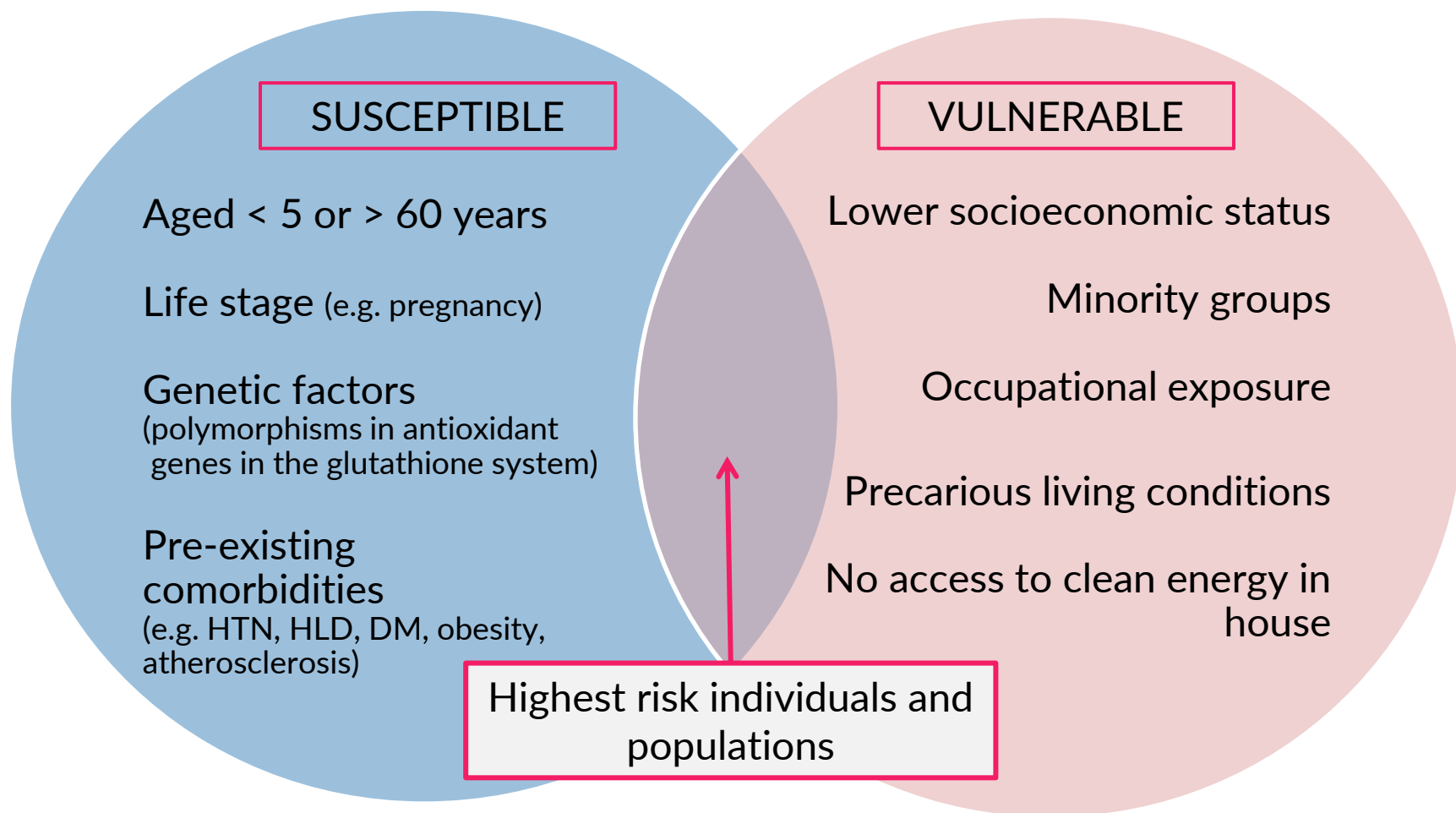
Place holder visual

3.

RISK ASSESSMENT

Identifying populations at risk

Maximize benefit by directing resources towards the groups most vulnerable and susceptible to air pollution



DM: diabetes; HLD: hyperlipidaemia; HTN: hypertension.

Individual risk assessment

- When seeing a susceptible/vulnerable patient, taking a history can identify exposures that they face in their daily lives.
- Clinicians can ask about exposures at home, while commuting, and at work or school.
- This assessment is performed alongside standard questions about CVD risk (e.g. diet, smoking).
- By identifying exposures, clinicians can design tailored interventions to mitigate CVD risk.



Individual risk assessment: an example

Clinical Screening Tool for Air Pollution Risk

An affirmative answer to any question is associated with increased cardiovascular risk.

Household Air Pollution

Does your household burn solid fuels (wood, coal, charcoal, dung, or agricultural residues) for cooking, heating, lighting or other purposes?	Yes	No
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If “yes”: *What type of fuel do you use?*
 What type of stove do you use?
 How often do you burn solid fuel?
 How much time do you spend around the fire?
 Do you burn solid fuels inside the home?
 How do you ventilate smoke from your house?

Outdoor Air Pollution

Do you live or work in an urban industrial center?	Yes	No
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If “yes”: *Are you aware of any sources of pollution near your home?*
 Do you perform physical exertion outdoors?

Do you spend time near heavy traffic (e.g., multi-lane, high-speed roads)	Yes	No
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If “yes”: *Do you commute in traffic?*
 Are you exposed to the open air when driving?
 Is your home located near major roads?

4.

INTERVENTIONS

Intervening: guiding principles

- **Target** individuals and communities that are **susceptible and vulnerable** to exposure to air pollution.
- **Seek co-benefits** (e.g. reduction of other diseases, or mitigation of climate change).
- **Prevention is key**; it is healthier and cheaper to reduce pollution than bear the costs of disease and environmental degradation.
- **Understand limitations of current research**. No trials have studied specific interventions for MI, stroke or CVD mortality. Some trials have found that certain interventions (e.g. air filters) can have an impact on markers of CVD (e.g. blood pressure).

Interventions for individuals

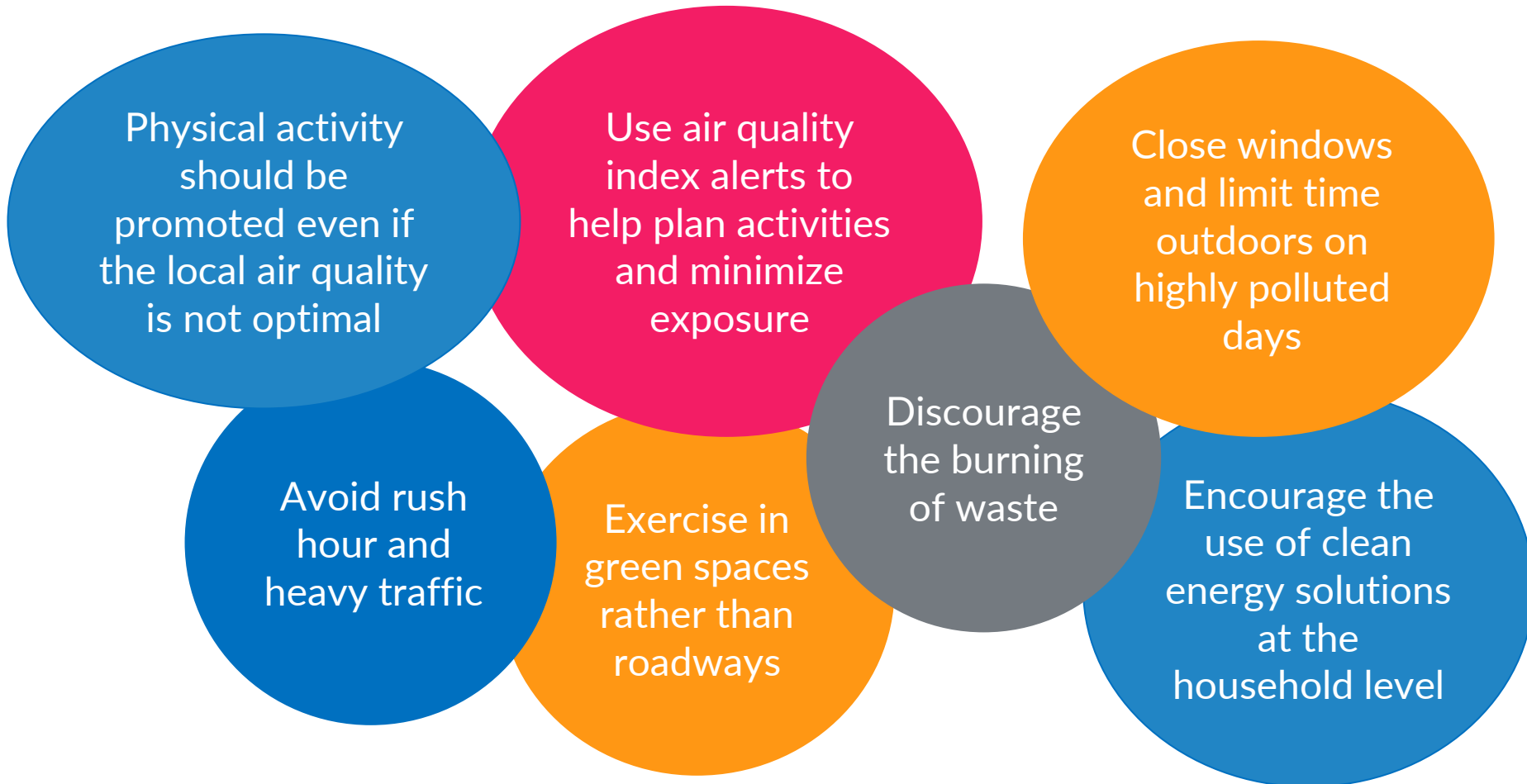
General measures

- **Education:** individuals should be educated on sources of pollution and associated risks. Reducing exposure to air pollution decreases the risk of CVD.
- **Target traditional CVD risk factors:** prevent and treat traditional risk factors to reduce susceptibility to pollution.
- **Medications:** ensure that medication is appropriate to control CVD and risk factors for CVD. Statins, antioxidants and omega-3 fatty acids have shown some degree of protective effect, but further research is needed. It is therefore currently premature to consider additional supplements/medications specifically to protect against air pollution.

Principles for protecting health against the harmful effects of ambient air pollution

What you can advise your patients to do

Behavioural modifications



Principles for protecting health against the harmful effects of household air pollution

What you can advise your patients to do



- Control household air pollution at source by exclusively using cleaner fuels and technologies such as LPG and/or electricity (avoid fuel/stove stacking).
- Ensure better ventilation of the spaces through chimneys, windows and vents.
- Reduce the time spent close to the pollution source (e.g. polluting cookstove), especially for susceptible population groups such as women and young children.

“Prescribe” clean household energy solutions for your families and communities to protect cardiovascular health!

Interventions for communities

Regulations

Regulate emissions: air quality standards, guidelines, regulations, taxes and penalties to regulate vehicles, households, buildings, and industrial and agricultural emissions.

Separate populations from pollution: zoning laws and other policies can divert traffic, relocate industry, reduce wildfires and dust, and build housing, schools or hospitals in cleaner areas.

Data sharing

Identify populations at greatest risk: exposure assessments to identify vulnerable populations that will benefit most from intervention.

Community networks: air quality monitoring and data-sharing systems, community alert networks, health-tracking and reporting systems.

Health promotion

Promote clean fuels and renewable energy: subsidies and market-based approaches for: clean fuels, low-emission stoves, air filtration devices, public transportation, electrification and renewable energy.

Education: media and education campaigns to teach communities about the risks of air pollution, as well as interventions and behavioural modifications to reduce exposure.

Clinical case study



Mrs Mutai is a 72-year-old woman with a history of hypertension and diabetes mellitus who visits Dr Chebet in Nairobi for a regular health checkup. The doctors is testing a new approach for screening and protecting patients from the harmful cardiovascular effects of air pollution. Mrs Mutai is identified as a patient at elevated risk of pollution-related cardiovascular events given her age and multiple cardiac risk factors. A brief risk assessment is performed: Mrs Mutai cooks her meals with an indoor wood-burning stove and commutes across town on a public bus. Dr Chebet locates Mrs Mutai's home on a publicly available pollution map and learns that average daily outdoor pollutant concentrations in her neighborhood are $61 \mu\text{g}/\text{m}^3$. Dr Chebet calculates that these various exposures impart an elevated risk of ischaemic heart disease and stroke.

What could Dr Chebet do?

- The health professional educates on CVD risks from air pollution and strategies to reduce her exposure.
- The patient is connected to an organization providing clean-burning gas stoves and home air filtration devices.
- The patient is connected to a community phone message service to warn her of elevated pollution levels.
- On heavily polluted days, the patient will avoid exercising outdoors and take the bus in the middle of the day to avoid rush hour.

Key messages

- Air pollution affects the cardiovascular health of nearly everyone, with the greatest health burden falling on LMICs.
- Addressing pollution-attributable CVD requires a paradigm shift from focusing on individual/traditional risks to environmental risks.
- Most of the evidence on pathophysiology and management of cardiovascular disease is attributable to particulate matter (PM). However, nitrogen dioxide (NO₂) and ozone (O₃) are also prominent pollutants that are associated with CVD.
- There is causal evidence of an impact of air pollution on ischaemic heart disease and stroke, particularly with regards to exposure to PM_{2.5}.
- There is evidence of a link between air pollution and cardiovascular diseases such as heart failure, atrial fibrillation, hypertension and type-2 diabetes.
- Growing evidence supports a set of interventions to mitigate the impact of air pollution on CVD risk.
- Clinicians can be empowered to reduce pollution-attributable cardiovascular risk in vulnerable and susceptible individuals, providing appropriate guidance and advice.
- Clinicians can be empowered to advocate for clean air policies.

Glossary

CVD Cardiovascular disease. A class of diseases involving the heart and blood vessels. Common CVDs include atherosclerosis, ischaemic heart disease, stroke, heart failure and cardiac arrhythmias.

PM_{2.5} Fine particulate matter air pollution of diameter $\leq 2.5 \mu\text{m}$. This is the pollutant best recognized as a hazard to cardiovascular health.

Clinicians Physicians, nurses, community health workers and other health professionals who work as caregivers of individuals to improve health.

Public health professionals Workers focused on improving the health of populations, via epidemiology, clinical research, environmental health, health policy or health management at both the national and local level.

Capacity-building A process by which individuals, organizations, institutions and societies develop abilities to perform functions, solve problems, and set and achieve objectives.

LMICs Low- and middle-income countries are those with a gross national income per capita of less than USD 12 376 in 2018.

Contributors and acknowledgements

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