APPENDIX C *

WORLD HEALTH ORGANIZATION: AIR QUALITY GUIDELINES FOR EUROPE
CHAPTER 3: SUMMARY OF THE GUIDELINES

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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. Table 1 summarizes the different endpoints on which guideline values and carcinogenic risk estimates have been based for organic and inorganic substances, showing that all relevant biological effects (endpoints) were evaluated and sometimes more than one endpoint was considered for guideline recommendations.

The numerical guideline values and the risk estimates for carcinogens (Tables 2–5) should be regarded as the shortest possible summary of a complex scientific evaluation process. Scientific results are an abstraction of real life situations, and this is even more true for numerical values and 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. 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 result in guideline values which are only comparable between pollutants to a limited extent.

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 guidelines are for individual chemicals. Pollutant mixtures can yield differing toxicities, but data are at present insufficient for guidelines relating to mixtures (except that of sulfur dioxide and suspended particulates) to be laid down.

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Guideline Values based on Effects other than Cancer

The guideline values for individual substances based on effects other than cancer and odour are given in Table 2. Guideline values for combined exposure to sulfur dioxide and particulate matter are indicated in Table 3.

The emphasis in the guidelines is placed on exposure, since this is the element that can be controlled to lessen dose and hence lessen response. 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 protection (safety) factors, the guideline values were established.

However, compliance with the guideline values does not 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 protection 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 metals for which a greater body-burden results from ingestion than from inhalation. For instance, available data show that the food chain is, for most people, the critical route of nonoccupational exposure to lead and cadmium. On the other hand, airborne lead and cadmium may contribute significantly to the contamination of food by these metals. Complications of this kind were taken into consideration and an attempt was made to develop air quality guidelines which would also prevent those toxic effects of air pollutants that resulted from uptake through 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.

The approach taken in the preparation of the air quality guidelines was to use expert panels to evaluate data on the health effects of individual compounds. As part of this approach, each chemical is considered in isolation. Inevitably, there is little emphasis on such factors as interaction between pollutants that might lead to additive or synergistic effects and on the environmental fate of pollutants (e.g. 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.

Unfortunately, the situation with regard to actual environmental levels and proposed guideline values for some substances is just the opposite,

Table 1. Established guideline values and risk estimates

Substance	IARC Group classification	Risk estimate based on carcinogenic endpoint	Guideline value(s) based on:		
			toxicological endpoint	sensory effects or annoyance reaction	ecological effects
Organic substances					
Acrylonitrile	2A	x			
Benzene	1	x			
Carbon disulfide	—		x	x	
1,2-Dichloroethane	—[a]		x		
Dichloromethane	—[a]		x		
Formaldehyde	2B		x		
Polynuclear aromatic hydrocarbons (Benzo[*a*]pyrene)	—[b]	x			
Styrene	3		x	x	
Tetrachloroethylene	3		x	x	
Toluene	—		x	x	
Trichloroethylene	3		x		
Vinyl chloride	1	x			
Inorganic substances					
Arsenic	1	x			
Asbestos	1	x			

Inorganic substances (contd)					
Cadmium	2B		x		
Carbon monoxide	—		x		
Chromium (VI)	1	x			
Hydrogen sulfide	—		x	x	
Lead	3		x		
Manganese	—		x		
Mercury	—		x		
Nickel	2A[c]	x			
Nitrogen dioxide	—		x		x
Ozone/photochemical oxidants	—		x		x
Radon -	—	x			
Sulfur dioxide and particulate matter	—		x		x
Vanadium	—		x		

[a] Not classified, but sufficient evidence of carcinogenicity in experimental animals.

[b] Not classified, but sufficient evidence of carcinogenicity of PAH in humans in some occupational exposures (*IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans*, Vol 34). Sufficient evidence of carcinogenicity for benzo[*a*]pyrene in animal studies. Benzo[*a*]pyrene is present as a component of the total content of polycyclic aromatic hydrocarbons in the environment (*IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans*, Vol 32).

[c] Exposures from nickel refineries are classified in Group 1.

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

Substance	Time-weighted average	Averaging time	Chapter
Cadmium	1– 5 ng/m^3 10–20 ng/m^3	1 year (rural areas) 1 year (urban areas)	19
Carbon disulfide	100 $\mu g/m^3$	24 hours	7
Carbon monoxide	100 mg/m^3[b] 60 mg/m^3[b] 30 mg/m^3[b] 10 mg/m^3	15 minutes 30 minutes 1 hour 8 hours	20
1,2-Dichloroethane	0.7 mg/m^3	24 hours	8
Dichloromethane (Methylene chloride)	3 mg/m^3	24 hours	9
Formaldehyde	100 $\mu g/m^3$	30 minutes	10
Hydrogen sulfide	150 $\mu g/m^3$	24 hours	22
Lead	0.5–1.0 $\mu g/m^3$	1 year	23
Manganese	1 $\mu g/m^3$	1 year[c]	24
Mercury	1 $\mu g/m^3$[d] (indoor air)	1 year	25
Nitrogen dioxide	400 $\mu g/m^3$ 150 $\mu g/m^3$	1 hour 24 hours	27
Ozone	150–200 $\mu g/m^3$ 100–120 $\mu g/m^3$	1 hour 8 hours	28
Styrene	800 $\mu g/m^3$	24 hours	12
Sulfur dioxide	500 $\mu g/m^3$ 350 $\mu g/m^3$	10 minutes 1 hour	30
Sulfuric acid	—[e]	—	30
Tetrachloroethylene	5 mg/m^3	24 hours	13
Toluene	8 mg/m^3	24 hours	14
Trichloroethylene	1 mg/m^3	24 hours	15
Vanadium	1 $\mu g/m^3$	24 hours	31

[a] Information from this table should *not* be used without reference to the rationale given in the chapters indicated.

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

[c] Due to respiratory irritancy, it would be desirable to have a short-term guideline, but the present data base does not permit such estimations.

[d] The guideline value is given only for indoor pollution; no guidance is given on outdoor concentrations (via deposition and entry into the food chain) that might be of indirect relevance.

[e] See Chapter 30.

Note. When air levels in the general environment are orders of magnitude lower than the guideline values, present exposures are unlikely to present a health concern. Guideline values in those cases are directed only to specific release episodes or specific indoor pollution problems.

Table 3. Guideline values for combined exposure to sulfur dioxide and particulate matter[a]

	Averaging time	Sulfur dioxide ($\mu g/m^3$)	Reflectance assessment: black smoke[b] ($\mu g/m^3$)	Gravimetic assessment: Total suspended particulates (TSP)[c] ($\mu g/m^3$)	Gravimetic assessment: Thoracic particles (TP)[d] ($\mu g/m^3$)
Short term	24 hours	125	125	120[e]	70[e]
Long term	1 year	50	50	—	—

[a] No direct comparisons can be made between values for particulate matter in the right- and left-hand sections of this table, since both the health indicators and the measurement methods differ. While numerically TSP/TP values are generally greater than those of black smoke, there is no consistent relationship between them, the ratio of one to the other varying widely from time to time and place to place, depending on the nature of the sources.

[b] Nominal $\mu g/m^3$ units, assessed by reflectance. Application of the black smoke value is recommended only in areas where coal smoke from domestic fires is the dominant component of the particulates. It does not necessarily apply where diesel smoke is an important contributor.

[c] TSP: measurement by high volume sampler, without any size selection.

[d] TP: equivalent values as for a sampler with ISO-TP characteristics (having 50% cut-off point at 10μm); estimated from TSP values using site-specific TSP/ISO-TP ratios.

[e] Values to be regarded as tentative at this stage, being based on a single study (involving sulfur dioxide exposure also).

i.e. guideline values are below the existing levels in some parts of Europe. For instance, the guideline values recommended for major urban air pollutants such as nitrogen oxides, ozone and sulfur oxides 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 4). In contrast to other air pollutants, odorous substances in ambient air often cannot be determined easily and systematically by analytical methods because the concentration is 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 4. 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 in viscose emissions			20 $\mu g/m^3$
Hydrogen sulfide	0.2-2.0 $\mu g/m^3$	0.6-6.0 $\mu g/m^3$	7 $\mu g/m^3$
Styrene	70 $\mu g/m^3$	210-280 $\mu g/m^3$	70 $\mu g/m^3$
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

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 are determined by theories of carcinogenesis which postulate that there is no threshold for effects (i.e. that there is no safe level). Therefore, risk managers are faced with two decisions: 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. Therefore, air quality guidelines are indicated in terms of incremental unit risks in respect of those carcinogens for which at least limited evidence of carcinogenicity in humans exists (Table 5).

Table 5. Carcinogenic risk estimates based on human studies[a]

Substance	IARC Group classification	Unit risk[b]	Site of tumour
Acrylonitrile	2A	2×10^{-5}	lung
Arsenic	1	4×10^{-3}	lung
Benzene	1	4×10^{-6}	blood (leukaemia)
Chromium (VI)	1	4×10^{-2}	lung
Nickel	2A	4×10^{-4}	lung
Polynuclear aromatic hydrocarbons (carcinogenic fraction)[c]		9×10^{-2}	lung
Vinyl chloride	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 $\mu g/m^3$.

[c] Expressed as benzo[*a*]pyrene (based on benzo[*a*]pyrene concentration of 1 $\mu g/m^3$ in air as a component of benzene-soluble coke-oven emissions).

Separate consideration is given to risk estimates for asbestos (Table 6) and radon daughters (Table 7) because they refer to different physical units and are indicated in the form of ranges.

Unfortunately, the recent reclassification of dichloromethane by IARC has not allowed sufficient time to publish a detailed risk estimate which takes into account important information on the metabolism of the compound. The risk estimate for cancer from the animal bioassay is not used for this reason in the guidelines.

Table 6. Risk estimates for asbestos[a]

Concentration	Range of lifetime risk estimates	
500 F*/m³ (0.0005 F/ml)	10^{-6} - 10^{-5}	(lung cancer in a population where 30% are smokers)
	10^{-5} - 10^{-4}	(mesothelioma)

[a] See Chapter 18 for an explanation of these figures.

Note. F* = fibres measured by optical methods.

Table 7. Risk estimates and recommended action level[a] for radon daughters

Exposure	Lung cancer excess lifetime risk estimate	Recommended level for remedial action in buildings
1 Bq/m^3 EER	(0.7×10^{-4}) - (2.1×10^{-4})	$\geqq$ 100 Bq/m^3 EER (annual average)

[a] See Chapter 29 for an explanation of these figures and for further information.

Formaldehyde represents a chemical for which cancer bioassays in rats have resulted in nonlinear exposure response curves. The nonlinearity of the tumour incidence with exposure concentrations led Starr & Buck[a] to introduce the "delivered dose" (amount of formaldehyde covalently bound to respiratory mucosal DNA) as the measure of exposure into several low-dose extrapolation models. Results showed considerable differences in the ratio between risk estimates based on the administered dose and those based on the delivered dose, with a great variance of ratios between models. Since estimates vary because of the inherent differences in approach, cancer risk estimates are referred to but not used for the guidelines. In addition, such estimates should be compared with human epidemiological data when an informed judgement has to be made.

The evidence for carcinogenicity of 1,2-dichloroethane in experimental animals is sufficient, being based on ingestion data. No positive inhalation bioassays are available. Consequently, an extrapolation from the ingestion route to the inhalation route is needed to provide a cancer risk estimate from the bioassay data. Such extrapolations are best conducted when detailed information is available on the kinetics of metabolism, distribution and excretion. Two estimates calculated from data on oral studies are provided for the risk of cancer through inhalation of 1,2-dichloroethane, but they lack detailed data for the route-to-route extrapolation and are not used in the guidelines.

It is important to note that quantitative risk estimates may give an impression of accuracy which in fact they do not 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. Therefore, the guidelines do not indicate that a specified lifetime risk is virtually safe or acceptable.

[a] **Starr, T.B. & Buck, R.D.** The importance of delivered dose in estimating low-dose cancer risk from inhalation exposure to formaldehyde. *Fundamental and applied toxicology*, **4**: 740–753 (1984).

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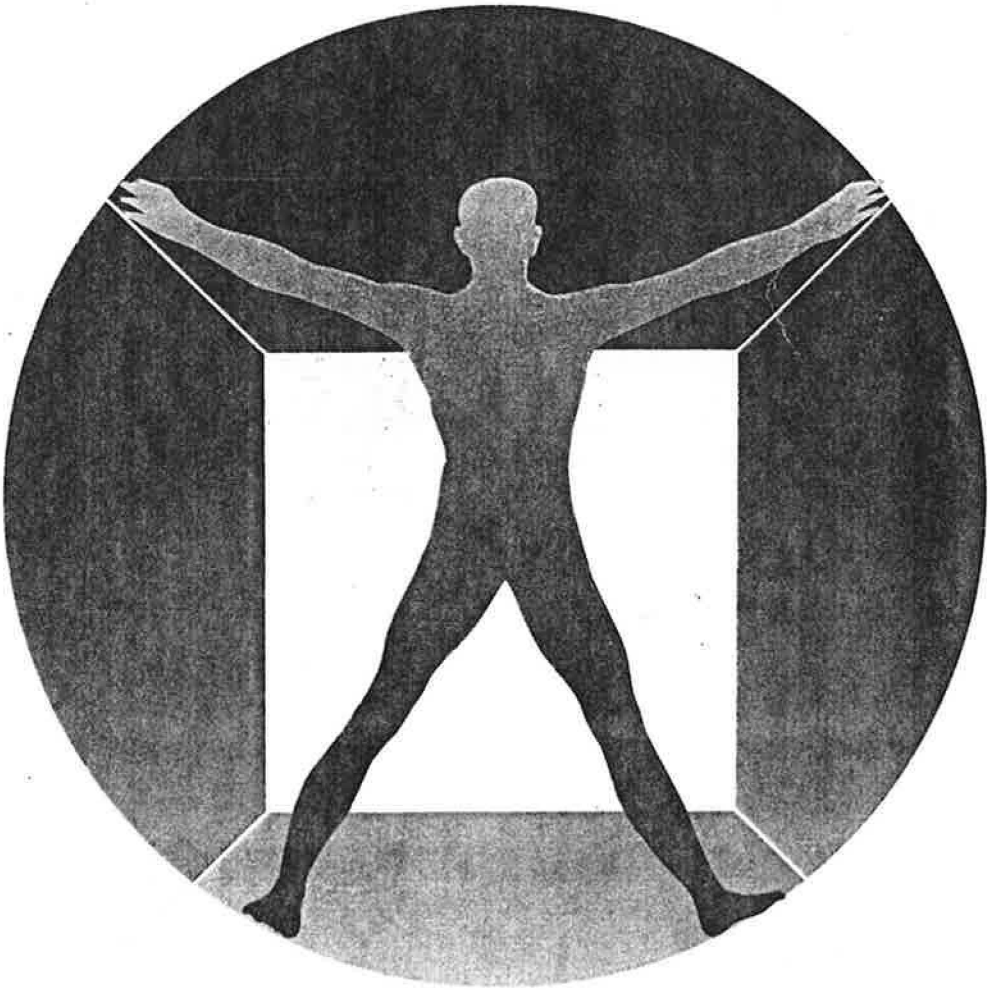

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