Chapter 3 Summary of the guidelines

The term “guidelines” in the context of this book implies not only numerical values (guideline values), but also any kind of guidance given. Accordingly, for some substances the guidelines encompass recommendations of a more general nature that will help to reduce human exposure to harmful levels of air pollutants. For some pollutants no guideline values are recommended, but risk estimates are indicated instead.

The numerical guideline values and the risk estimates for carcinogens (Tables 2–4) should be regarded as the shortest possible summary of a complex scientific evaluation process. Nevertheless, the information given in the tables should not be used without reference to the rationale given in the chapters on the respective pollutants. Scientific results are an abstraction of real situations, and this is even more true for numerical values and risk estimates based on such results. Numerical guideline values, therefore, are not to be regarded as separating the acceptable from the unacceptable, but rather as indications. They are proposed in order to help avoid major discrepancies in reaching the goal of effective protection against recognized hazards for human health and the environment. Moreover, numerical guidelines for different substances are not directly comparable. Variations in the quality and extent of the scientific information and in the nature of critical effects, although usually reflected in the applied uncertainty factor, result in guideline values that are only to a limited extent comparable between pollutants.

Owing to the different bases for evaluation, the numerical values for the various air pollutants should be considered in the context of the accompanying scientific documentation giving the derivation and scientific considerations. Any *isolated* interpretation of numerical data should therefore be avoided, and guideline values should be used and interpreted in conjunction with the information contained in the appropriate sections.

It is important to note that the approach taken in the preparation of the guidelines was to evaluate data on the health effects of individual compounds. Consequently, each chemical was considered in isolation. Pollutant mixtures can yield different toxic effects, but data are at present insufficient for guidelines relating to mixtures to be laid down. There is little emphasis on interaction between pollutants that might lead to additive or synergistic effects and on the environmental fate of pollutants, though there is growing evidence about the role of solvents in atmospheric photochemical processes leading to the formation or degradation of ozone, the formation of acid rain, and the propensity of metals and trace elements to accumulate in environmental niches. These factors militate strongly against allowing a rise in ambient pollutant levels. Many uncertainties still remain, particularly regarding the ecological effects of pollutants, and therefore efforts should be continued to maintain air quality at the best possible level.

Guideline values based on non-cancer effects other than cancer

The guideline values for individual substances based on effects other than cancer and annoyance from odour are given in Table 2. The emphasis in the guidelines is placed on exposure, since this is the element that can be controlled to lessen dose and hence lessen the consequent health effect. When general ambient air levels are orders of magnitude lower than the guideline values, present exposures are unlikely to cause concern. Guideline values in those cases are directed only to specific release episodes or specific indoor pollution problems.

Table 2. Guideline values for individual substances based on effects other than cancer or odour/annoyance

Substance	Time-weighted average	Averaging time
Cadmium	5 ng/m^{3}[a]	annual
Carbon disulfide[b]	100 µg/m^{3}	24 hours
Carbon monoxide	100 mg/m^{3}[c]	15 minutes
	60 mg/m^{3}[c]	30 minutes
	30 mg/m^{3}[c]	1 hour
	10 mg/m^{3}	8 hours
1,2-Dichloroethane[b]	0.7 mg/m^{3}	24 hours
Dichloromethane	3 mg/m^{3}	24 hours
	0.45 mg/m^{3}	1 week
Fluoride[d]	–	–
Formaldehyde	0.1 mg/m^{3}	30 minutes
Hydrogen sulfide[b]	150 µg/m^{3}	24 hours
Lead	0.5 µg/m^{3}	annual
Manganese	0.15 µg/m^{3}	annual
Mercury	1 µg/m^{3}	annual
Nitrogen dioxide	200 µg/m^{3}	1 hour
	40 µg/m^{3}	annual
Ozone	120 µg/m^{3}	8 hours
Particulate matter[e]	Dose–response	–
Platinum[f]	–	–
PCBs[g]	–	–
PCDDs/PCDFs[h]	–	–
Styrene	0.26 mg/m^{3}	1 week
Sulfur dioxide	500 µg/m^{3}	10 minutes
	125 µg/m^{3}	24 hours
	50 µg/m^{3}	annual
Tetrachloroethylene	0.25 mg/m^{3}	annual
Toluene	0.26 mg/m^{3}	1 week
Vanadium[b]	1 µg/m^{3}	24 hours

[a] The guideline value is based on the prevention of a further increase of cadmium in agricultural soils, which is likely to increase the dietary intake.

[b] Not re-evaluated for the second edition of the guidelines.

[c] Exposure at these concentrations should be for no longer than the indicated times and should not be repeated within 8 hours.

[d] Because there is no evidence that atmospheric deposition of fluorides results in significant exposure through other routes than air, it was recognized that levels below 1 µg/m^{3}, which is needed to protect plants and livestock, will also sufficiently protect human health.

[e] The available information for short- and long-term exposure to PM_{10} and $PM_{2.5}$ does not allow a judgement to be made regarding concentrations below which no effects would be expected. For this reason no guideline values have been recommended, but instead risk estimates have been provided (see Chapter 7, Part 3).

[f] It is unlikely that the general population, exposed to platinum concentrations in ambient air at least three orders of magnitude below occupational levels where effects were seen, may develop similar effects. No specific guideline value has therefore been recommended.
[g] No guideline value has been recommended for PCBs because inhalation constitutes only a small proportion (about 1–2%) of the daily intake from food.
[h] No guideline value has been recommended for PCDDs/PCDFs because inhalation constitutes only a small proportion (generally less than 5%) of the daily intake from food.

As stated earlier, the starting point for the derivation of guideline values was to define the lowest concentration at which adverse effects are observed. On the basis of the body of scientific evidence and judgements of uncertainty factors, numerical guideline values were established to the extent possible. Compliance with the guideline values does not, however, guarantee the absolute exclusion of undesired effects at levels below the guideline values. It means only that guideline values have been established in the light of current knowledge and that uncertainty factors based on the best scientific judgements have been incorporated, though some uncertainty cannot be avoided.

For some of the substances, a direct relationship between concentrations in air and possible toxic effects is very difficult to establish. This is especially true of those pollutants for which a greater body burden results from ingestion than from inhalation. For instance, available data show that for the general population the food chain is the critical route of non-occupational exposure to lead and cadmium, and to persistent organic pollutants such as dioxins and PCBs. On the other hand, emissions of these pollutants into air may contribute significantly to the contamination of food by these compounds. Complications of this kind were taken into consideration, and an attempt was made to develop guidelines that would also prevent those toxic effects of air pollutants that resulted from uptake by both ingestion and inhalation.

For certain compounds, such as organic solvents, the proposed health-related guidelines are orders of magnitude higher than current ambient levels. The fact that existing environmental levels for some substances are much lower than the guideline levels by no means implies that pollutant burdens may be increased up to the guideline values. Any level of air pollution is a matter of concern, and the existence of guideline values never means a licence to pollute.

Unfortunately, the situation with regard to actual environmental levels and proposed guideline values for some substances is just the opposite – guideline values are below existing levels in some parts of Europe. For instance, the guideline values recommended for major urban air pollutants such as nitrogen dioxide, ozone and sulfur dioxide point to the need for a significant reduction of emissions in some areas.

For substances with malodorous properties at concentrations below those where toxic effects occur, guideline values likely to protect the public from odour nuisance were established; these were based on data provided by expert panels and field studies (Table 3). In contrast to other air pollutants, odorous substances in ambient air often cannot be determined easily and systematically by analytical methods because the concentrations are usually very low. Furthermore, odours in the ambient air frequently result from a complex mixture of substances and it is difficult to identify individual ones; future work may have to concentrate on odours as perceived by individuals rather than on separate odorous substances.

Table 3. Rationale and guideline values based on sensory effects or annoyance reactions, using an averaging time of 30 minutes

Substance	Detection threshold	Recognition threshold	Guideline value
Carbon disulfide[a] (index substance for viscose emissions)	200 μg/m^3	–	20 μg/m^3
Hydrogen sulfide[a]	0.2–2.0 μg/m^3	0.6–6.0 μg/m^3	7 μg/m^3
Formaldehyde	0.03–0.6 mg/m^3	–	0.1 mg/m^3
Styrene	70 μg/m^3	210–280 μg/m^3	70 μg/m^3
Tetrachloroethylene	8 mg/m^3	24–32 mg/m^3	8 mg/m^3
Toluene	1 mg/m^3	10 mg/m^3	1 mg/m^3

[a] Not re-evaluated for the second edition of the guidelines.

Guidelines based on carcinogenic effects

In establishing criteria upon which guidelines could be based, it became apparent that carcinogens and noncarcinogens would require different approaches. These approaches are determined by theories of carcinogenesis, which postulate that there is no threshold for effects (that is, that there is no safe level). Risk managers are therefore faced with two choices: either to prohibit a chemical or to regulate it at levels that result in an acceptable degree of risk. Indicative figures for risk and exposure assist the risk manager to reach the latter decision. Air quality guidelines are therefore indicated in terms of incremental unit risks (Table 4) in respect of those carcinogens that are considered to be genotoxic (see Chapter 2). To allow risk managers to judge the acceptability of risks, this edition of the guidelines has provided concentrations of carcinogenic air pollutants associated with an excess lifetime cancer risk of 1 per 10 000, 1 per 100 000 and 1 per 1 000 000.

For butadiene, there is substantial information on its mutagenic and carcinogenic activity. It has been shown that butadiene is mutagenic in both bacterial and mammalian systems, but metabolic activation into DNA-reactive metabolites is required for this activity. In general, metabolism of butadiene to epoxides in humans is significantly less than in mice and rats, with mice having the highest metabolic activity. Human cancer risk estimates for butadiene based on bioassays vary considerably depending on the animal species used, with risk estimates based on data in mice being 2–3 orders of magnitude higher than those based on rat data. At present, no definite conclusion can be made as to which animal species is most appropriate for human cancer risk estimates, and thus no guideline value is recommended for butadiene.

Table 4. Carcinogenic risk estimates based on human studies[a]

Substance	IARC Group	Unit risk[b]	Site of tumour
Acrylonitrile[c]	2A	2×10^{-5}	lung
Arsenic	1	1.5×10^{-3}	lung
Benzene	1	6×10^{-6}	blood (leukaemia)
Butadiene	2A	–	multisite

Chromium (VI)	1	4×10^{-2}	lung
Nickel compounds	1	4×10^{-4}	lung
Polycyclic aromatic hydrocarbons (BaP)[d]		9×10^{-2}	lung
Refractory ceramic fibres	2B	1×10^{-6} (fibre/l)$^{-1}$	lung
Trichloroethylene	2A	4.3×10^{-7}	lung, testis
Vinyl chloride[c]	1	1×10^{-6}	liver and other sites

[a] Calculated with average relative risk model.
[b] Cancer risk estimates for lifetime exposure to a concentration of 1 μg/m^3.
[c] Not re-evaluated for the second edition of the guidelines.
[d] Expressed as benzo[*a*]pyrene (based on a benzo[*a*]pyrene concentration of 1 μg/m^3 in air as a component of benzene-soluble coke-oven emissions).

Separate consideration is given to risk estimates for asbestos (Table 5) and radon daughters (Table 6) because they refer to different physical units, and the risk estimates are indicated in the form of ranges.

Table 5. Risk estimates for asbestos

Concentration	Range of lifetime risk estimates	
500 F*/m^3 (0.0005 F/ml)[a]	10^{-6}–10^{-5}	(lung cancer in a population where 30% are smokers)
	10^{-5}–10^{-4}	(mesothelioma)

[a] F* = fibres measured by optical methods.

Risk estimation for residential radon exposure has often been based on extrapolation of findings in underground miners. Several circumstances, however, make such estimates uncertain for the general population: exposure to other factors in the mines; differences in age and sex; size distribution of aerosols; the attached fraction of radon progeny; breathing rate; and route. Furthermore, uncertainties in the exposure–response exist, and possible differences in the relative risk estimates for smokers and non-smokers are not fully understood (see Chapter 8, Part 3).

For radon, a unit risk of approximately $3–6 \times 10^{-5}$ per Bq/m^3 can be calculated assuming a life time risk of lung cancer of 3% (Table 6). This means that a person living in an average European house with 50 Bq/m^3 has a lifetime excess lung cancer risk of $1.5–3 \times 10^{-3}$ Thus current levels of radon in dwellings and other buildings are of public health concern. In addition it should be noted that a lifetime lung cancer risk below about 10^{-4} could normally not be expected to be achievable because natural concentration of radon in ambient air outdoors is about 10 Bq/m^3. Therefore no numerical guideline value for radon is recommended.

Table 6. Risk estimates and recommended action level for radon progeny

Exposure	Lung cancer excess lifetime risk estimate	Recommended level for remedial action in buildings
1 Bq/m^3	$3–6 \times 10^{-5}$	≥ 100 Bq/m^3 (annual average)

It is important to note that quantitative risk estimates may give an impression of accuracy that they do not in fact have. An excess of cancer in a population is a biological effect and not a mathematical function, and uncertainties of risk estimation are caused not only by inadequate exposure data but also, for instance, by the fact that specific metabolic properties of agents are not reflected in the models. The guidelines do not indicate therefore that a specified lifetime risk is virtually safe or acceptable.

The decision on the acceptability of a certain risk should be taken by the national authorities in the context of a broader risk management process. Risk estimate figures should not be applied in isolation when regulatory decisions are being made; combined with data on exposure levels and individuals exposed, they may be a useful contribution to risk assessment. Risk assessment can then be used together with technological, economic and other considerations in the risk management process.

Guidelines based on effects on vegetation

Although the main objective of the air quality guidelines is the direct protection of human health, it was decided that ecological effects of air pollutants on vegetation should also be considered. The effects of air pollutants on the natural environment are of special concern when they occur at concentrations lower than those that damage human health. In such cases, air quality guidelines based only on effects on human health would not allow for environmental damage that might indirectly affect human wellbeing.

Ecologically based guidelines for preventing adverse effects on terrestrial vegetation were included in the first edition of this book, and guidelines were recommended for some gaseous air pollutants. Since that time, however, significant advances in the scientific understanding of the impacts of air pollutants on the environment have been made. For the updating and revision of the guidelines, the ecological effects of major air pollutants were considered in more detail within the framework of the Convention on Long-range Transboundary Air Pollution. This capitalizes on the scientific work undertaken since 1988 to formulate criteria for the assessment of the effects of air pollutants on the natural environment, such as critical levels and critical loads.

It should be understood that the pollutants selected (SO_2, NO_x and ozone/photochemical oxidants) (Table 7) are only a few of a larger category of air pollutants that may adversely affect the ecosystem, and that the effects considered are only part of the spectrum of ecological effects. Effects on aquatic ecosystems were not evaluated, nor were effects on animals taken into account. Nevertheless, the available information indicates the importance of these pollutants and of their effects on terrestrial vegetation in the European Region.

Table 7. Guideline values for individual substances based on effects on terrestrial vegetation

Substance	Guideline value	Averaging time
SO_2: critical level	10–30 µg/m^3[a]	annual
critical load	250–1500 eq/ha/year[b]	annual
NO_x: critical level	30 µg/m^3	annual
critical load	5–35 kg N/ha/year[b]	annual
Ozone: critical level	0.2–10 ppm.h[a, c]	5 days–6 months

[a] Depending on the type of vegetation (see Part III).
[b] Depending on the type of soil and ecosystem (see Part III).
[c] AOT: Accumulated exposure Over a Threshold of 40 ppb.

