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2024 update

Chapter 2. Air pollution

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2. Air pollution

2.1 Introduction

The combined effects from ambient (outdoor) air pollution and indoor (household, in particular) air pollution cause approximately 7 million premature deaths every year, largely as a result of increased mortality from stroke, IHD, COPD, lung cancer and acute respiratory infections *(1)*. Air pollution can occur in both the outdoor and indoor environments. Cook-stoves in homes, motor vehicles, industrial facilities and forest fires are common sources of air pollution. Air pollutants with the strongest evidence for adverse health outcomes include particulate matter (PM; both $PM_{2.5}$ (i.e. particles with an aerodynamic diameter equal to or less than 2.5 µm) and PM_{10} (i.e. particles with an aerodynamic diameter equal to or less than 10 µm), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and carbon monoxide (CO). Air pollution is however composed of many more pollutants *(1)*.

2.2 Ambient air pollution

This section contains the guidance to improve air quality in a location or country, information on the context and additional tools. While in-depth local assessments are generally needed to identify the most appropriate and efficient solutions, some lines of action are fundamental to achieve cleaner air, such as clean energy generation and transport, sustainable consumption and sound agricultural and waste management practices.

As part of local air pollution originates from sources far from the local context, some of the required action will go beyond the scope of the local practitioner, and will require action at another level, such as through international activities not addressed here *(2)*.

Many of the measures suggested also reduce those harmful emissions that lead to air pollution and climate change, and thereby create multiple benefits. Synergies between measures to reduce air pollution and those mitigating climate change should be actively sought when prioritizing action.

Overview

Air pollution originates from numerous sources of emission, both natural and anthropogenic, with the latter becoming globally dominant since the beginning of industrialization. The process of combustion is the greatest contributor to air pollution, in particular, combustion of fossil fuels and biomass to generate energy. Outdoor combustion sources include ground, air, and water transport; industry and power generation; and biomass burning, which includes controlled and uncontrolled forest and savannah fires and agricultural waste burning as well as waste burning in urban areas. Other sources and processes contributing to outdoor pollution are re-suspension of surface dust and construction activities. Long-range atmospheric transport of pollutants from distant sources contributes to local pollution, particularly urban air pollution *(3)*.

Over 90% of people live in places where the air is unhealthy to breathe, resulting in 4.2 million deaths globally each year (2016 data). Of all deaths from ambient air pollution, 38% were due to IHD, 20% were due to stroke and 43% were due to COPD *(4, 5)*.

Air pollution has an especially devastating impact on children's health and has been linked to respiratory infections, adverse birth outcomes, adverse impacts on brain development and lung function, obesity, asthma, otitis media, cancers and increased mortality *(6, 7)*. Air pollution also disproportionally affects older people.

Chapter updated in 2022

How polluted is the ambient air in my country?	When people are exposed to air pollution levels above the WHO guideline levels, they are at increased risk of health impacts, in particular cardiovascular and respiratory diseases and lung cancer. The current air quality (for PM) can be informed through the following. a. In-situ measurements: Annual mean $PM_{2.5}$ is the indicator of ambient air pollution that best predicts health impacts, and can be measured locally. Assessment of additional indicators is also useful.[1] In-situ measurements are generally provided by national or subnational institutions. In addition, a global database, the WHO Global Ambient Air Quality Database *(8)* compiles annual $PM_{2.5}$ measurements for more than 4000 cities or localities in the world. In the absence of a monitoring system, modelled satellite data or use of low-cost sensors may be considered. b. Interactive air pollution map *(9)*: This global interactive map shows modelled $PM_{2.5}$ annual concentration for every location, based on about 60 000 in-situ measurements. Other indicators and their monitoring are also relevant, such as nitrogen and sulfur dioxides, ground-level ozone, carbon monoxide, black and elemental carbon and ultrafine particles. Source apportionment of PM allows for the analysis of PM composition (e.g. with regard to sand and dust). At national level, UN Sustainable Development Goal (SDG) indicators also monitor progress related to ambient air quality. – SDG indicator 3.9.1: Mortality rate attributed to household and ambient air pollution *(10)*. – SDG indicator 11.6.2: Annual mean levels of fine particulate matter (e.g. $PM_{2.5}$ and PM_{10}) in cities (population weighted) *(10)*.
What are the main sources contributing to ambient air pollution?	Source apportionment studies assist in identifying the main sources contributing to air pollution, in view of identifying efficient strategies to reduce the pollution in the area of interest (e.g. country, district, city). Some of the air pollution sources may be obvious, or can be assessed through other means (such as estimation of emissions). While local sources contribute to air pollution, sources located further away (even hundreds of kilometres, or transboundary) are important contributors as well. A database on source apportionment studies for airborne PM is available, and a global review provides an overview *(11, 12)*. Main sources of $PM_{2.5}$ have also been estimated through modelling *(13)*.

[1] Specific information is available from national, subnational and intergovernmental institutions.

What is the air quality we want to achieve?

WHO air quality guidelines *(3)* are available for a number of pollutants and cover concentrations of pollutants in the air for different averaging times, applicable to both outdoor and indoor environments (Table 2.1). The interim targets shown in Table 2.1 are proposed as incremental steps in the reduction of air pollution and are intended for use in areas where pollution is high. Interim targets should be regarded as steps towards ultimately achieving air quality guideline (AQG) levels, rather than as end targets.

Table 2.1. Recommended AQG levels and interim targets

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, µg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
NO_2, µg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
	1-hour	–	–	–	–	200
SO_2, µg/m³	24-hour	125	50	–	–	40
	10-minute	–	–	–	–	500
CO, mg/m³	24-hour[a]	7	–	–	–	4
	8-hour	–	–	–	–	10
	1-hour	–	–	–	–	35
	15-minute	–	–	–	–	100

Source: Adapted from *(3)*.

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running average O_3 concentration.

The air quality guideline levels recommended in previous WHO air quality guidelines for pollutants and averaging times not covered in the 2021 update remain valid (the reader is referred to *Air quality guidelines for Europe (14), Air quality guidelines for Europe, 2nd edition (15); and WHO guidelines for indoor air quality: selected pollutants (16)).* A summary of all air quality guidelines is also available *(17).*

Current evidence is insufficient for guideline levels for specific types of PM, notably black carbon or elemental carbon, ultrafine particles and particles originating from sand and dust storms. Good practice statements are included in the current WHO global air quality guidelines *(3)*; some of them are included below.

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
Transport systems: policies and actions			
Note: More guidance that promotes walking and cycling is listed in Section 9.2 Environments for safe and sustainable transport, active mobility and physical activity.			
1. Develop or improve transport systems that prioritize efficiency, pollution reduction and inclusiveness; and which take into account vulnerable users, use of non-motorized transportation and alternatives to private motorized transport.[2] This includes plans for rapid urban transit and walking and cycling networks, as well as consideration of urban and regional development policies, integrated transport and spatial planning, and travel demand management *(18-21)*.	Transport Land use planning	Community; national	Infrastructure, technology and built environment; taxes and subsidies
2. Shift to cleaner lower-emission vehicles and fuels, including fuels with reduced sulfur content, for public transport, transport of goods and services and private vehicle users *(18, 21, 22)*. This may involve disincentives for the use of private vehicles.	Transport Environment	National	Taxes and subsidies; regulation; infrastructure, technology and built environment
3. Implement stricter vehicle emissions and efficiency standards *(21)*.	Transport	National	Regulation
4. Enforce mandatory inspection and maintenance for vehicles *(21, 22)*.	Transport	National	Regulation
5. Regulate the trade of used vehicles using for example age limits for imported vehicles and fiscal instruments such as age-based taxation, progressive excise tax based on CO_2 emissions or engine size, and exemptions for specific vehicles, such as hybrid electric and electric vehicles *(23)*.	Transport	National	Regulation
Industry: policies and actions			
6. Adopt improved industrial emission standards, clean technologies that reduce industrial smokestack emissions and post-emission controls *(21, 24)*.	Industry Environment	National	Regulation; infrastructure, technology and built environment
7. Enforce energy efficiency standards for industries *(21)*.	Industry Environment	National	Regulation
8. Improve efficiency and emission standards for brick kilns and coke ovens *(21)*.	Industry Environment	National	Regulation
9. Reduce industrial solvent emissions through leak detection, repairs and solvent recovery *(21)*.	Industry	National; community	Infrastructure, technology and built environment

[2] Transport, often on rapid transit (rail, bus or metro), with high passenger capacities and frequency of service, and usually separated from other traffic.

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
10. Introduce low-solvent paints *(21)*.	Industry	National	Infrastructure, technology and built environment
11. Improve existing oil and gas production by increasing recovery and use of gas released during fossil fuel production, stopping routine flaring and improving leakage control *(21)*.	Industry	National; community	Infrastructure, technology and built environment
12. Improve efficiency of existing coal mining by encouraging pre-mining recovery of coal mine gas *(21)*.	Industry	National; community	Infrastructure, technology and built environment
Power generation: policies and actions			
13. Transition away from fossil fuel combustion (oil, coal) for large-scale energy production, and diesel generators for small-scale production *(21)*.	Energy Environment	National	Taxes and subsidies; regulation; infrastructure, technology and built environment
14. Increase the use of low-emission fuels and renewable combustion-free power sources (like solar or wind); use incentives to achieve this *(21)*.	Energy Environment	National	Taxes and subsidies; infrastructure, technology and built environment; regulation
15. Increase reliance on the co-generation of heat and power, and distributed energy generation (e.g. mini-grids and rooftop solar power generation) *(21)*.	Energy	National; community	Taxes and subsidies; infrastructure, technology and built environment; regulation
Waste and wastewater management: policies and actions			
Further actions, interventions and solutions on waste management can be found in Chapter 4. Solid waste.			
16. Support waste reduction, waste separation, recycling and reuse or waste reprocessing *(21)*.	Environment Industry Waste	National; community	Taxes and subsidies; infrastructure, technology and built environment; regulation
17. Stop open waste burning *(21)*.	Environment Industry Waste	National; community	Regulation

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
18. Improve methods of biological waste management such as anaerobic waste digestion to produce biogas, and low-cost alternatives to the open incineration of solid waste. Where incineration is unavoidable, use of combustion technologies with strict emission controls are critical *(21)*.	Environment Industry Waste	National; community	Regulation; infrastructure, technology and built environment
19. Practise landfill gas recovery *(21, 25)*.	Environment Industry Waste	National; community	Infrastructure, technology and built environment
20. Introduce two-stage wastewater treatment with biogas recovery *(21)*.	Environment Water/sanitation	National; community	Infrastructure, technology and built environment
Agriculture and forestry: policies and actions			
21. Reduce or ban the burning of agricultural fields and waste *(21)*.	Agriculture Environment	National; community	Regulation
22. Alternate wet/dry rice irrigation *(21)*.	Agriculture	National; community	Infrastructure, technology and built environment
23. Improve the management of agricultural waste and livestock manure, including the capture of methane gas emitted from waste processing and waste sites *(21)*.	Agriculture Waste Environment	National; community	Infrastructure, technology and built environment
24. Improve the use of nitrogen fertilizers through efficient application; for urea use urease inhibitors and/or substitute with, for example, ammonium nitrate *(21)*.	Agriculture	National; community	Infrastructure, technology and built environment
25. Adopt improved forest, land and water management and fire prevention strategies to prevent forest and peatland fires *(21)*.	Agriculture Forestry Water	National; community	Other management and control
Housing: policies and actions			
26. Improve energy efficiency of homes and commercial buildings through insulation and passive design principles such as natural ventilation and lighting *(21)*.	Housing Construction	National community	Infrastructure, technology and built environment

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
27. Optimize ventilation methods, siting of access roads and exercise areas in order to minimize population exposure *(26)*.	Housing Construction Land use planning	National; community	Infrastructure, technology and built environment
Land use: policies and action			
28. Design land use and reallocation policies that reduce travel demand, shift transport modes towards non-motorized mobility options, ensure adequate access to public open space and favour more densely (compact and diverse) urban design and energy-efficient housing *(18)*.	Land use planning	National; community	Infrastructure, technology and built environment
29. Consider planning or redesigning sites with reduced air pollution exposure for facilities with vulnerable populations (nurseries, schools, care facilities) *(26)*.	Land use planning Health Education	National; community	Infrastructure, technology and built environment
30. Reduce dusts from construction and roads, for example by increasing green areas, their quality and management *(21, 27, 28)*.	Land use planning Construction Transport	National community	Infrastructure, technology and built environment
Other: policies and actions			
31. Consider mass sport events in locations and/or times when reduced air pollution is expected *(26)*.	Health Other sectors	National; community Universal health coverage	Other management and control
32. Consider provision of end-of-trip facilities for cycling in urban centres and at all public amenities; and design access to prioritize walking and cycling *(29)*.	Building Construction	National; community	Infrastructure, technology and built environment
33. Consider measures for reducing exposure for vulnerable occupations *(26)*.	Health Other sectors	National; community Universal health coverage	Other management and control
34. To reduce exposure to sand and dust storms *(3)*: • implement wind erosion control through carefully planned expansion of green spaces; • clean the streets in urban areas with high population density and low rainfall to prevent resuspension by road traffic as a short-term measure after intense sand and dust storms.	Land use planning Other sector	National; community	Infrastructure, technology and built environment

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
Awareness raising and capacity building			
35. Raise awareness about health effects of air pollution and personal measures to reduce air pollution. Examples include: • promote walking, cycling and other forms of active mobility *(29)*; • promote healthy diets low in red and processed meat and rich in plant-based foods *(30)*.	Health Environment	National; community Universal health coverage	Information, education and communication
36. Raise awareness about vulnerable populations including children, periods with high air pollution/high ozone levels and recommended behaviour *(5, 7, 26)*. Examples include: • schedule outdoor activities for the morning or evening when ozone is usually lower, and select less physically intense activities *(31)*; • adapt timing and intensity of physical activity to the level of air pollution *(26)*.	Health Environment	National; community Universal health coverage	Information, education and communication
37. Implement dust forecasting programmes including early warning systems and short-term air pollution action plans to alert the population to stay indoors and take personal measures to minimize exposure *(3)*.	Health Environment	National; community Universal health coverage	Information, education and communication

Selected tools
WHO 2021: *WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide (3)*
UNEP 2021: *Actions on air quality: a global summary of policies and programmes to reduce air pollution (32)*
UNEP 2021: *Regulating air quality: the first global assessment of air pollution legislation (33)*
UNEP 2020: *Frequently asked questions on air pollution (34)*
EEA 2019: *EMEP/EEA air pollutant emission inventory guidebook 2019 (35)* This report provides technical guidance to prepare national emission inventories.
WHO Regional Office for Europe 2017: *Evolution of WHO air quality guidelines: past, present and future (17)*
UNICEF 2017: *Danger in the air: how air pollution may be affecting the brain development of young children around the world (7)*
UNICEF 2016: *Clear the air for children. The impact of air pollution on children (36)*
WHO/CCAC/UNEP 2018: *The BreatheLife Campaign (37)* The campaign combines public health and climate change expertise with guidance on implementing solutions to air pollution in support of global development goals.

Selected tools
WHO Regional Office for Europe 2020: *AirQ+ software tool for health risk assessment of air pollution (38)*
WHO Regional Office for Europe 2019: *Health and Economic Assessment Tool (HEAT) for walking and cycling (39)*
UNECE 1979: *1979 Convention on Long-range Transboundary Air Pollution (40)*
The protocols of the Convention, including its protocols, programmes and activities, identify specific measures to be taken by the parties that ratified the Convention to cut their emissions.
EMEP 2020: Tools under the *Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (41)*
The United Nations Economic Commission for Europe (UNECE) also has materials on capacity building activities *(42)* and programmes *(43)*

2.3 Indoor air pollution: household air pollution, second-hand tobacco smoke, dampness and mould

This section covers guidance to improve the quality of air within and around household environments from various pollutants and polluting sources. The most important source of pollution worldwide, in particular in low- and middle-income countries,[3] comes from inefficient fuel combustion for cooking, heating and lighting, generating PM and other noxious gases. Other harmful pollutants include second-hand tobacco smoke, as well as radon and compounds released into the air from microbial growth (moulds). This section also includes information on the context and relevant tools for assessment and implementation.

Measures to reduce indoor air pollution from combustion sources overlap with those to reduce harmful emissions that contribute to ambient air pollution and climate change – and thereby create multiple benefits. Synergies between measures to reduce air pollution and those mitigating climate change should be actively sought when prioritizing action.

Most households using unclean fuels and technologies are poor. General measures to reduce poverty often will enable people to switch to cleaner fuels and technologies and thereby reduce their exposure to air pollutants.

For guidance on radon, see Section 6.4 Radon.

[3] Country income classification of low, lower-middle, upper-middle and high are determined by the World Bank and based on gross national income (GNI) per capita; see: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups and https://blogs.worldbank.org/opendata/new-country-classifications-income-level-2019-2020. Classifications are updated annually.

Chapter updated in 2022

Overview

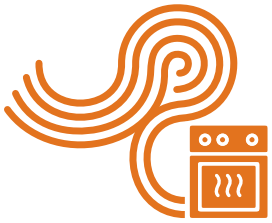
Almost half of the world's population live in households polluted with smoke from cooking with unclean fuels and technologies. Exposure is particularly high among women and young children, who spend the most time near the domestic hearth *(44)*. The fine PM (e.g. $PM_{2.5}$ and PM_{10}) component of this pollution mix leads to an estimated 3.8 million deaths per year (2016 data) *(5)*. Of those 3.8 million deaths, 27% were due to IHD, 18% were due to stroke and 54% were due to COPD. Household air pollution is responsible for 45% of all pneumonia deaths in children aged under 5 years and contributes to 28% of all pneumonia deaths in adults *(4, 44)*.

In addition, small PM and other pollutants in indoor smoke lead to airway inflammation, which impedes normal immune function and the oxygen-carrying capacity of the blood *(44)*.

Exposure to second-hand tobacco smoke and radon cause 1.3 million and 84 000 deaths per year (2019 data) respectively *(45)*.

Note: active smoking causes 7.7 million deaths per year but is not considered an environmental risk and therefore not directly considered in this compendium.

2.3.1 Particulate matter, carbon monoxide and other pollutants from incomplete combustion processes



What is the proportion of households impacted by indoor combustion in my country?

When people are exposed to household air pollution levels above the WHO air quality guidelines, they are at increased risk of health impacts, in particular cardiovascular and respiratory diseases and lung cancer, cataract and adverse pregnancy outcomes.

The proportion of households using polluting or unclean fuels and technologies can be informed through the following.

a. Household surveys: Household surveys are used to assess the proportion of households mainly using clean fuels and technologies used for cooking, heating and lighting. Harmonized household energy survey questions are available to assist in this assessment *(46)*.

b. Global database on clean fuel and technology use *(4)*: Energy use at household level is monitored by an SDG indicator *(10)*: 7.1.2 – Proportion of population with primary reliance on clean fuels and technology.

   WHO data on this indicator are available in this global database with estimates of the proportion of the population cooking with clean fuels and technologies by country, based on recent household surveys; this database is used for SDG reporting *(47)*.

c. Global household energy database *(48)*: WHO maintains an exhaustive database that compiles all nationally representative survey data on fuels and technologies used for cooking, heating and lighting.

What is the proportion of households impacted by indoor combustion in my country?

Conducting field measurements of household air pollution is not required (although encouraged); use of the resources above to ascertain the extent of polluting fuel use for cooking should be sufficient to motivate action to expand clean household energy in the home. However, if there is interest in monitoring the level of household air pollution, this can be assessed through the following.

a. In-situ measurements: Guidance on how to collect household and personal $PM_{2.5}$[4] and carbon monoxide measurements is provided by WHO *(49)*.

b. Global database of household air pollution measurements *(50)*: This database contains household air pollution measurements (household and/or personal measurements) collected in hundreds of studies.

What is the contribution of residential biomass burning to ambient air pollution?

The contribution of domestic fuel burning to ambient air pollution can be estimated through source apportionment studies.

A database on source apportionment studies for airborne PM is available, and a global review provides an overview *(11, 12)*.

What is the indoor air quality we want to achieve?

WHO air quality guidelines are available for a number of pollutants and cover concentrations of pollutants in the air. Worldwide, the most important indoor air health hazard originates from PM due to combustion. Health-based guideline values include the following maximum values and interim targets (Table 2.2). Interim targets are proposed as incremental steps in the reduction of air pollution and are intended for use in areas where pollution is high *(3)*. Interim targets should be regarded as steps towards ultimately achieving AQG levels, rather than as end targets.

Table 2.2. AQG levels and interim targets for selected (indoor) air

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
CO, mg/m³	24-hour[a]	7	–	–	–	4
	8-hour	–	–	–	–	10
	1-hour	–	–	–	–	35
	15-minute	–	–	–	–	100

Source: Adapted from *(3)*

[a] 99th percentile (i.e. 3–4 exceedance days per year).

Additional information, including on other pollutants, is available:

- *WHO global air quality guidelines. Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide (3);*
- *WHO guidelines for indoor air quality: household fuel combustion (51);*
- *WHO guidelines for indoor air quality: selected pollutants (16).*

[4] That is, particles with an aerodynamic diameter equal or less than 2.5 micrometre.

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
General: policies and actions			
1. 1. Develop or update policies and strategies to meet the following device and fuel emission rate targets for household fuel combustion *(51)*: $PM_{2.5}$ (unvented): 0.23 mg/min $PM_{2.5}$ (vented): 0.80 mg/min Carbon monoxide (unvented): 0.16 g/min Carbon monoxide (vented): 0.59 g/min Where intermediate steps are necessary, transition fuels and technologies that offer substantial health benefits should be prioritized.	Environment Health	National	Regulation
2. Establish effective mechanisms for policy coordination at government level, to address the challenge of taking action by multiple sectors to address household energy *(51)*.	Environment Health Other sectors	National	Governance
3. Conduct systematic monitoring and evaluation of policies that promote progress towards cleaner fuels and technologies for household energy *(51)*.	Environment Health Other sectors	National	Assessment and surveillance
Use of clean fuels and technologies: policies and actions			
4. Support implementation of clean cooking solutions: a combination of fuel and technology for cooking that is considered clean for health. A cooking device burning biomass is classified as clean if it meets the emission rate targets in the WHO *Guidelines for indoor air quality: household fuel combustion*, according to the international laboratory testing protocol and tested by a third party *(21, 51, 52)*.	Health Environment Energy Industry	National; community Universal health coverage	Taxes and subsidies; infrastructure, technology and built environment; regulation
5. Support implementation of clean space heating solutions – a combination of fuel and technology that is considered clean for health. A heating device burning biomass is classified as clean if it meets the emission rate targets in the WHO Guidelines for indoor air quality: household fuel combustion, according to the international laboratory testing protocol and tested by a third party *(21, 51, 52)*.	Health Industry Environment	National; community Universal health coverage	Taxes and subsidies; regulation
6. Support implementation of clean lighting solutions – a combination of fuel and technology that is considered clean for health *(21, 51, 52)*.	Health Environment	National; community Universal health coverage	Taxes and subsidies; regulation

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
7. Restrict using unprocessed[5] coal as a household fuel *(51)*.	Health Environment	National; community Universal health coverage	Regulation
8. Discourage use of kerosene as a household fuel until data show its safety *(51)*.	Health Environment	National; community Universal health coverage	Regulation; information, education and communication
9. Improve energy efficiency of household appliances, buildings, lighting, heating and cooling *(21)*.	Housing Industry Energy	National; community	Infrastructure, technology and built environment
10. Encourage solar and wind-based electricity; support installation of rooftop solar panels *(21, 52)*.	Housing Industry Energy	National; community	Infrastructure, technology and built environment
11. Subsidize or exempt tax on cleaner fuels and improved technologies for household cooking, heating and lighting *(52)*.	Finance Environment Other sectors	National; community	Taxes and subsidies
12. Foster consumer credit/lease arrangements for cook-stove purchases (52).	Finance Industry	National; community	Taxes and subsidies
13. Make available microfinance schemes to help entrepreneurs and small businesses set up kiosks to sell or service cleaner technologies, such as solar light charging points *(52)*.	Finance Industry	National; community	Taxes and subsidies
14. Develop/adopt standards for laboratory testing of cook-stoves, including PM and carbon monoxide emissions and safety (which are in line with the WHO *Guidelines for indoor air quality: household fuel combustion (51)*), *such as Household air pollution: interventions & tools (52)* or ISO 19867-1:2018 *(53)*.	Health Industry Environment	National	Regulation
15. Implement third-party emission rate testing before promoting a technology or fuel, optimally including measuring of actual air pollution levels during everyday use in homes *(51)*.	Health Environment	National	Regulation
Housing: policies and actions			

[5] Which has not been treated by chemical, physical or thermal means to reduce contaminants.

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
16. Reduce the need for extra heating or cooling by designing homes that utilize passive heating and cooling principles *(52)*.	Housing Construction	National; community	Infrastructure, technology and built environment
17. Incorporate adequate ventilation sources into homes to vent smoke from cooking, heating and lighting activities *(52)*.	Housing Construction	National; community	Infrastructure, technology and built environment
Awareness raising and capacity building			
18. Encourage health-protective behaviour appropriate to the local setting, such as cooking outdoors, improving ventilation, spending less time close to the smoky cooking and heating hearths, drying fuel wood before use and using lids on pots to shorten cooking time *(31)*.	Health	National; community Universal health coverage	Information, education and communication
19. Promote replacing traditional household solid fuel cook-stoves with lower-emission cook-stoves *(37, 51, 54)*.	Health Environment	National; community Universal health coverage	Information, education and communication
20. Conduct awareness raising activities to promote behaviour change for use of cleaner technologies and fuel use *(51, 55)*.	Health Environment	National; community Universal health coverage	Information, education and communication
21. Implement labelling scheme for cooking devices and fuels with information for consumers on whether device emissions are safe for health *(51)*.	Health Environment	National	Information, education and communication

Selected tools
WHO 2021: *WHO global air quality guidelines. Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide (3)*
WHO/CCAC/UNEP 2018: *The BreatheLife Campaign (37)* The campaign combines public health and climate change expertise with guidance on implementing solutions to air pollution in support of global development goals.
WHO 2018: *Clean Household Energy Solutions Toolkit (CHEST) (56)* A step-by-step guide and tools to support the implementation of the WHO *Guidelines for indoor air quality: household fuel combustion (51).* The module Guidance on Standards and Testing provides practical guidance on setting national standards for and testing of cook-stoves and clean cooking solutions.
WHO 2020: *Household Energy Assessment Rapid Tool (HEART) for Situational Assessment and Stakeholder Mapping (57)* This tool is a component of the WHO CHEST.
WHO 2020: *Household Multiple Emission Sources (HOMES) model (58)* This model helps planners and policy-makers estimate the pollution concentration (PM, CO) that will result from the use of different cook-stoves or devices in different settings.
WHO 2020: *Performance Target (PT) model (59)* This model calculates the emission performance of cook-stoves or other household energy devices (e.g. space heaters or lights). The primary application of the PT model is to derive context-specific targets (or tiers) for PM and carbon monoxide emissions, such as tier of performance for cook-stoves when locally collected data are available.
Clean Cooking Alliance 2020: *Clean cooking catalogue (60)* This catalogue contains a list of cooking fuels and technologies with emissions data from laboratory testing.
WHO 2008: *Evaluating household energy and health interventions: a catalogue of methods (49)* This catalogue includes information on evaluating laboratory performance, cook-stove adoption and use, household and personal concentrations of various pollutants, including exposure levels, health and safety, economic impacts and more.

2.3.2 Environmental impacts of tobacco: second-hand tobacco smoke and environmental pollution

This section particularly relates to exposure to second-hand tobacco smoke and the environmental pollution that results from tobacco agriculture and the production and use of tobacco products. This section focuses on air pollution, so the environmental impacts of tobacco and tobacco use are discussed here, although other issues are also covered. Specific guidance about preventing and stopping tobacco use and related interventions can be found on the WHO website *(61)*.

Overview

Tobacco pollutes the planet and damages the health of all people *(62)*. More than 8 million deaths are attributable to tobacco each year. More than 7 million of those deaths are the direct result of tobacco use (e.g. active smoking, the immense health impacts of which are not addressed in this chapter). An estimated 1.3 million deaths are the result of nonsmokers being exposed to second-hand smoke (i.e. tobacco smoke that is present in the environment during and after smoking), which is proven to cause cancer and cardiovascular, respiratory and other diseases *(63, 64)*. Moreover, the use of tobacco pollutes the air and leaves third-hand smoke toxins on surfaces (i.e. residual pollutants that remain on surfaces and in dust after tobacco has been smoked) *(65)* that harm smokers and nonsmokers *(66)*. It is estimated that in the United States alone, cigarette smoking cost US$ 600 billion in 2018. Of this total amount, US$ 7 billion resulted from lost productivity due to premature deaths caused by exposure to second-hand smoke *(67)*. The costs of tobacco's impact on health and the environment are underestimated (e.g. the economic cost of waste generated by the tobacco industry, its contribution to climate change and the loss in productivity resulting from poor health among farmers). More research is needed to better understand the full cost of the tobacco epidemic *(66, 68)*.

The toxic mix in tobacco smoke contains more than 7 000 chemicals, and at least 70 are known to cause cancer in humans and animals *(66)*; the chemicals are similar to those resulting from other incomplete combustion processes and include additional ones that are specific to tobacco smoke. This smoke is often measured as particulate matter. Children and infants are particularly susceptible to second-hand smoke, and exposure puts them at increased risk for respiratory disease, ear infections and sudden infant death syndrome. Exposure to tobacco smoke occurs mostly in private settings, such as homes, and has a disproportionate impact on children and women *(67)*.

Exposure to second-hand smoke is an urgent public health concern due to its pervasive and severe health risks. It has been acknowledged as one of the three time-bound measures in the WHO Framework Convention on Tobacco Control (FCTC) due to its significant impact on nonsmokers' health. In recognition of its immediate and detrimental effects, addressing exposure to second-hand smoke became a critical goal within the WHO FCTC to safeguard the health of individuals globally *(69, 70)*. Comprehensive laws to ensure smoke-free environments result in reduced exposure to second-hand smoke, reduced hospital admissions for acute coronary syndrome and reduced mortality from smoking-related illnesses, including reduced infant mortality *(67)*.

Growing tobacco, producing tobacco products, and packaging and transporting them have widespread environmental impacts through generating substantial amounts of greenhouse gas emissions; causing deforestation (up to 5% of global deforestation is associated with growing and curing tobacco, further contributing to CO_2 emissions and climate change) and soil and water depletion; and generating waste, including toxic waste *(62, 66)*. In particular, cigarette butts create large amounts of toxic waste, and there is growing public concern regarding environmental plastic pollution resulting from single-use cellulose acetate cigarette filters, which do not have any proven health benefits and harm the environment *(71)*. The problem of waste is aggravated by the growing number of single-use electronic smoking devices and nicotine delivery products, which contain metals, plastics and batteries, thus increasing the amount of toxic waste produced *(66)*.

Growing tobacco is resource intensive and requires the heavy use of pesticides, fertilizers and water, which contribute to soil degradation and contamination. This means that land used for growing tobacco has less capacity to support growing other crops, such as food *(62, 66)*.

Tobacco farmers and their families are exposed to several health risks. For example, about 25% of tobacco farmers suffer from green tobacco sickness, caused by nicotine absorbed while handling tobacco leaves. They are also exposed to harmful substances, such as tobacco dust and pesticides. Additionally, tobacco farmers often carry harmful substances home on their bodies, clothes or shoes, leading to tertiary exposure for their families. Children are especially vulnerable due to their smaller size and greater nicotine absorption through the skin. Pregnant women are at higher risk of miscarriage *(62, 66)*.

What is the proportion of people impacted by second-hand tobacco smoke in my country?	Information about current exposure to second-hand tobacco smoke can be found through the following websites: – national and regional household surveys, such as the Global Adult Tobacco Survey *(72, 73)* and the Global Youth Tobacco Survey *(74, 75)*; – WHO's STEPwise approach to risk factor surveillance (STEPS) for noncommunicable diseases (NCDs) *(76)*; the STEPS approach is a simple, standardized method for collecting, analysing and disseminating data about NCDs and risk factors; – Global Burden of Disease estimates for second-hand tobacco smoke *(64)*.
What levels of exposure to second-hand tobacco smoke do we want to achieve?	There is no safe level of exposure to tobacco smoke. Only 100% smoke-free indoor environments without any exceptions – such as for designated smoking areas or smoking rooms – are proven to protect health *(67, 69)*. Note: Indoor areas include any space covered by a roof or enclosed by one or more walls or sides, regardless of the type of material used for the roof, wall or sides, and regardless of whether the structure is permanent or temporary *(69)*.
What are the environmental impacts resulting from tobacco in my country?	Despite the challenges that might be faced in collecting most of these data, the environmental impact resulting from tobacco can be assessed by: – collecting data about water use, deforestation, soil depletion and the chemicals in tobacco products, including those that are lethal and those that degrade the environment, and about the environmental harm caused by these components to soil, drinking-water and human and animal health; – estimating the total amount of waste from tobacco products, as well as its impact and the total environmental impact of a single tobacco product; ◦ to inform health policy and practice and improve public health outcomes, governments and society can benefit from cost estimates of preventing, properly disposing of and cleaning up tobacco product waste, and these estimates could motivate a shift in accountability for the costs of tobacco product waste to the global tobacco industry *(77)*.

The Guidance table provides an overview of the most relevant advice from WHO and other UN organizations. The guidance is further classified according to principally involved sectors, level of implementation, instruments and evidence category.

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments	Category of evidence
Policies and actions: Reducing tobacco use				
1. Comprehensively implement the WHO FCTC *(70)*. To help countries implement the WHO FCTC, WHO introduced MPOWER *(78)*, a package of technical measures and resources intended to assist in the country-level implementation of effective interventions to reduce the demand for tobacco. MPOWER builds the capacity of countries to implement six measures to reduce the demand for tobacco products by: • monitoring policies for tobacco use and prevention; • protecting people from tobacco use; • offering help to quit tobacco use; • warning about the dangers of tobacco; • enforcing bans on tobacco advertising, promotion and sponsorship; • raising taxes on tobacco.	Health Multiple sectors	National	Regulation; governance	A, B
2. Ban smoking in all public indoor areas, including but not limited to public transport; workplaces; health institutions; educational and government facilities; universities; retail shops and shopping malls; hospitality and catering facilities, such as restaurants, pubs, bars, hotels, and community and sports centres; manufacturing and processing plants; and all public areas in multiple-unit dwellings, including lobbies, elevators and stairwells *(69, 79)*.	Multiple sectors	National	Regulation	A, B
3. Protect tobacco control policies from commercial interests and others with vested interests in the tobacco industry *(70)*.	Multiple sectors	National	Regulation	A, B
4. Refrain from approaches that do not aim to ensure a 100% smoke-free indoor environment *(67, 69)*. Other approaches – such as ventilation, air filtration and the use of designated smoking areas – are ineffective to sufficiently protect the health of the population.	Multiple sectors	National	Regulation	A, B
5. Consider making outdoor or quasi-outdoor areas and public places smoke-free, for example playgrounds, parks, beaches, outdoor stadiums and patios *(67)*. This will also reduce tobacco product waste from smoked cigarettes, which contains more than 7 000 toxic chemicals, including 70 known human carcinogens that leach into and accumulate in the environment *(68)*.	Multiple sectors	National	Regulation	B
6. Monitor compliance with smoking bans, and impose legal responsibilities both on businesses and individual smokers, specifying fines or administrative sanctions for violations, or both *(69)*.	Multiple sectors	National	Assessment and surveillance; regulation	A

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments	Category of evidence
7. Require managers or owners of public establishments to implement the smoking ban *(67, 69)*. Key actions might include: • posting signs at entrances that clearly state smoking is not permitted; • displaying clear instructions about how to report a violation; • removing ashtrays from premises; • supervising observance of the rules; • discouraging individuals from smoking by asking them not to smoke. In case of noncompliance, encourage owners or managers to: • discontinue service; • ask the person to leave the premises; • contact a law enforcement agency.	Multiple sectors	National	Regulation; other management and control; assessment and surveillance	A, B
8. Implement inspections to ensure compliance with nonsmoking policies in all businesses and workplaces *(67, 69)*.	Multiple sectors	National	Assessment and surveillance	A, B
9. Implement national smoking cessation services, ideally with full cost coverage *(67, 70)*.	Multiple sectors	National	Other management and control	A, B
Policies and actions: reducing the environmental impact of tobacco				
10. Impose on the tobacco industry the policy principle of "extended producer responsibility" (based on the "polluter pays" principle) to hold it accountable for the risks posed to the environment and the costs of cleaning up tobacco product waste *(62, 66, 68)*. This means that the tobacco industry should be responsible for the cost of cleaning up improperly discarded waste from tobacco products, among other responsibilities *(66)*.	Environment Industry	National	Regulation	B
11. Require tobacco manufacturers to supply timely and regular information and data about the environmental and health risks of tobacco throughout the production and distribution processes *(68)*.	Environment Agriculture Industry	National	Regulation; assessment and surveillance	B
12. Levy an environmental tax on tobacco manufacturers, distributors and consumers, across the supply chain, to account for carbon emissions, air pollution and other environmental costs *(66)*. Levying an environmental tax on tobacco products adds an additional charge to their cost, and the revenue generated can be directed towards environmental protection and restoration efforts.	Environment Industry Transport	National	Regulation	B

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments	Category of evidence
13. Progressively ban single-use plastics, including cigarette filters, which do not have any proven health benefit and are known to harm the environment *(66)*.	Industry	National	Regulation	B
14. Stop providing direct tobacco subsidies to tobacco farming and reallocate them to tobacco control programmes (e.g. support alternative livelihoods for tobacco farmers) *(62, 66)*.	Agriculture Food	National; community	Governance	B
15. Strengthen the regulation of tobacco agriculture to prevent deforestation and land degradation *(68)*.	Environment Agriculture	National	Regulation	B
16. Support academic and intergovernmental organizations to collect data about water use, deforestation, soil depletion and the chemicals in tobacco products that are lethal and degrade the environment so the total environmental impact of tobacco can be estimated *(66)*, and make this evidence available to policy-makers *(68)*.	Industry Environment Education	National	Assessment and surveillance	B
Awareness-raising and capacity-building				
17. Raise awareness about the risks of exposure to second-hand tobacco smoke (e.g. through information campaigns and community engagement sessions), and implement educational strategies to reduce exposure to second-hand smoke in homes *(67, 69)*.	Health	National; community Universal health coverage	Information, education and communication	A, B
18. Raise awareness about the environmental impacts of tobacco across the life cycle, including impacts from cultivation to production, distribution, use and waste *(66, 68)*. This might also include raising awareness about the tobacco industry's greenwashing tactics, as well as raising awareness among farmers and informing them about viable alternative livelihoods and the benefits of switching to other value chains *(62, 66)*.	Environment Multiple sectors	National; community	Information, education and communication	B
19. Inform, consult with and involve the public by clearly explaining the purpose of a smoking ban to ensure support and smooth implementation. This may involve engaging the community in monitoring compliance and reporting violations, for example by establishing a free telephone complaint hotline or similar system *(69)*.	Health	National; community Universal health coverage	Information, education and communication; assessment and surveillance	A

FCTC: WHO Framework Convention on Tobacco Control; MPOWER: monitoring tobacco use; protecting people from tobacco smoke; offering help to quit tobacco; warning about the dangers of tobacco; enforcing bans on tobacco advertising, promotion and sponsorship; raising taxes on tobacco.

A – WHO guideline, B – WHO best practice/strategy, C – other UN best practice/strategy

Selected resources for the Guidance table

Please note that only selected references are listed here. Please consult the reference section for all cited resources.

WHO 2023: WHO report on the global tobacco epidemic, 2023: protect people from tobacco smoke *(67)* – This report tracks the progress made in tobacco control by countries since 2008 and marks 15 years since the introduction of the MPOWER technical package *(78)*, which is designed to help countries implement the demand-reduction measures of the WHO FCTC.

WHO 2022: Tobacco: poisoning our planet (66) – This report not only describes the health risks of tobacco but also the environmental risks of tobacco cultivation, production, distribution, consumption and waste.

WHO 2017: Tobacco and its environmental impact: an overview *(68)* – This overview assembles evidence from an environmental perspective about the ways in which tobacco affects human well-being.

WHO 2013: Guidelines for implementation of Article 8: WHO Framework Convention on Tobacco Control. Protection from exposure to tobacco smoke *(69)* – These guidelines contain recommendations for the steps required to satisfy the obligations of the Convention and to achieve effective protection from the hazards of second-hand tobacco smoke.

WHO 2003: WHO Framework Convention on Tobacco Control *(70)* – The WHO FCTC was the first treaty negotiated under the auspices of the World Health Organization.

Additional selected tools and further resources

This list contains additional selected material that is not cited in the Guidance table.

WHO 2024: Noncommunicable disease surveillance, monitoring and reporting: STEPwise approach to NCD risk factor surveillance (STEPS) [website] *(76)* – STEPS is a simple, standardized method for collecting, analysing and disseminating data about NCDs and their risk factors.

WHO 2023: Heated tobacco products: summary of research and evidence of health impacts *(80)* – This policy brief summarizes the eighth report of the WHO Study Group on Tobacco Product Regulation *(81)*, which addresses novel and emerging nicotine and tobacco products and provides a quick reference guide for countries.

WHO Regional Office for Europe 2023: Nicotine- and tobacco-free schools: policy development and implementation toolkit *(82)* – This toolkit provides practical advice about developing policies to ensure nicotine- and tobacco-free schools.

WHO 2022: Q&A: World No Tobacco Day 2022 [website] *(83)* –This website provides information in the format of questions and answers about multiple issues, including the environmental impacts of tobacco (e.g. deforestation, soil depletion, water and air pollution, and waste).

Lam et al. 2022: *Modelling the global economic costs of tobacco product waste (77)* – This article proposes an approach to estimate the economic costs of waste from tobacco products based on its negative environmental externalities.

WHO 2020: How to make your campus smoke-free *(84)* – This step-by-step guide provides support for establishing smoke-free campuses.

WHO 2019: Second-hand smoke: training for health care providers, second edition *(85)* – This set of slides provides an overview of the health effects of tobacco and second-hand tobacco smoke, and addresses the special vulnerability of children. It describes strategies to prevent and reduce exposure to second-hand smoke.

WHO 2018: Cigarette smoking: an assessment of tobacco's global environmental footprint across its entire supply chain, and policy strategies to reduce it *(86)* – This report assesses all of the resources needed across the tobacco supply chain and the environmental impact of tobacco smoking.

WHO, UN Development Programme 2017: The WHO Framework Convention on Tobacco Control: an accelerator for sustainable development *(87)* – This discussion paper supports the integration of tobacco control efforts as part of implementation of the Sustainable Development Goals *(88)*.

2.3.3 Dampness and mould

This section summarizes measures to control mould growth indoors. The most important means for avoiding adverse health effects is the prevention (or minimization) of persistent dampness and microbial growth on interior surfaces and in building structures.

Overview

Indoor moisture can lead to microbial pollution caused by hundreds of species of bacteria and fungi, in particular filamentous fungi (mould), growing indoors. The most important effects are increased prevalence of respiratory symptoms, allergies and asthma as well as perturbation of the immunological system.

What is the indoor air quality we want to achieve?

Persistent dampness and microbial growth on interior surfaces and in building structures should be avoided or minimized, as they may lead to adverse health effects *(89)*.

Additional information, including on other pollutants, is available: *WHO guidelines for indoor air quality: dampness and mould (89)*.

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
Policies and actions: prevention of dampness and mould			
1. Develop comprehensive national regulations, strategies and campaigns about healthy buildings that include dampness and mould prevention *(90)*	Housing Construction Health	National	Regulation
2. Equip local authorities with a clear mandate and sufficient resources to work on the prevention of dampness and mould *(90)*.	Housing Construction	National	Governance
3. Implement preventive measures against dampness and mould in building design and construction such as adequate insulation, ventilation and heating *(90)*. Building design and construction needs to consider climate, culture, location and intended use.	Housing Construction	National; community	Other management and control; infrastructure, technology and built environment
4. Implement regular professional building inspection and maintenance *(90)*.	Housing Construction	National; community	Assessment and surveillance; other management and control

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
Policies and actions: existing dampness and mould			
5. Provide targeted and easy-to-access information by health, housing and consumer protection agencies, which tend to be the first agencies contacted for support *(90)*.	Housing Construction Health	National; community	Information, education and communication
6. Ensure prompt and adequate remediation including both moisture control and mould abatement *(90)*.	Housing Construction	National; community	Other management and control
7. Remove or mechanically clean all mould and contaminated materials *(90)*.	Housing Construction	National; community	Other management and control
8. Identify the root causes of damp, moisture or mould occurrence *(90)*. Selected key actions include: • identify and address indoor and outdoor sources of dampness; • improve thermal insulation; • control or adapt ventilation; • increase indoor temperatures as necessary.	Housing Construction	National; community	Assessment and surveillance; other management and control
9. Avoid the use of biocides and/or chemical compounds for the prevention of mould and, to the extent possible, minimize their use in mould remediation *(90)*.	Housing Construction	National; community	Other management and control
Awareness raising and capacity building			
10. Develop and disseminate information to the public with a focus on vulnerable population groups – such as people with asthma, allergies or respiratory disorders; those immunocompromised; and children, older people and people living in substandard housing *(90)*. This should entail information on the health effects of indoor dampness and mould, advice on preventing dampness and excessive moisture (e.g. through information on adequate residential behaviour, ventilation and building maintenance) and on suitable steps to take if mould growth does occur.	Health Housing Construction	National; community Universal health coverage	Information, education and communication
11. Implement appropriate training and education curricula within the housing and construction sectors to address the relevance of building quality and its links to health *(90)*.	Housing Construction Health	National	Information, education and communication

Guidance	Sector principally involved in planning/ implementation	Level of implementation	Instruments
12. Raise awareness among building users about key indicators and signs that indicate problems with moisture or mould *(90)*.	Housing Construction Health	National; community Universal health coverage	Information, education and communication
13. Raise awareness among building owners about their responsibility for providing healthy workplaces or living environments that are free of excessive moisture and mould *(90)*.	Health Housing Construction	National; community Universal health coverage	Information, education and communication
14. Raise awareness among the health sector about key indicators and typical health outcomes associated with indoor environments *(90)*.	Health	National; community Universal health coverage	Information, education and communication
15. Develop housing manuals that summarize the operative tasks and challenges of the building, its construction style and its equipment as a guidance and information tool for building users *(90)*.	Housing Construction	National; community	Information, education and communication

Selected tools
WHO Regional Office for Europe 2010: *Technical and policy recommendations to reduce health risks due to dampness and mould (90)*
WHO Regional Office for Europe/Health and Environment Alliance 2009: *Damp and mould: health risks, prevention and remedial actions. Information brochure (91)*
WHO Regional Office for Europe 2007: *Guidelines for indoor air quality: dampness and mould (89)*

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