RAPIDC
Regional Air Pollution in Developing Countries

SEI STOCKHOLM ENVIRONMENT INSTITUTE

Typical concentrations of air pollutants, air quality guidelines and standards

Presentation
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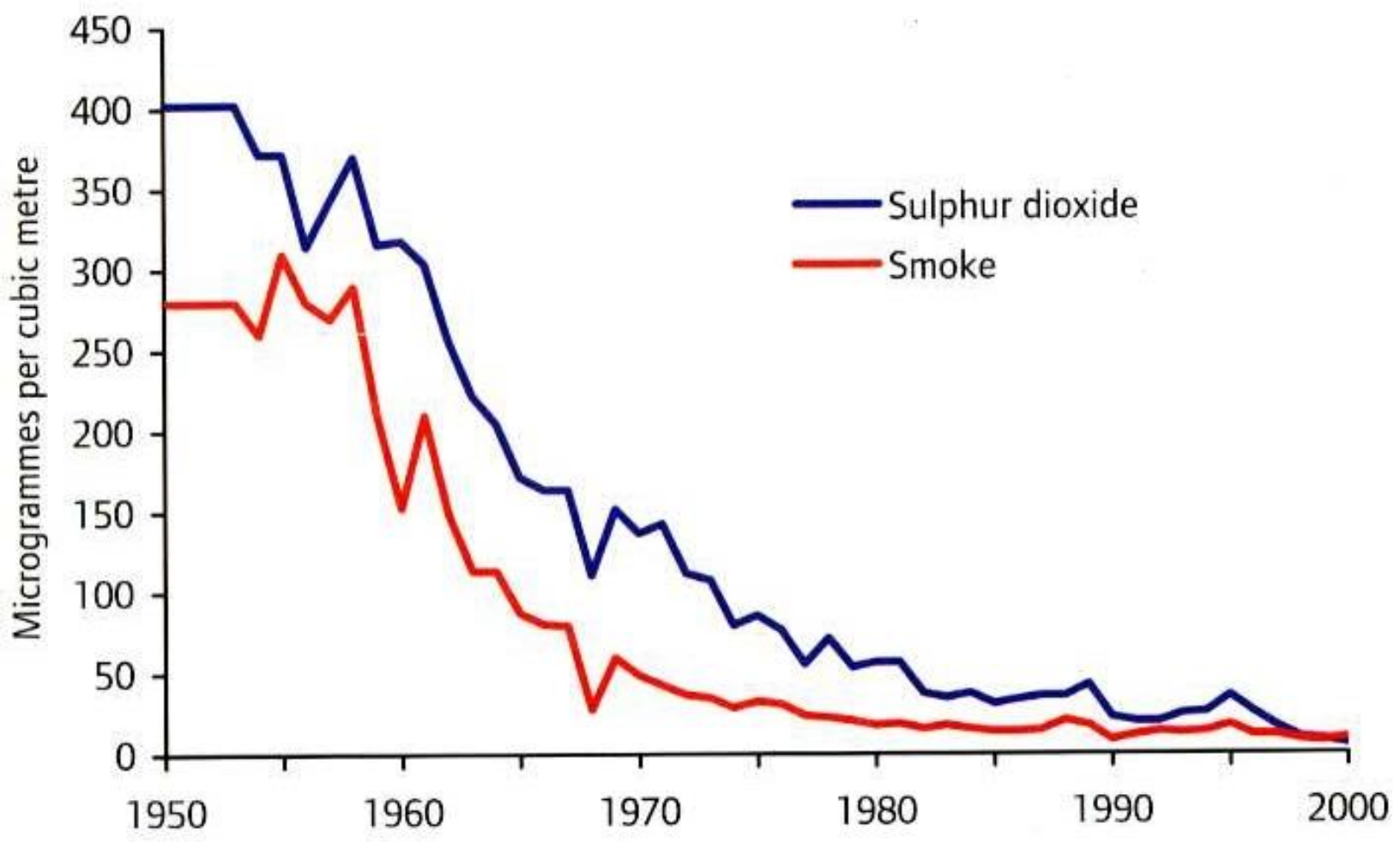
Malé Declaration: Workshop on
Air Quality and Health Impacts

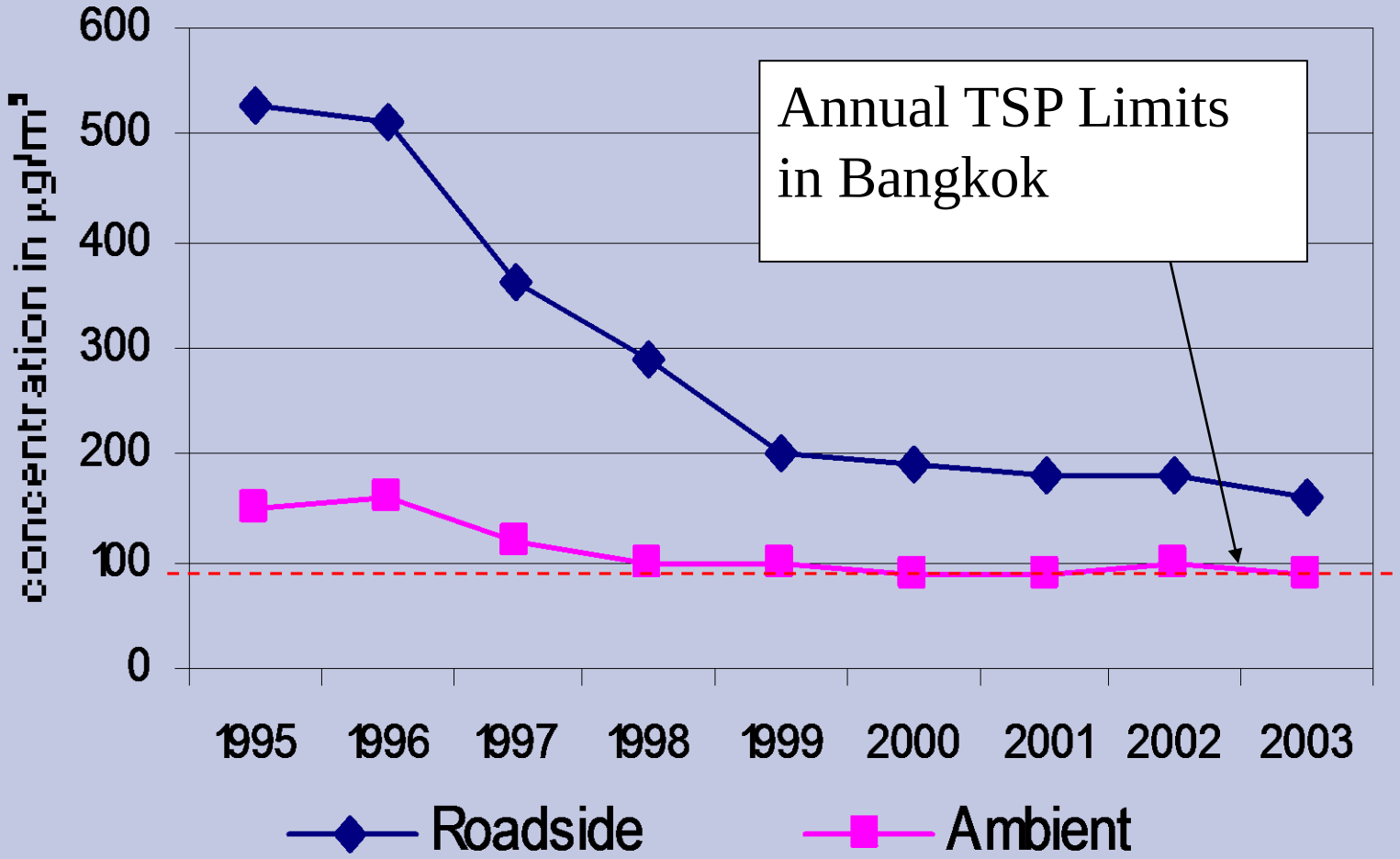
19-22 February 2007, Bangkok, Thailand

Learning objectives

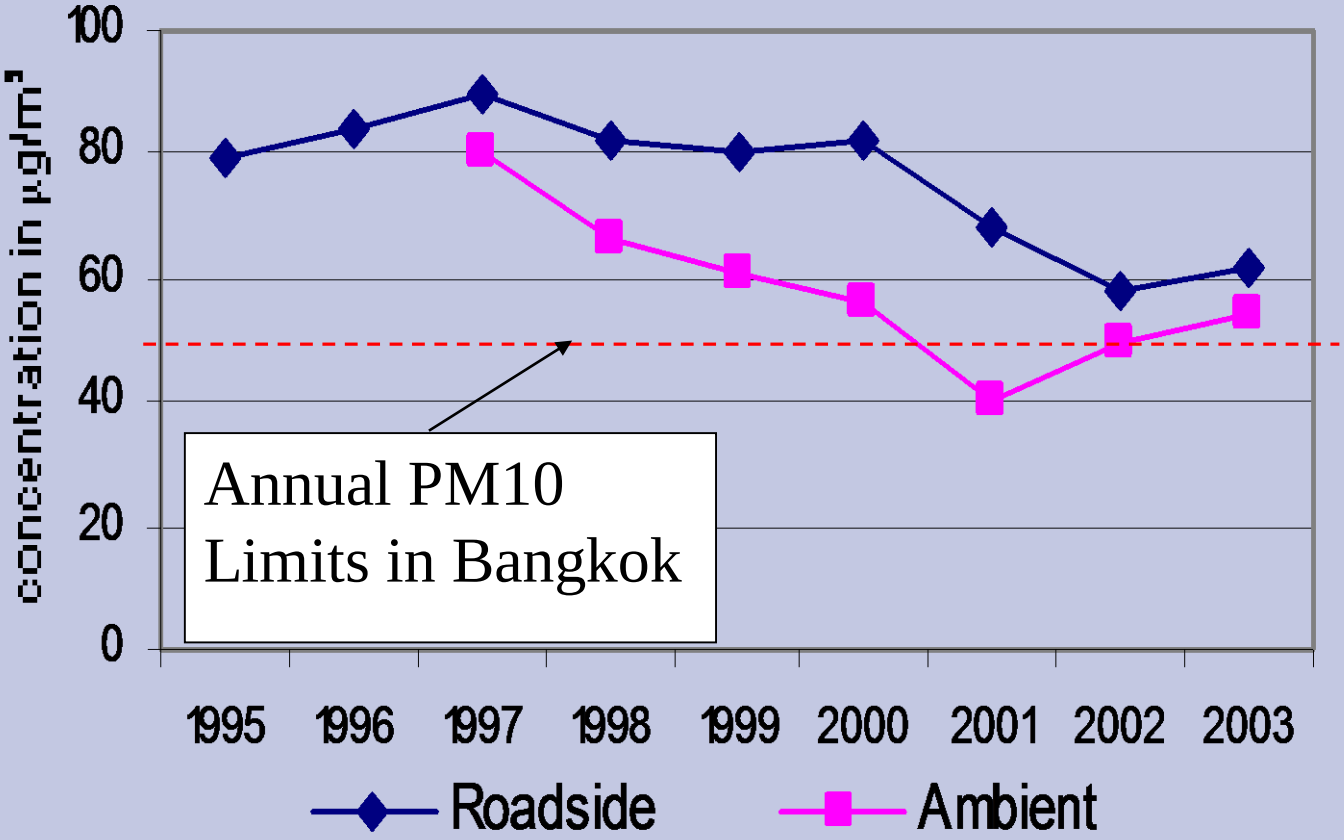
- **Understanding the magnitude of concentrations of the key air pollutants in outdoor and indoor environments**
- **Understanding rationale and objectives for setting air quality standards**
- **Some international guidelines and standards**

Annual average smoke and sulphur dioxide concentrations in London

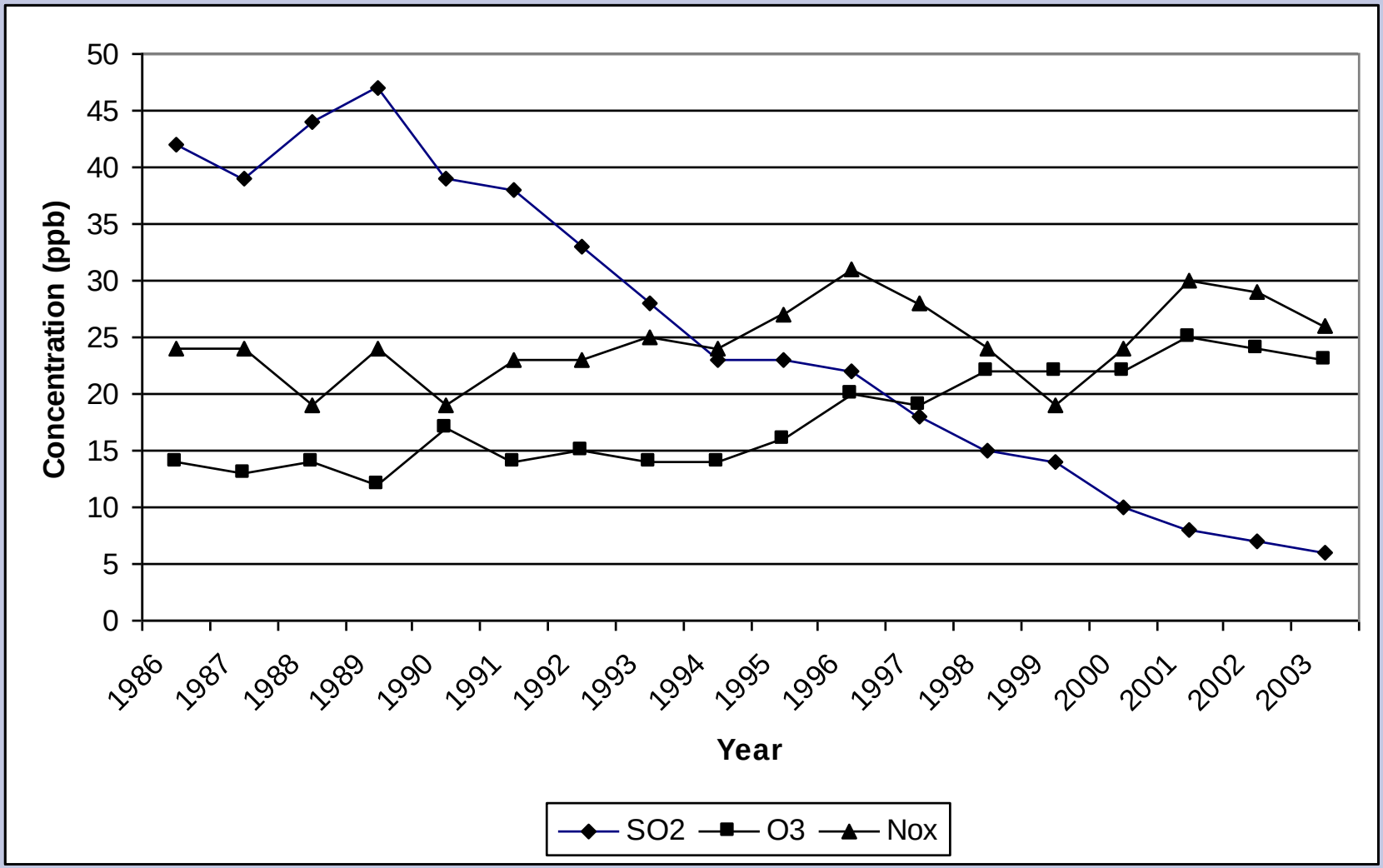




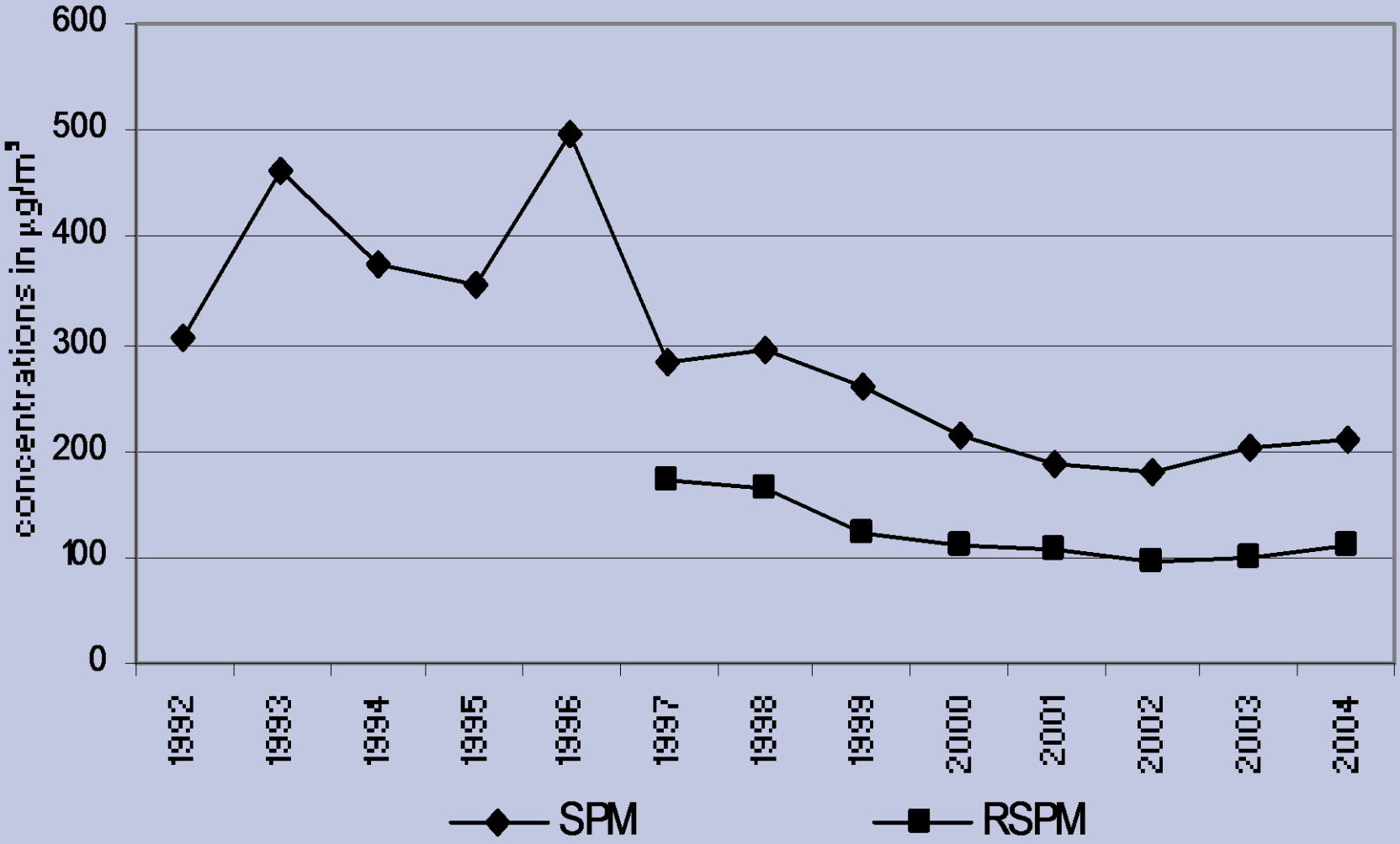
Annual TSP concentrations in Bangkok



Annual PM10 concentrations in Bangkok



Annual SO_2, NO_x, O_3 concentrations in Busan, ROK

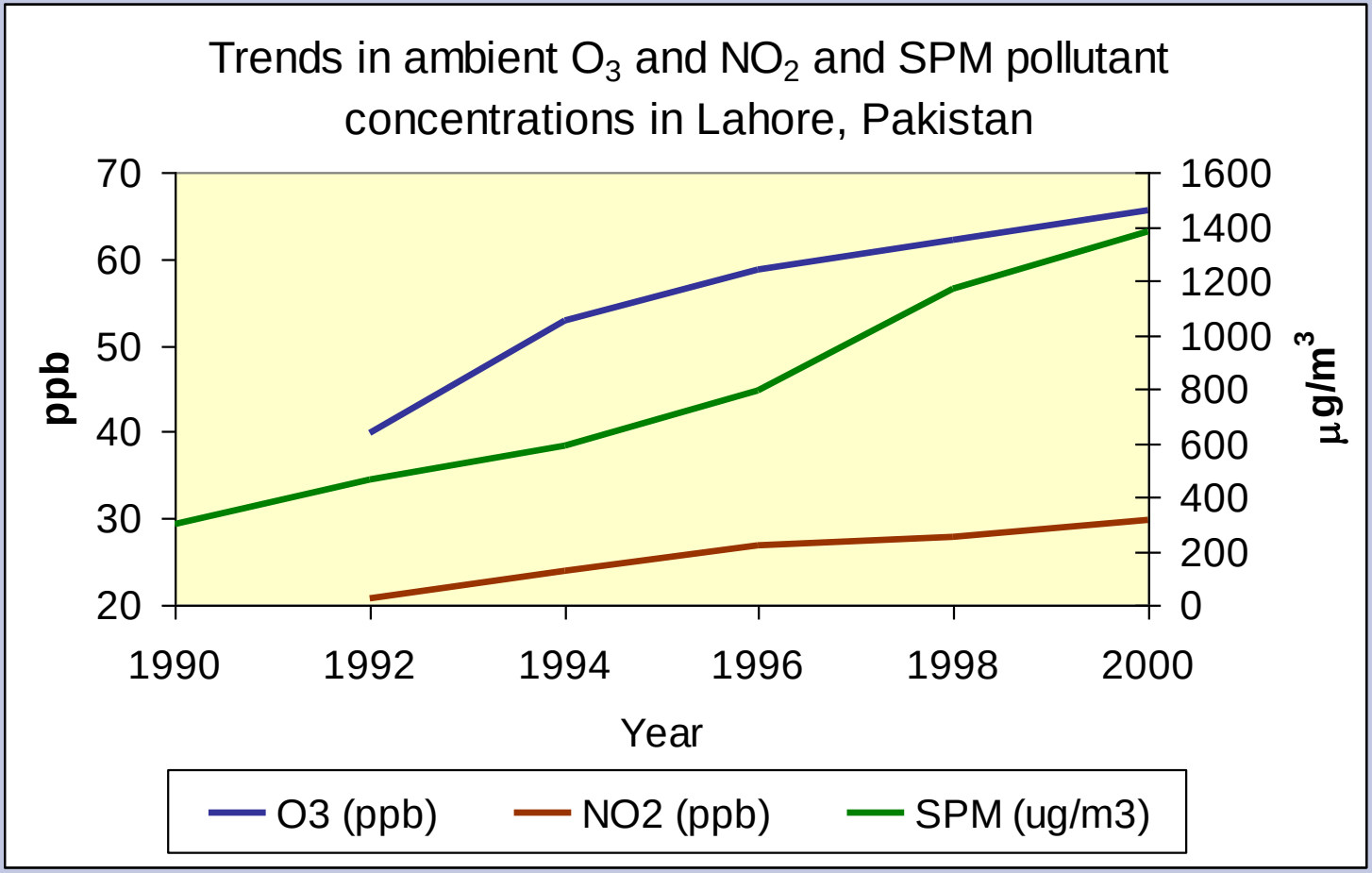


Annual average SPM and RSP concentrations in Kolkata

Urban pollution in Asia - in excess of current European concentrations

Chongqing, China, SO_2 ($\mu g.m^{-3}$)

Year	Range of daily average values	Annual Average
1996	16 - 1711	321
1998	16 - 576	183
2000	1 - 613	156



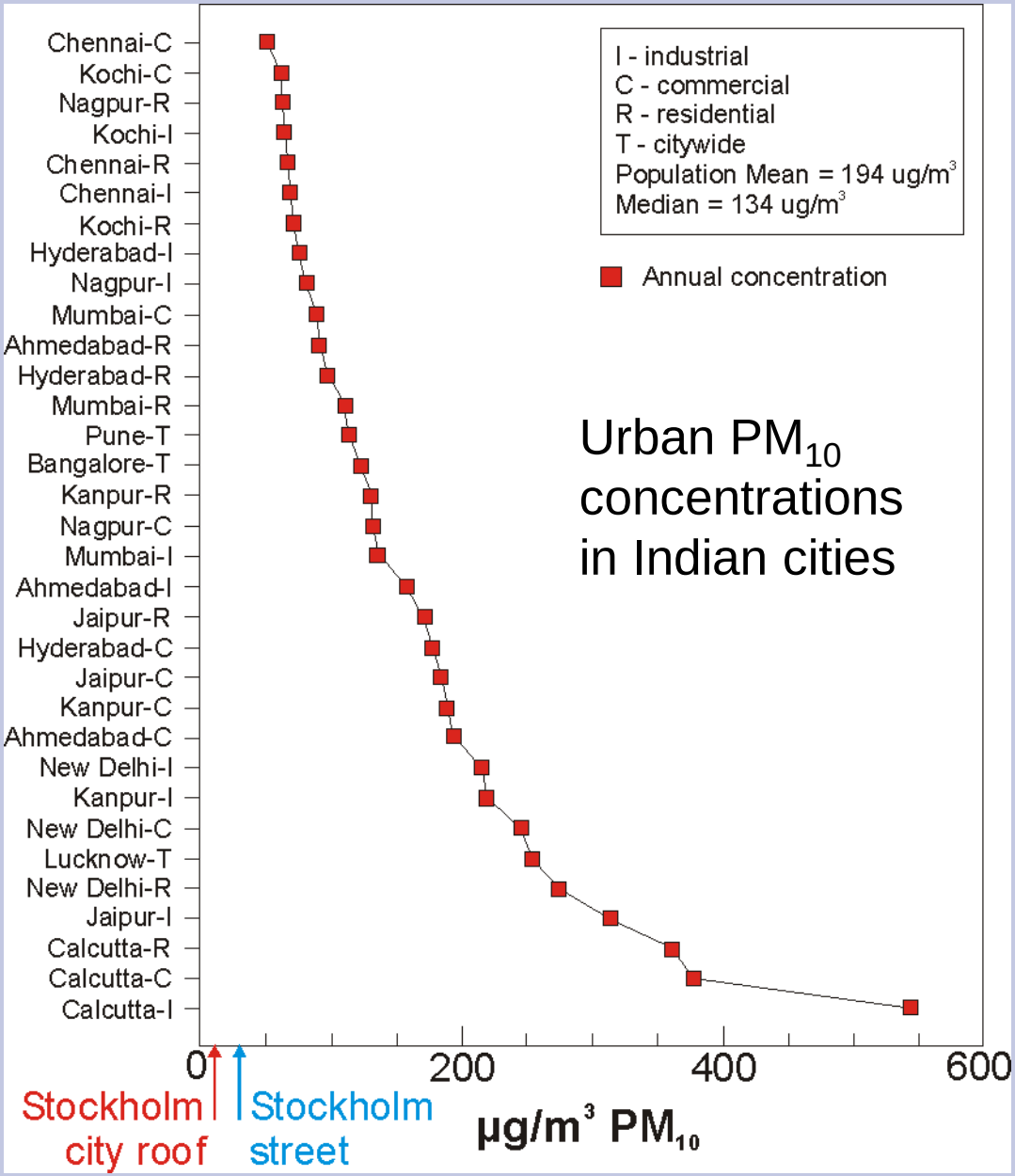
SO_2 concentrations between 10 to 14 µg / m^3

Urban Particulate Matter

Particulate matter one of the major air pollution causes of mortality and morbidity

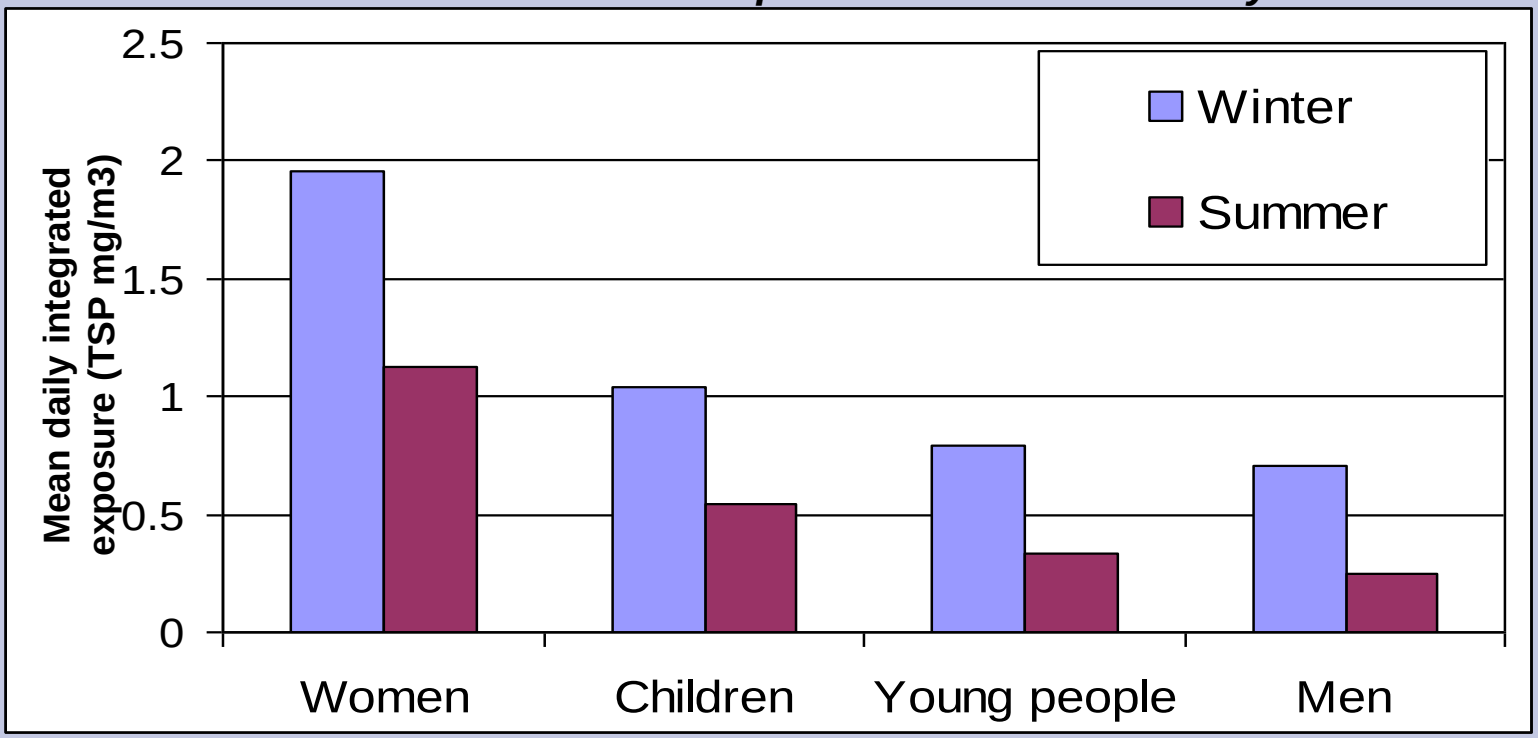
PM_{10} and $PM_{2.5}$ used to characterise exposure

About 62 million people live in these cities in India



Indoor Air Pollution: women and children are particularly at risk

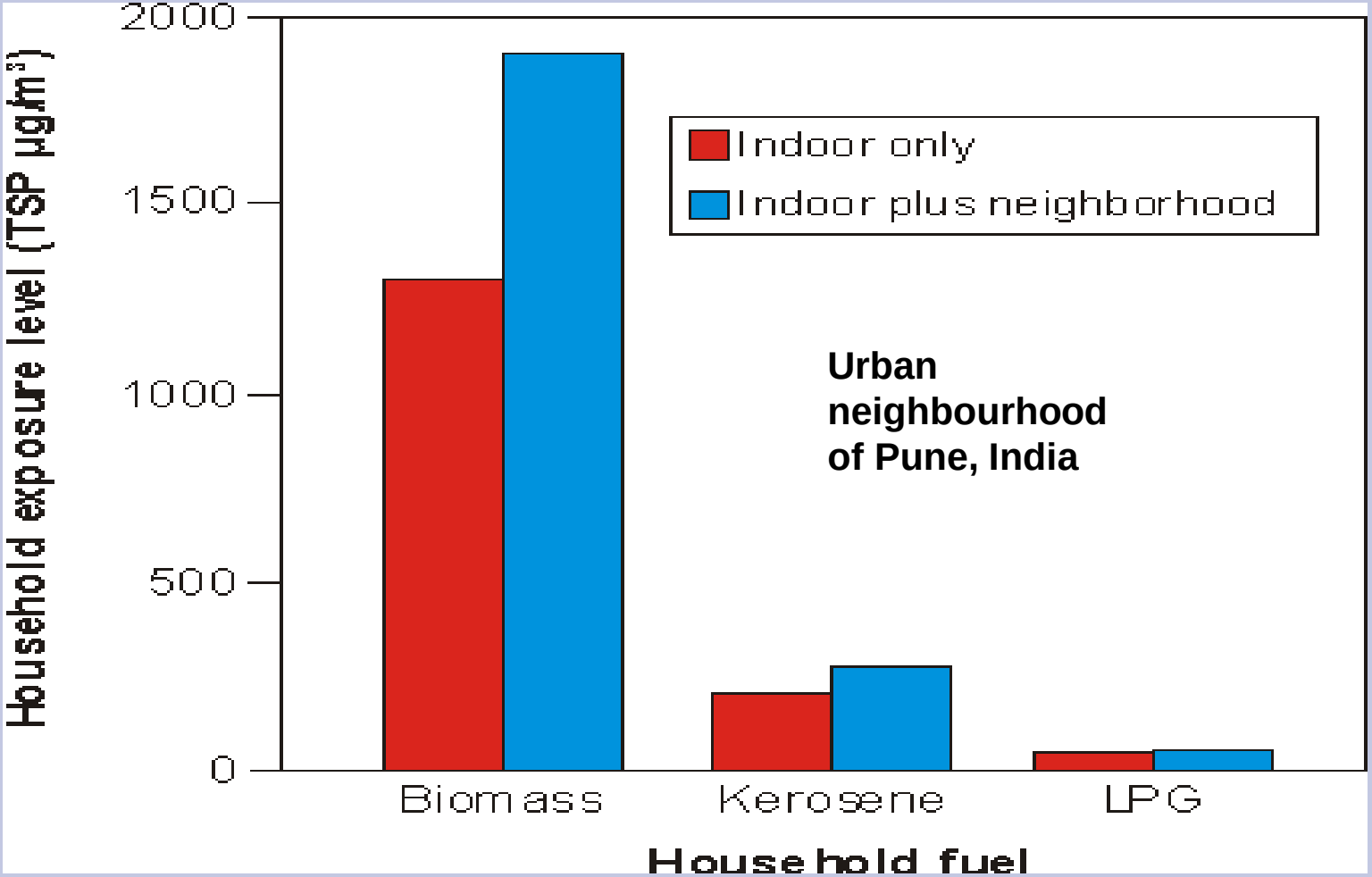
Exposure data for rural hilly area of India



More research to give reliable estimates of health burden

Currently a large uncertainty and lack of data exists

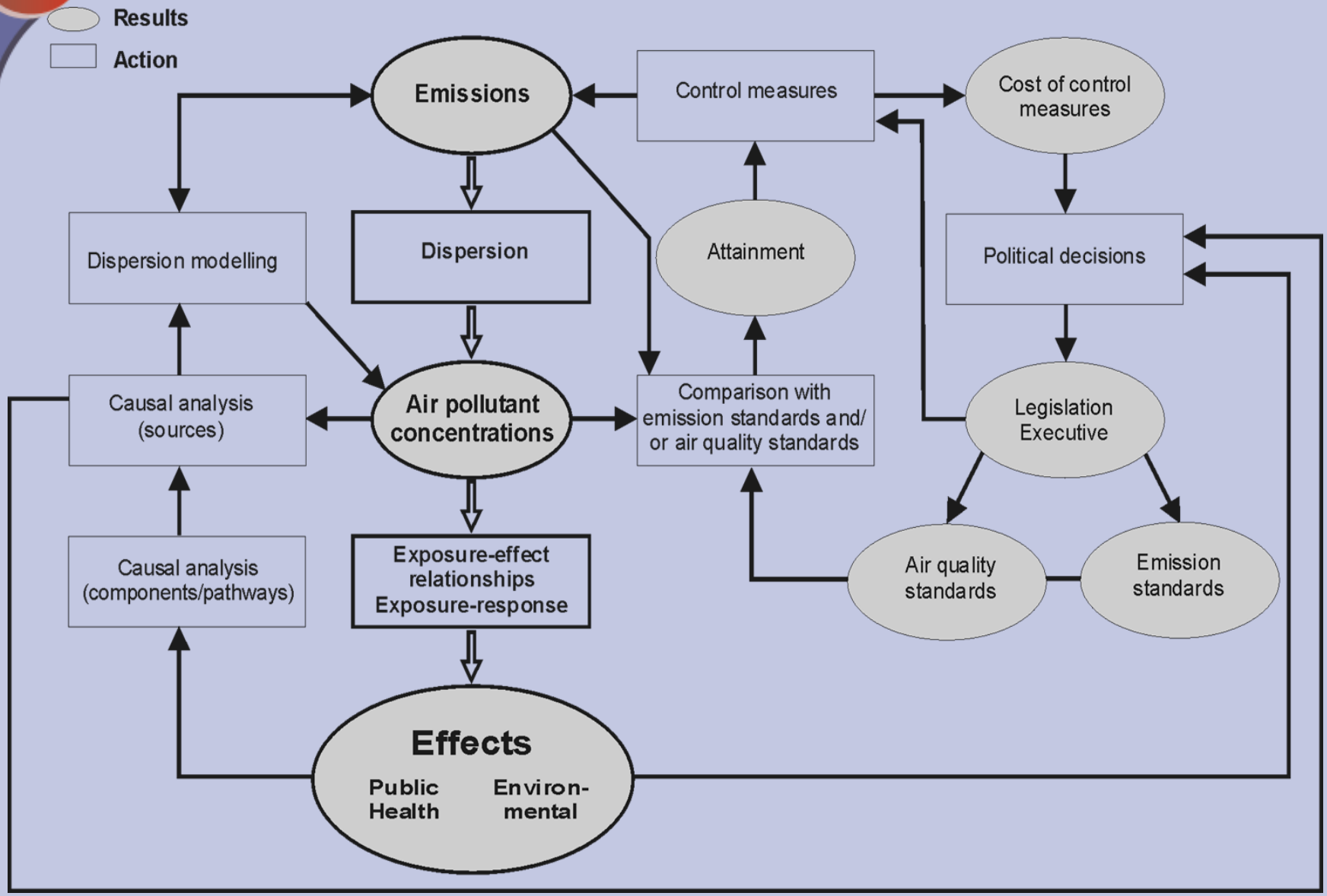
Indoor Air Pollution: biomass burning increases outdoor concentrations also



Range of annual concentrations for key pollutants

Compound	Outdoor environment		Indoor environment
	Urban	Background	with open burning
SO_2	< 100	< 3	
NO_2	< 150	5	
O_3	< 400	40-90	
CO	< 10,000	< 2,000	
TSP	50-700	< 10	100-20,000
PM_{10}	20-500	≤ 1	
$PM_{2.5}$	10-200	≤ 1	
Pb	0.01-2	< 0.001	

Units in $\mu g/m^3$



Air pollution management model

Rationale and objectives for air quality standards

- Air pollution is known to cause adverse health and environmental effects
- In order to protect human health, ambient air pollutant concentrations have to be limited to values at which adverse health effects have a negligible or an acceptable risk
- In order to protect the environment, similar limits have to be applied
- Air quality standards are intended to protect human health and the environment if enforced
- Air quality standards are values for air quality promulgated by governments

Phases of standard setting

- **Risk assessment - criteria document**
  - **Hazard characterisation**
  - **Risk characterization**
  - **Effects assessment**
  - **Exposure -response relationships**
  - **Uncertainty factors**
  - **Guidelines**
- **Applying criteria documents to set standards**
  - **Consideration of the other factors**

Criteria documents

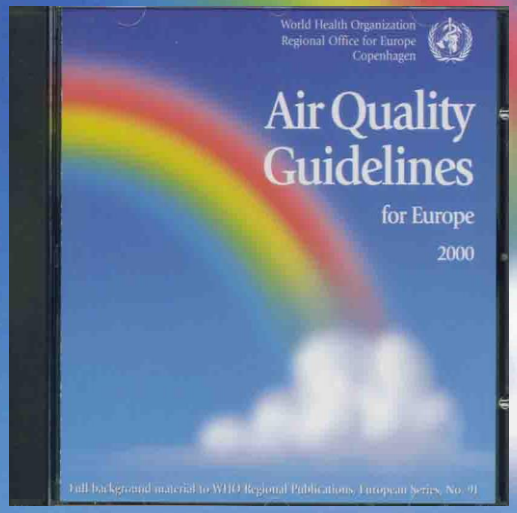
- IPCS Environmental Health Criteria
- WHO: Air Quality Guidelines
- RIVM: Concentrations of no concern
- US ATSDR: Minimal risk Levels
- US EPA: Air Quality Criteria
- EU: Technical Guidance Documents
- Health Canada: Guidelines for the Preparation of Health Risk Assessment

World Health Organization
Regional Office for Europe
Copenhagen

Air Quality Guidelines

for Europe

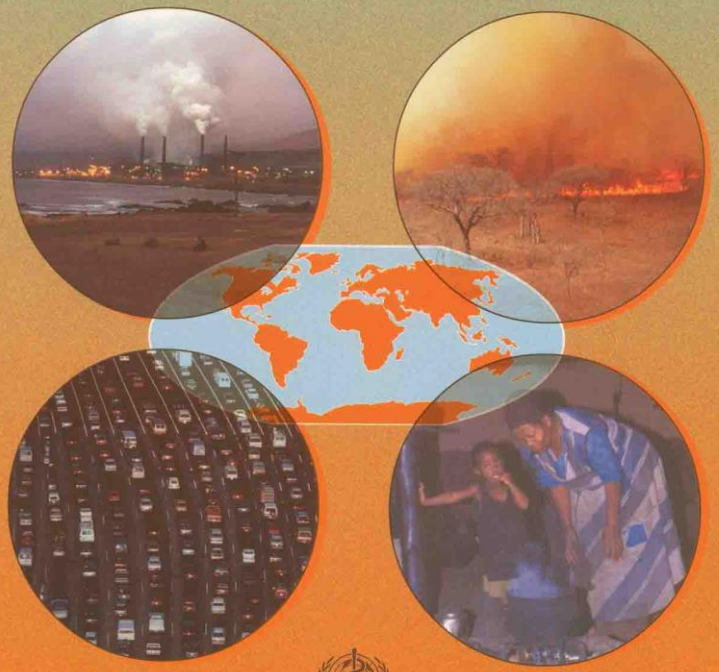
Second Edition



WHO Regional Publications, European Series, No. 91

WHO/SDE/OEH/00.02
Distr.: Limited
Original: English

Guidelines for Air Quality



World Health Organization
Sustainable Development and Healthy Environments
Protection of the Human Environment
Occupational and Environmental Health

World Health Organization

WHO air quality guidelines global update 2005

Report on a Working Group meeting, Bonn, Germany, 18-20 October 2005

Nature of air quality guidelines

Aim:

To provide a basis for protecting public health from adverse effects of environmental pollutants, and for eliminating or reducing to a minimum, contaminants that are known or likely to be hazardous to human health and well-being.

- **Provision of background information and guidance to governments in making risk management decisions, particularly in setting standards**
- **Assistance in carrying out local control measures**
- **No green light for pollution**
- **Levels below which lifetime exposure or exposure for a given averaging time does not constitute a health risk, but**
- **Short-term exceedances of guideline values are no catastrophe**
- **Provision of risk estimates for PM, O_3 and carcinogens**

Guidelines and guideline values

- A guideline for air quality is any relationship between exposure and health effect, i.e. an exposure-response relationship
- A guideline value is a fixed concentration at and below the risk of any health effect is very small

Criteria used in establishing air quality guidelines

Distinction between: absolute safety and acceptable risk

Absolute safety: detailed knowledge of

- **Dose-response relationships;**
- **Types of toxic effects elicited by specific pollutants;**
- **Existence of "thresholds";**
- **Significance of interactions;**
- **Variation in sensitivity and exposure levels within human population.**

Acceptable risk:

- **Tolerated or unavoidable;**
- **Not equally distributed within a population.**

Criteria common to Non-carcinogens and Carcinogens

Available data on

Sources, levels, routes of exposure:

- **Air - Water - Food;**
- **Urban, non-polluted rural areas, indoor, workplace;**
- **Uptake by inhalation, ingestion, dermal contact.**

Kinetics and metabolism:

- **Body-burden from long-term, low-level exposure;**
- **Mode of toxic action;**
- **Metabolites with greater toxic potential than original agent.**

Criteria for Non-carcinogens

Lowest-observed-adverse-effect-level (LOAEL)

Lowest-observed-effect-level (LOEL)

No-observed-effect-level (NOEL)

Uncertainty factors

Averaging times

Risk considerations (Exposure-response relationships)

Criteria for selection of a LOAEL

Difficulties in distinguishing:

Adverse - non-adverse effect

Definition:

An adverse effect is " any effect resulting in functional impairment and/or pathological lesions that may affect the performance of the whole organism or which contributes to a reduced ability to respond to an additional challenge".

Significant degree of subjectivity and uncertainty!

Criteria for selection of uncertainty factors

Uncertainty factor = safety factor = protection factor = margin of protection = margin of safety;

Variety of uncertainties:

Undetected effects on particular sensitive subgroups;

Synergistic effects of multiple exposures;

Adequacy of existing data (number of mutually supportive scientific observations);

Extrapolation from animals to humans;

Extrapolation from small groups to the population.

Uncertainty factors are based on

Scientific judgement;
Interplay of various criteria;
Diverse in magnitude.

Complex decision process.

Exceeding a guideline value with an incorporated uncertainty factor does not necessarily mean that adverse effects will result; however risk will increase.

Criteria for selection of averaging times

Complex time-concentration interrelationships

Acute, minor, reversible effects after brief exposure;

Irreversible or incapacitating effects after prolonged exposure;

Short-term averaging times;

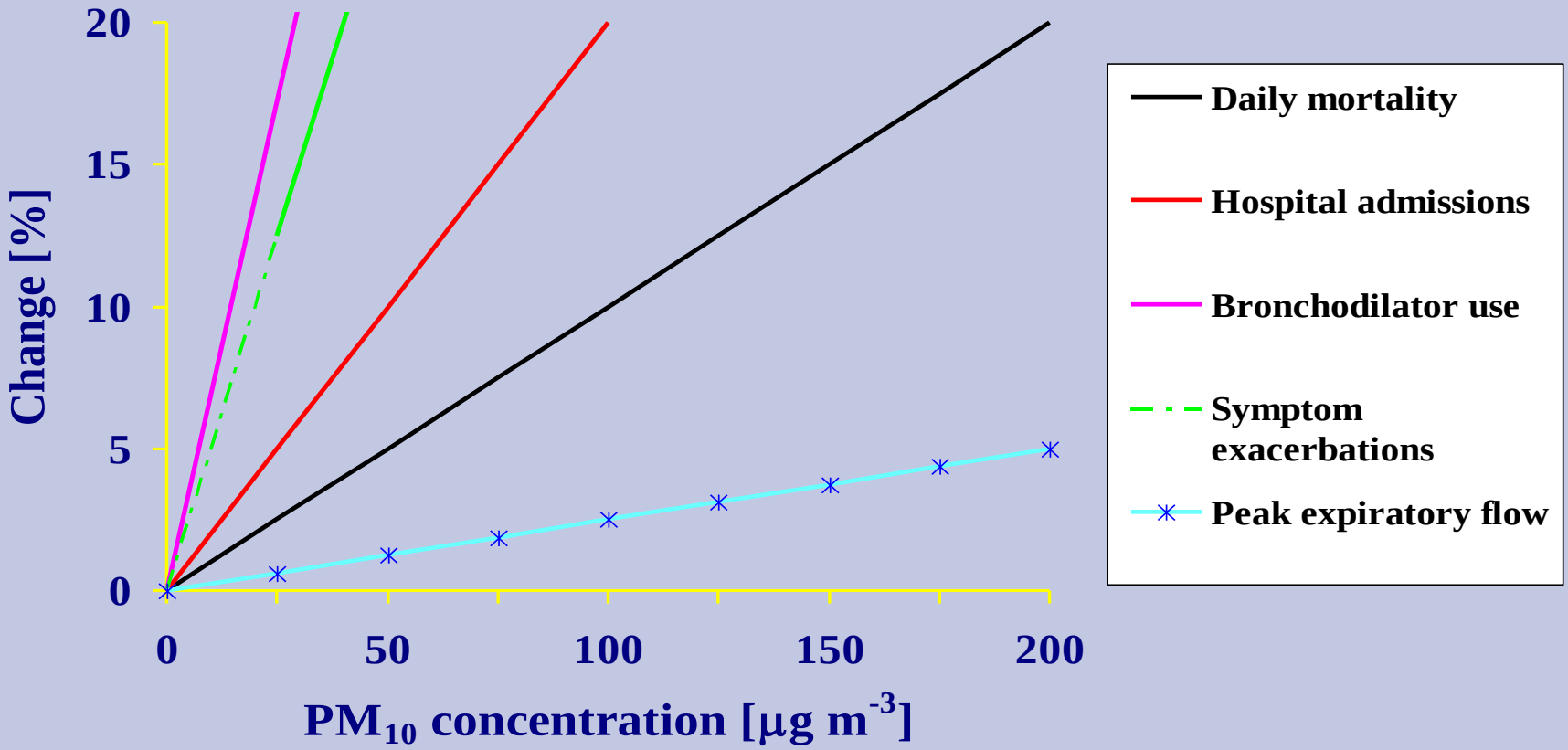
Long-term averaging times

Air quality guideline values for non-carcinogenic compounds (~ 50)

Compound	Guideline value [$\mu g\ m^{-3}$]	Averaging time
Carbon monoxide	100 000	15 min
	60 000	30 min
	30 000	1 h
	10 000	8 h
Nitrogen dioxide	200	1 h
	40	1 a
Ozone	120	8 h
Sulphur dioxide	500	10 min
	125	24 h
	50	1 a

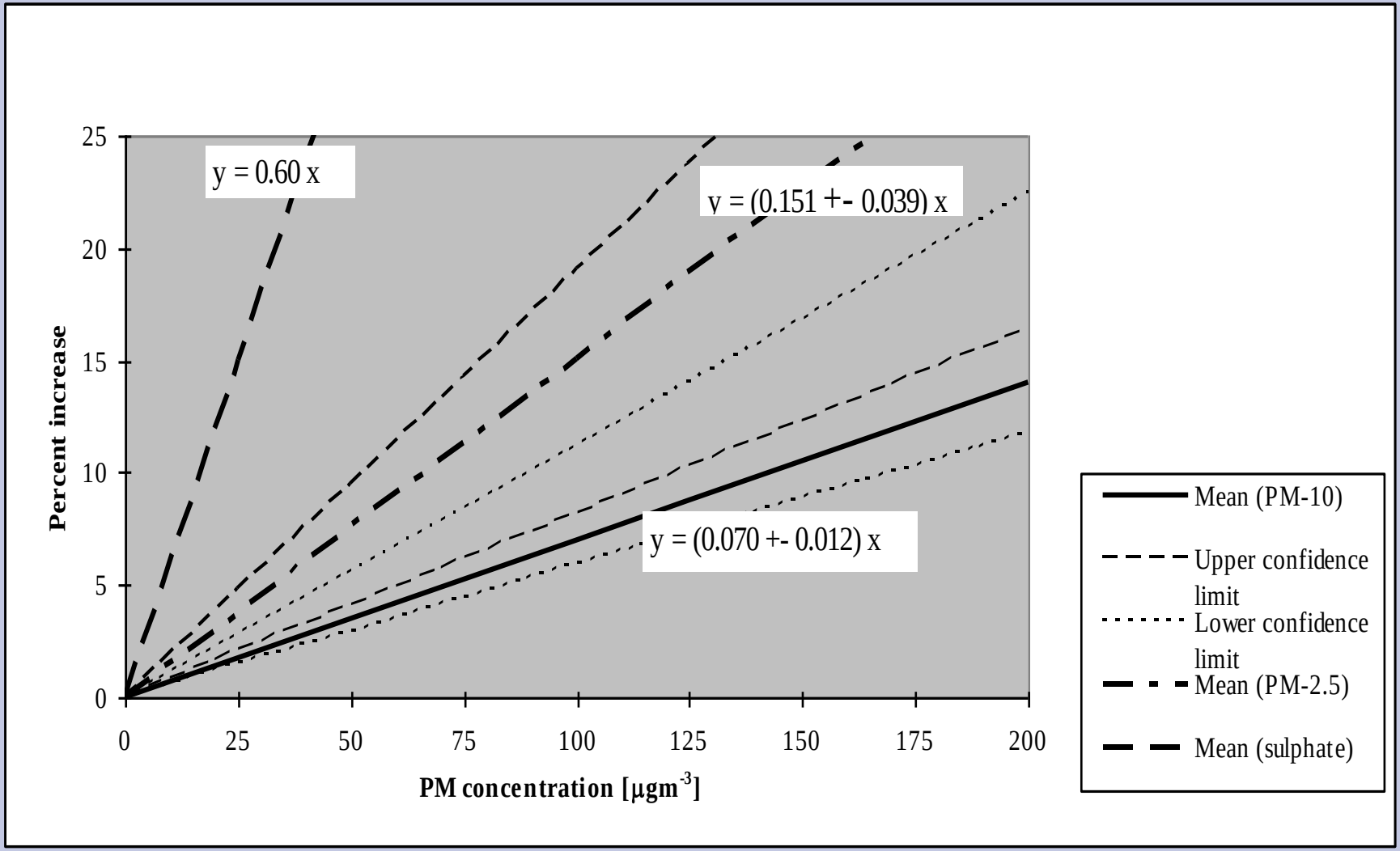
WHO (2000)

Relationship of PM10 with different health effect indicators



WHO 2000/2006)

Increase in daily mortality as a function of PM concentration



Criteria for Carcinogens

Qualitative assessment: how likely an agent is a human carcinogen?

Quantitative assessment of the cancer rate the agent is likely to cause at given levels and exposure.

Classification criteria of IARC in qualitative assessment:

Group 1: Proven human carcinogens: Risk estimates

Group 2: Probable human carcinogens

Group 2A: Limited evidence of carcinogenicity in humans; Sufficient evidence of carcinogenicity in animals; Risk estimates

Group 2B: Inadequate evidence of carcinogenicity in humans; Guidelines based on non-cancer endpoints

Group 3: Unclassified chemicals

Quantitative assessment

Extrapolation from occupational studies

Extrapolation from animal studies

to the general population

=

Extrapolation in dose-response relationships from high dose levels to low dose levels

Extrapolation dependent on extrapolation model

Unit risk model

Definition:

Unit risk is the additional lifetime cancer risk occurring in a hypothetical population in which all individuals are exposed continuously from birth throughout their lifetimes to a concentration of 1 $\mu g\ m^{-3}$ of the agent in the air they breathe.

Unit risk estimates:

- **provide the opportunity to compare the carcinogenic potency of different agents;**
- **can help to set priorities in pollution control;**
- **avoid reference to the "acceptability" of risk;**
- **are not equivalent to the true cancer risk.**

Quantitative Risk Analysis (QRA)

Assessment method determined by mechanism

Extrapolation model bases on available data

QRA for Group 1 and 2A

Uncertainty factor approach for Group 2B and 3

Exceptions

Arsenic

Route	Air	Food	Water	Tobacco
Daily intake [μg/d]	<0.6	7-273	<20	<2
absorption [μg/d]	<0.5	6-250	<18	<2

Groups at high exposure risks:

- **Occupationally exposed in copper smelters**
- **People drinking water with very high concentrations**
- **Children living in the vicinity of copper smelters**

IARC: 1

Critical effect: Lung cancer

Risk assessment: Relative risk ~ cumulative arsenic dose in workers

Unit risk: $1.5 \cdot 10^{-3}$ [μg m^{-3}]$^{-1}$

Polycyclic aromatic hydrocarbons

Route	Air	Food	Water	Tobacco
Daily intake [µg/d]	~0.1	~5	~0.02	~1
absorption [µg/d] ~0.05	~2.5	~0.01	<0.5	

Groups at high exposure risks:
Occupationally exposed coke oven workers
IARC: 2A (Benzo(a)pyrene, BaP)
Critical effect: Lung cancer
Risk assessment: Linearized multistage model for BaP exposure in coke oven workers

Unit risk for BaP: $8.7 \cdot 10^{-2}\ [\mu g\ m^{-3}]^{-1}$

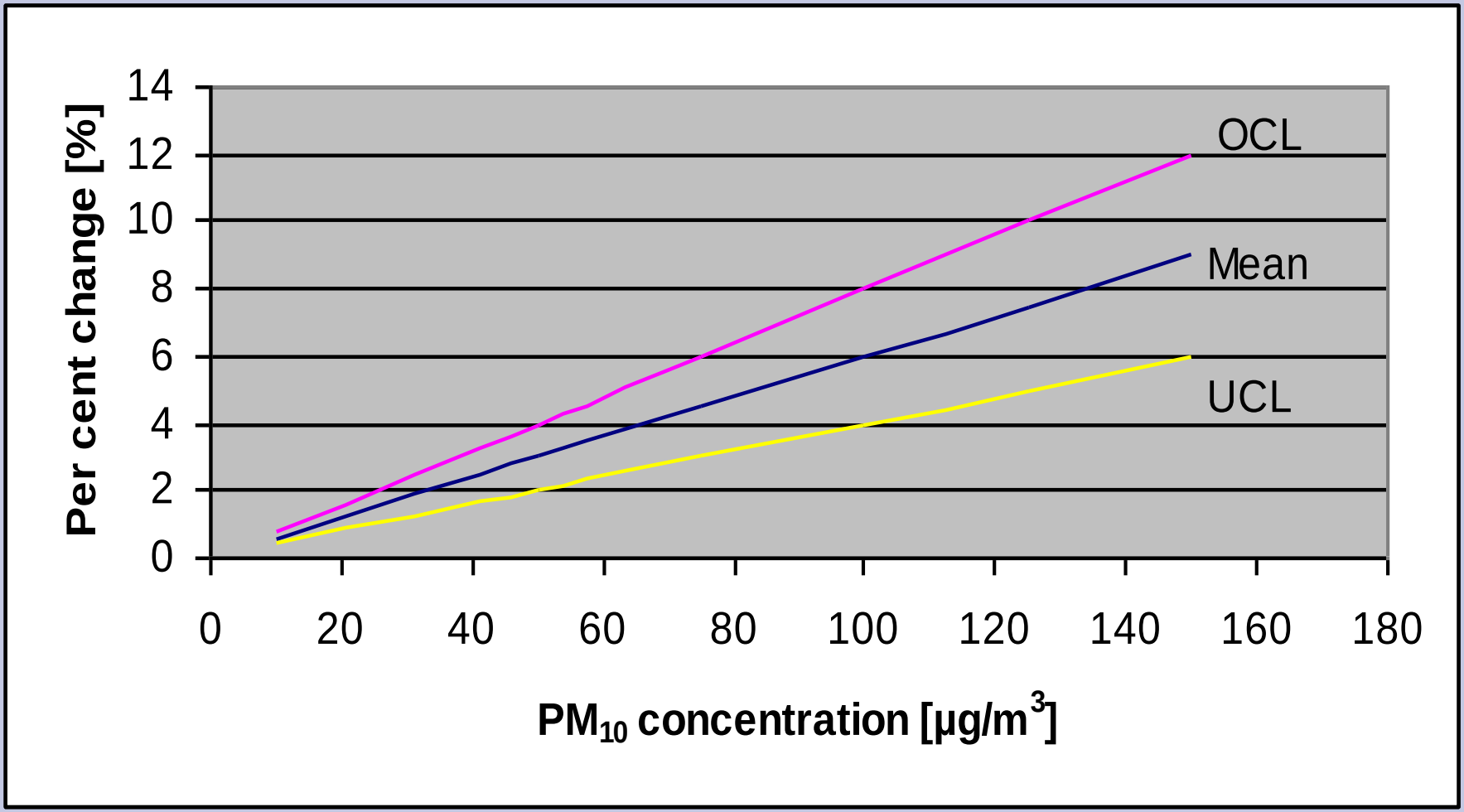
Unit risk estimates and concentrations associated with a lifetime cancer risk of 10^{-5} for carcinogenic compounds (~30)

Compound	Unit risk [μg m^{-3}]$^{-1}$	Lifetime risk conc. [μg m^{-3}]
Arsenic	$1.5 \cdot 10^{-3}$	0.007
Benzene	$6 \cdot 10^{-6}$	1.7
Chromium (VI)	$4 \cdot 10^{-2}$	0.00025
ETS	$1 \cdot 10^{-3}$	0.01
Nickel	$3.4 \cdot 10^{-4}$	0.03
PAH (BaP)	$8.7 \cdot 10^{-2}$	0.00011
TCE	$(0.9\text{-}4.3) \cdot 10^{-7}$	23.2-111

WHO air quality guideline values 2005

Pollutant	Averaging time	AQG value 2005 (2000) [µg/m³]
$PM_{2.5}$	1 year	10
	24 hours (99-percentile)	25
PM_{10}	1 year	20
	24 hours (99-percentile)	50
O_3	8 hours, daily maximum	100 (120)
NO_2	1 year	40
	1 hour	200
SO_2	24 hours	20 (125)

Paradigm shift in setting PM guideline values



Air quality guideline values and standards

- **A careful distinction is necessary**
- **Very often even experts do not distinguish between air quality guidelines and standards**

Guideline values versus standards

- Guideline values are health- (or environment-) based levels, not standards per se
- In setting standards, additional factors may be considered, e.g.:
  - (a) Prevailing exposure levels
  - (b) Environmental conditions
  - (c) Social, economic and cultural condition
- Standards may be above/below guidelines

Setting standards: Factors to consider

- Natural background contamination (e.g. high natural PM)
- Geophysical and meteorological factors:
  - Temperature extremes
  - Humidity extremes
  - Altitude
- Socioeconomic factors

Setting standards: Policy options

- Which proportion of the general population should be protected?
- Which susceptible groups should be protected? And how?
- Protection vs. alert/action levels
- Source control, abatement measures, early warning measures

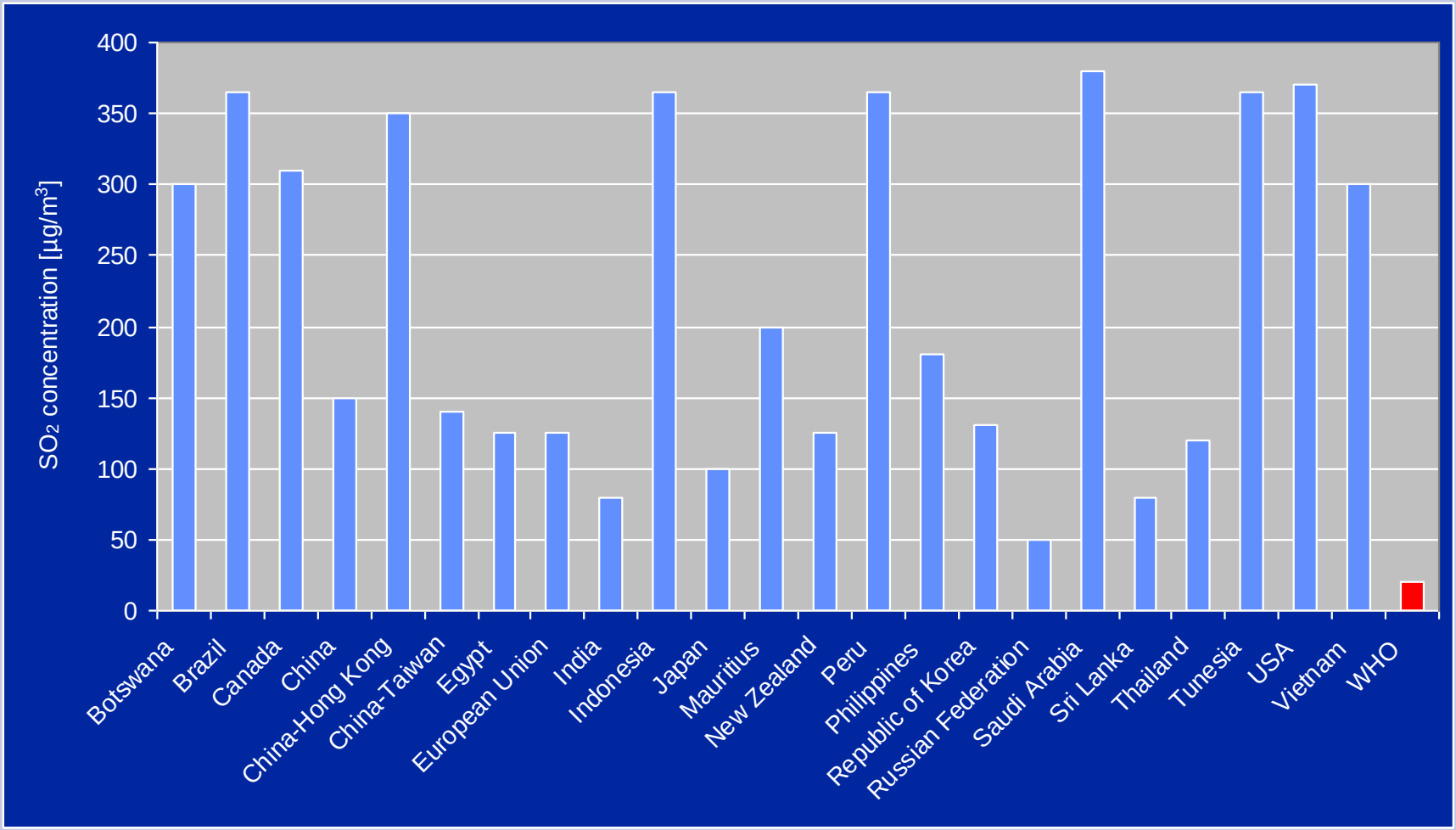
Setting standards: Some problem areas

- Susceptible population groups
- Environmental levels are already effect levels
- At every pollutant level, a proportion of the population will be affected

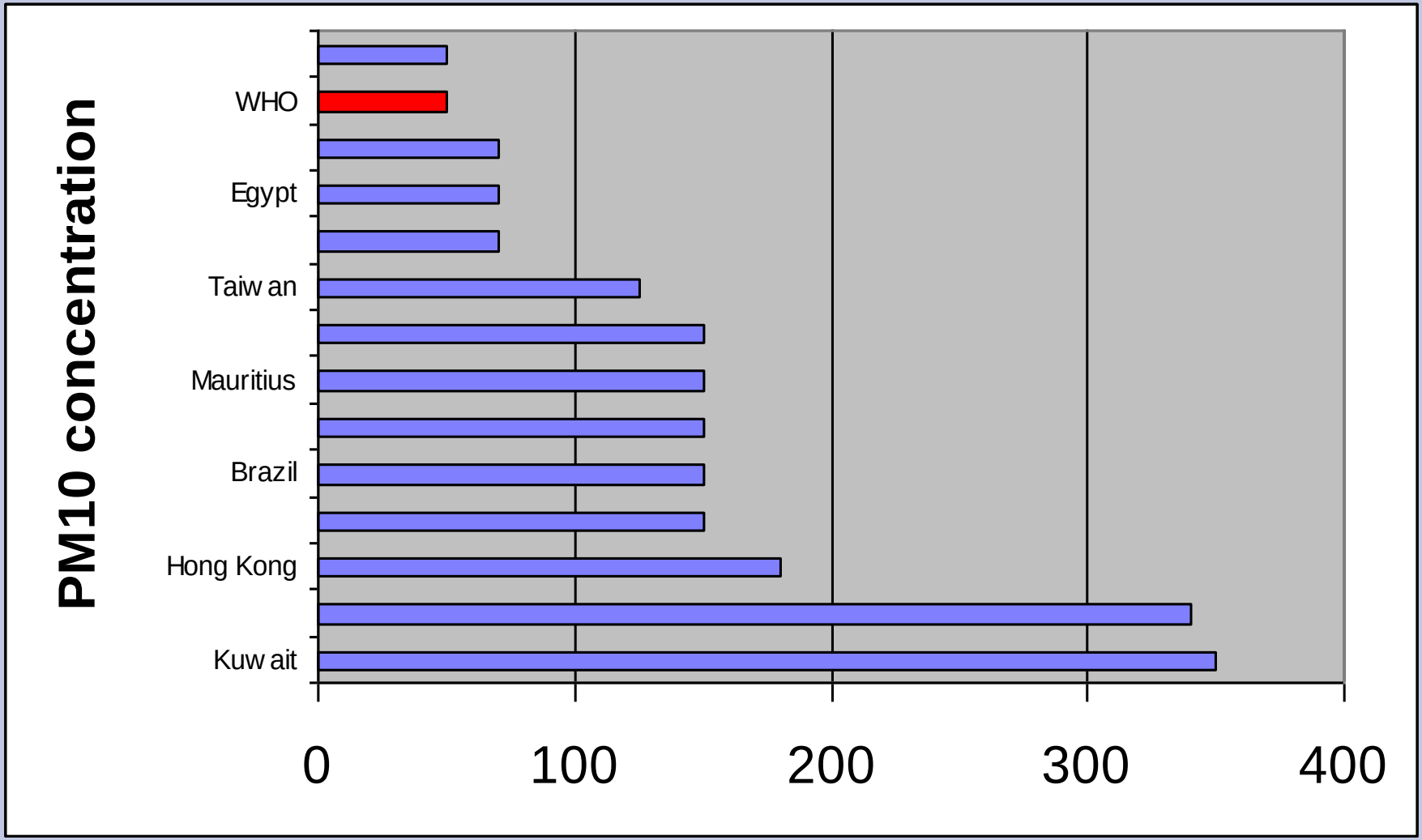
Standards in environmental and occupational health

- **Air quality standards**
  - **Wider range of ages**
  - **Wider range of health states**
  - **Greater susceptibility**
  - **Community involvement**
  - **24 hour continuous exposure**
- **Occupational standards**
  - **Healthy workers**
  - **Employers involvement**
  - **8 hour exposure**

24-hour standards for SO_2



Air quality standards for 24-hour PM_{10} [$\mu g/m^3$]



US EPA air quality standards

Pollutant	Averaging time	AQS [µg/m³]
$PM_{2.5}$	1 year	15
	24 hours	65
PM_{10}	1 year	50
	24 hours	150
O_3	8 hours, daily maximum	160
NO_2	1 year	100
SO_2	1 year	80
	24 hours	370

EU air quality limits

Pollutant	Averaging time	AQS [µg/m³]
PM_{10}	1 year 24 hours	40 50
O_3	8 hours, daily maximum	120
NO_2	1 year 1 hour	40 200
SO_2	1 year 24 hours	20 125