atmosphere

Article

Challenges in IAQ for Indoor Spaces: A Comparison of the Reference Guideline Values of Indoor Air Pollutants from the Governments and International Institutions

Gaetano Settimo [1,†], Yong Yu [2,†], Marco Gola [2,*], Maddalena Buffoli [2] and Stefano Capolongo [2]

1 Department of Environment and Health, Italian National Institute of Health (Istituto Superiore di Sanità), 00161 Rome, Italy
2 Design & Health Lab, Department Architecture, Built Environment and Construction Engineering, Politecnico di Milano, Via G. Ponzio 31, 20133 Milan, Italy
* Correspondence: marco.gola@polimi.it
† These authors contributed equally to this work.

Abstract: Since people spend most of their time inside buildings, indoor air quality (IAQ) remains a highlighted topic to ensure in the built environment to improve public health, especially for vulnerable users. To achieve a better indoor environment quality (IEQ), some countries' governments or regional institutions have developed and published reference guideline values of various air pollutants to prevent the IAQ from becoming adverse to occupants. Beyond guidelines by World Health Organization (WHO), in some countries, there are specific institutional requirements on the IAQ, and others integrated it into the building regulation for the built environment. This paper is based on the literature research, summarized from previously conducted works by the authors, on the chemical reference values of IAQ-related regulations and guidelines published by several Governments or related institutions from various regions around the World. Despite these efforts at standardization and legislation, many indoor air quality monitoring activities conducted in several countries still fall short of the main indications produced. By comparing the reference values of 35 pollutants, both physical and chemical ones, which are proposed in documents from 23 regions included so far, the IAQ research and prevention actions on progress in different regions should be included in monitoring plans with guidelines/reference values in their current state. The outcome of the paper is to define the current trends and suggest some perspectives on the field of interest for improving the indoor air quality of generic spaces at an international level. It becomes evident that, at the global level, IAQ represents a complex political, social, and health challenge, which still suffers from the absence of a systematic and harmonized approach. This is not a new situation; the issue was raised more than 40 years ago, and despite efforts and a pandemic, the situation has not changed.

Keywords: indoor air quality (IAQ); air pollutants; indoor environment quality (IEQ); reference values; guidelines values; international regulations; built environment; perspectives in IAQ; chemical contaminants

Citation: Settimo, G.; Yu, Y.; Gola, M.; Buffoli, M.; Capolongo, S. Challenges in IAQ for Indoor Spaces: A Comparison of the Reference Guideline Values of Indoor Air Pollutants from the Governments and International Institutions. *Atmosphere* **2023**, *14*, 633. https://doi.org/10.3390/atmos14040633

Academic Editors: Adrianos Retalis, Vasiliki Assimakopoulos and Kyriaki-Maria Fameli

Received: 28 February 2023
Revised: 24 March 2023
Accepted: 25 March 2023
Published: 27 March 2023

1. Introduction

1.1. The Present Scenario

Indoor and outdoor air pollution is one of the greatest environmental health risks, affecting everyone in low-, middle-, and high-income countries [1]. People spend on average about 90% of their hours indoors. The development of information and communication technologies has increased the ability to work remotely, and the time spent at home has risen to 100% [1,2].

The scientific community shows that adverse health effects do not only result from acute events but also chronic exposure [3], and most low-level exposures are not perceivable before the symptom is found and have risks to be accumulated during long-term exposure, leading to irreversible health conditions [4–7]. Correspondingly, several guidelines and standards on IAQ are published by many states and several research institutions and professional associations (e.g., related to the ventilation approach) for indoor settings, starting from the documents and guidelines by World Health Organization (WHO) [1,5], with useful suggestions on no impacts on users [8] and best practices for the building managers [9,10].

Currently, several cities started—from their building regulations [11]—to impose the presence of green areas [12], green roofs [13], and other solutions related to green building design for trying to reduce pollution in the built environment. Nowadays, in fact, some companies are developing technologies (paintings, façade solutions, etc.) aimed at improving the quality of indoor and outdoor air, such as the works by Bianchi et al. [14].

The guidelines and standards for IAQ are not only for the target audience of buildings designers who make decisions, such as architects, engineers, internal designers, and construction teams [15], but also for specific users inside the indoor spaces and facility managers who occupied the indoor spaces during the running period in the building lifespan.

Some countries have specific government departments and affiliated or cooperated institutions that independently suggest and publish IAQ reference values based on their national needs, such as Italy [16], France (recently updated on 27.12.2022) [17], Germany [18], Finland [19–21], Denmark [22], Australia [23], Canada [24], New Zealand [25], China [26] and Hong Kong (China) [27], Japan [28], Russian [29], etc. Others include IAQ requirements in the building regulations, guiding the design and construction [30], as one section of the requirements for the built environment, such as the United Kingdom [31,32] and Singapore [33].

Meanwhile, also many international organizations such as the WHO, ISO (International Organization for Standardization), ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), etc., and their working groups regularly provide standards for the IAQ and related guidelines on best practices to help designers, building managers, hygienists, employers, and users to avoid IAQ deterioration. Based on the difference among the geographies, climate conditions, and local features, the presence of industries and developing conditions, as well as the progress of research, the list of pollutants and the reference values vary for each document, lacking a common perspective [34].

In most countries, there is no independent national government authority responsible for IAQ, and the various actions usually lead to an unclear central role of the issue (e.g., prevention activities in offices, schools, hospitals, transportation, and the role of energy efficient interventions).

1.2. Exposure to Chemical Compounds

The exposure to chemical compounds and their health effects in indoor environments have been taken into consideration by several governments and the main environmental and health institutions [35–37].

Exposure to indoor pollutants may cause a significant overall intake of pollutants by users. As a result of long-term work from the 1970s, the WHO has shifted from air quality guidelines on indoor air pollutants, with reports in 1987, 1999, 2000, and 2006, to specific indoor air guidelines, with several documents in 2009, 2010, 2014, and 2016 [34,38]. These guidelines consider many pollutants, including nitrogen dioxide, naphthalene, polycyclic aromatic hydrocarbons (for example, benzo[a]pyrene, etc.), benzene, trichloroethylene, tetrachloroethylene, carbon monoxide, radon, etc. [39], and also dampness and mold [40].

The European Environmental Agency (EEA) defined that IAQ is affected by the quality of ambient air, ventilation systems, construction materials, cleaning products, energy-saving strategies, users' behavior (such as smoking, E-CIG), etc. [41,42], as well as the activities carried out and the use of construction materials, finishing materials, equipment, furniture, etc. [43–46].

In the international scenario, there is a trend for integrated health promotion related to IAQ issues to drastically decrease the presence of pollutants, even though not all countries have specific regulatory legislation. All the guidelines available internationally constitute a framework that can support it in case of the absence of legislation, scholars, researchers, and experts in the topic and strategies to be applied.

As Settimo highlighted, with a specific focus on the European context, norms, and regulations on indoor air pollution are applied only in some punctual countries [34]. Harmonization of contents and parameters related to indoor air pollution control and monitoring should be implemented [34]. This calls for a review and improvement of the information and problems related to the quantity, nature, and origin of pollutants, starting from the existing protocols and norms.

Starting from these considerations, the ISO and CEN (European Committee for Standardization) institutions have provided a set of specific references on standard operating procedures for IAQ monitoring with EN ISO 16000 [47]. The EC (European Commission) and ECA (European collaborative action) have carried out a multidisciplinary research project, with the collaboration of several experts producing 30 specific documents from 1988 to 2020.

In terms of harmonization, several guidelines and indications on IAQ are also available from the WHO, for which health-based evidence is extracted from the related research on health effects [39,48]. The guidelines define the starting point for establishing reference values and limits adopted by various countries that are subject to regular revisions. In any case, the guidelines related to airborne pollutants are limited due to the large number of indoor compounds.

In general, as Settimo already specified, "reference values permit indoor spaces to be more restrictive than those suggested for industrial workplaces, based on 8-h a day, 5-day a week exposure and for a maximum period of 40 years, and targeted to the protection of workers against professional disease and illnesses" [34]. Identifying the appropriate reference values is critical to making appropriate assessments for the type of exposure. Several countries have applied specific and punctual references and guideline values; for example, the "Plan d'actions sur la Qualité de l'Air Intérieur" in France listed several monitoring and procedures.

At the same time, the deepening of knowledge on the topic has conditioned some countries through the development of multidisciplinary working groups for guideline values for IAQ, such as Germany with the AG IRK/AOLG (Federal Environmental Agency and the States Health), France with CSTB (Scientific and Technical Centre for Building) and AFSSET (French Agency for Environmental and Occupational Health Safety), the United Kingdom with the COMEAP (Committee on the Medical Effects of Air Pollutants), The Netherlands with the RIVM (National Institute for Public Health and the Environment), Finland with the MSAH (Ministry of Social Affairs and Health) commission, the Flemish Region, etc.

They have thus included reference values or limits in their regulation/guideline, including formaldehyde, benzene, trichlorethylene, tetrachlorethylene, carbon monoxide, carbon dioxide, nitrogen dioxide, PM_{10}, $PM_{2.5}$, etc. Because of the different methods used for determining the guide values, they may differ for the same substances, as compared to the WHO guidelines [39].

Methodologies are a strategic factor, as well as guideline values. In all the regions, values proposed are related to monitoring methods and analysis developed by several institutes (such as The Netherlands Instituut Normalisatie, NEN; British Standards, BS; German Institute for Standardization, DIN; Association Française de Normalisation, AFNOR; Bureau de Normalisation, NBN; Austrian Standards Institute, ASI; Finnish Standards Association, SFS, etc.). Thus, a global framework for pollutants that are taken into account by several nations and the WHO can be developed with significant technical information from these key institutions.

1.3. Aims and Scope of the Position Paper

This position paper aims to compare the reference values related to physical and chemical pollutants applied in several countries in order to highlight the current trends and perspectives on the field of interest for improving the quality. It is based on the existing standards and guidelines (mostly available and in English) from international countries' governments and regional institutions, as well as starting from a previous research work by Settimo [34].

The comparisons between values from adjacent regions reveal a wide range of values and show the needs of IAQ from the regions. On the other hand, a list of pollutants and reference values is proposed with highest requirement on values from all documents collected so far for achieving higher requirements of IAQ in some specific indoor spaces, such as those with medical needs or as the future targets in some regions.

2. Methodology and Data Collection

2.1. Inclusion of Documents

For defining the current trends in chemical and physical pollutant reference values, the research team selected and compared mandatory and voluntary guidelines and standards of several countries coming from different continents; in particular, the ones considered are the most representative, accessible ones from the webpages. In particular, the analysis aims to give rise to a matrix of analyses, with the list of pollutant types and their reference values.

As shown in Table 1, the documents included in this position paper are mainly about guidelines and standards that defined reference values to guide the intervention to the IAQ to make the comparisons, but not those about measurement standards and strategies' implementations (e.g., ISO 16000). All the references selected were published by international governments, professional associations, affiliated departments, and regional/local institutions. They were collected from published regulations, government websites, national standard departments, and online archives of institutions. In particular, they are collected from the following:

- Existing guidelines and standards with reference values collected in the previous research with the updates if they had;
- Standard or regulation documents from the local government from the countries with research on IAQ and published in English;
- Searches according to the related papers, published documents, mentioned references, and websites.

Among the regions searched so far, the local governments from some regions did not publish any official guidelines, standards, or regulations on the IAQ, such as USA and India. In this case, the documents from local authoritative institutions are included, for example, ASHRAE [49] and the Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) [50].

For the USA, the United States Environmental Protection Agency (USEPA) published Acute Exposure Guideline Levels (AEGL) for Airborne Chemicals [51] to describe the human health effects of once-in-a-lifetime or rare exposure to airborne chemicals. Because those values are not proposed for IAQ but air in general, and during the comparison, they are found to be far higher than the IAQ reference values from other documents; thus, those documents will not be included. Meanwhile, some values from this website of USEPA [51] have been adapted to other documents, such as the values for VOCs from Canada [24,52] and the UK [32], and the adapted values need double checks before comparisons.

Moreover, for the USA, even if USEPA has published the National Ambient Air Quality Standards (NAAQS) for outdoor air quality, there is no such integrated document published officially for the IAQ. From the website of USEPA [53], there are several concerned pollutants listed with guidelines about how to prevent exposure, including asbestos, biological pollutants, carbon monoxide (CO), formaldehyde/pressed-wood products, lead (Pb), nitrogen dioxide (NO_2), pesticides, indoor particulate matter, secondhand smoke/environmental tobacco smoke, stoves and heaters, fireplaces and chimneys, volatile organic compounds (VOCs), and radon (Rn), but no value proposed for them. Apart from ASHRAE, there are some organizations that are cited for the permissible exposure limit (PEL) or recommended exposure limit (REL) from organizations including the Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH), and American Conference of Governmental Industrial Hygienists (ACGIH). It is worth mentioning that these limits (i.e., Threshold Limit Value—Time-Weighted Average, TLV®-TWA; Threshold Limit Value—Short-Term Exposure Limit, TLV®-STEL; and TLV®-Ceiling) are related to the industrial field, and therefore they cannot be applied in generic environments. Moreover, for ASHRAE, there are several documents related to the IAQ, including Indoor Air Quality Guide [54] and Standards 62.1 [55] and 62.2 [56], but no reference value proposed officially. Therefore, apart from the specifically proposed values found, such as for CO_2, other documents from the USA are not included.

2.2. Matrix Analysis

The documents found from the existing literature and websites so far are listed in Table 1. The documents are from not only the countries but also from regional organizations, which are applied in the local context, as the WHO document stated [39].

In general, it is well-known that countries' guidelines and standards usually reflect the particular social economic, geographical, and climate conditions of each state. For this reason, the authors of this position paper will take into consideration the different values suggested by the regions to suggest representative values for improving the IAQ performance in indoor spaces.

In the table, the authors also added Hong Kong and Taiwan. Although they are regions in China, the local regulations are usually different from those of the mainland; therefore, they are also included to represent the reference value applied in those regions.

Table 1. Documents included in the comparison.

Region	Country or Institution	Update Year(s)	Publication Department	Citation
International	WHO	2000 2010 2021	World Health Organization (WHO), Regional Office for Europe	[4,37,39]
Asia	China	2002	Ministry of Ecology and Environment of the People's Republic of China (MEE)	[26]
	Hong Kong (China)	2019	The Government of the Hong Kong Special Administrative Region Indoor Air Quality Management Group	[27]
	Taiwan (China)	2013	Taiwan Environmental Protection Administration (Taiwan EPA)	[57,58]
	India	2019	Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE)	[50]
	Japan	2019	Ministry of Health Labour and Welfare of Japan (MHLWJ)	[28]
	Malaysia	2010	Department of occupational safety and health ministry of human resources Malaysia (DOSH)	[59]
	Singapore	2016	Singapore Standard Council (SSC)	[33]

Table 1. *Cont.*

Region	Country or Institution	Update Year(s)	Publication Department	Citation
Europe	Austria	1996 2012 2011 2014 2013 2011	Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology; Association of Ecological Research Institutes (AGÖF); Federal Ministry of Agriculture Regions and Tourism	[60–66]
	Belgium	2018 2019 2022 2017	Flemish government; Federal public service employment labor and social dialogue; Service Public Fédéral Sécurité Sociale; FPS Public Health, Food Chain Safety and Environment of Belgium; Superior Health Council	[67–70]
	Denmark	2010	Danish Building Regulations	[22]
	Finland	2015 2012	Ministry of the Environment Department of Built Environment; Ministry of Social Affairs and Health (STM)	[19–21]
	France	2018 2016 2015 2011 2010	French Agency for Food Environmental and Occupational Health & Safety (ANSES); Légifrance	[17,71–78]
	Germany	2022	Federal Environment Agency (UB)	[18]
	Lithuania	2007	Minister of Health Protection of the Republic of Lithuania	[79]
	Netherlands	2010	Health Council of The Netherlands	[80]
	Norway	2013 1991	Ministry of Labour and Social Inclusion	[81,82]
	Poland	1996	Minister of Health and Social Welfare	[83]
	Portugal	2006 2013	Ministério das Obras Públicas Transportes e Comunicações (MOPTC); Ministério da Economia e do Emprego (MEE)	[84,85]
	Russia	2001	Department of State Sanitary and Epidemiological Supervision of the Ministry of Russia	[29]
	Spain	2021	Instituto Nacional de Seguridad y Salud en el Trabajo (INSST)	[86]
	United Kingdom	2018 2019 2021	Education & Skills Funding Agency; Public Health England; His Majesty's Government	[31,32,87]
North America	Canada	2022	Government of Canada	[24,52,88]
	United States	2019	American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)	[49]
Oceania	Australia	2021	Commonwealth of Australia and States and Territories of Australia (CASTA)	[23]
	New Zealand	1990	Standards New Zealand (SNZ)	[25]

2.3. Value Comparison Methods

The reference values from each document are generally based on two aspects: one aspect is the values of the safe level verified by clinical medical and epidemiological research, such as those proposed by the WHO (health based) [39], which have been proved based on previous case studies that pollutants at this level will not lead to acute or accumulated adverse health effects; and the other is that the values are proposed based on their national action and plans, for which the values of the specific pollutants can be higher or lower accordingly (e.g., based on new exposure studies, based on new exposure studies, or based on the results of the national actions and plans). So, in general, the values are inside reasonable ranges for the proposed average periods, especially for those most discussed pollutant types. Moreover, these values can be concluded to be adaptable for other regions as the reference values. It is then necessary to consider environmental background levels.

However, during the collection of reference values, some values are found with large deviations from the ranges. For those values, the specific reasons will be double-checked in their source. There can be various reasons, including the following: (1) the definition of the proposed values is different from the other reference value; (2) the applicable indoor space is defined to be with special functions or for different building types, such as the parking space in the building in Australia; (3) the proposed time of values are too early and lack of updates in the past decades; and (4) some values are proposed for the future scenario or as the next stage targets, etc. For those values, they are excluded from the comparisons, with reasons found in their sources.

3. Results and Discussion

3.1. Comparison of the Chemical Pollutants Investigated

The research team gave rise to a detailed Excel file with all the data related to the reference values collected from the existing standards; Table 2 aims to emphasize the trends and the list of pollutants argued for each country. *(In the paper, the authors use the following abbreviations: "INT" for international scenario, "AS" for Asia, "EU" for Europe, "NA" for North America, and "OC" for Oceania)*. All the data collected are related to the values to be guaranteed in indoor generic spaces.

As is quite apparent from the detailed analysis, the concentrations and values suggested by each region are strongly affected by the epidemiological trends, health status of the local population, norms and laws related to industrial issues, etc., as well as the advancements of the research progresses.

There are some regions, especially Italy, that directly refer to the WHO documents [39] and indicatively report the most restrictive guidance values.

3.2. Main Pollutants Included in Most Documents

Starting from the data analysis, the research group focused its attention on the main ones. As Table 2 shows, not all the pollutants are argued by the countries, and therefore the team focused the discussion on the most cited ones (at least by three countries), as the last column of Table 2 highlights.

In the following paragraphs, the team analyzes pollutant by pollutant, suggesting the trends to be adopted for a common perspective in healthy spaces.

3.2.1. Acetaldehyde

Acetaldehyde is a clear, colorless, fuming liquid with a pungent, fruity odor; it is volatile at ambient temperature and pressure, with a boiling point of 21 °C. Acetaldehyde has a widespread natural occurrence. It occurs in nature as an intermediate product in the respiration of higher plants and can be found in ripening fruit such as apples. Moreover, acetaldehyde is an intermediate product of the fermentation of alcohol and in the metabolism of sugars in the body [89].

The main exposure is from the inhalation of ambient air from urban areas or near sources of combustion. Workers in the organic chemicals industry, with some exposure to fabricated rubber products and biological products industries, have higher risks of exposure to it. Moreover, it is emitted from some building materials, such as rigid polyurethane foams, and some consumer products, such as adhesives, coatings, lubricants, inks, and nail-polish remover [89]. The International Agency for Research on Cancer (IARC) listed acetaldehyde as a Group 1 carcinogen.

Table 2. Documents included in the comparison.

Included Pollutants	WHO	AS						EU														NA		OC		Inclusion Times
		China	Hong Kong (China)	India	Japan	Malaysia	Singapore	Austria	Belgium	Denmark	Finland	France	Germany	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	United Kingdom	Canada	The United States	Australia	New Zealand	
Acetaldehyde				■	■							■										■				4
Acrolein												■										■				2
Ammonia		■																								1
Asbestos							■				■															2
Benzene	■	■		■					■			■		■	■		■	■			■					10
Benze[a]pyrene (BaP)	■	■	■											■	■											5
Carbon dioxide		■	■			■	■		■		■	■	■		■	■		■		■	■	■	■	■	■	17
Carbon monoxide	■	■	■			■	■		■		■	■	■	■	■	■	■	■	■		■	■		■		18
Chlordane																									■	1
Chlorpyrifos					■																					1
Diazinon					■																					1
Dichloromethane	■												■	■	■											4
Di-n-butyl phthalate					■																					1
Di-2-ethylhexyl phthalate					■																					1
Ethylbenzene					■							■														2
Fenobucarb					■																					1
Formaldehyde	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■		■	■		■		21
Hydrocyanic acid												■														1
Naphthalene	■		■	■							■	■	■	■	■		■				■	■				11
Nicotine							■																			1
Nitrogen dioxide	■	■	■	■			■		■			■	■	■	■	■			■		■	■		■		15
Ozone	■	■	■	■		■	■														■	■		■	■	10
Paradichlorobenzene					■																					1
Polycyclic aromatic hydrocarbons	■																									1
$PM_{2.5}$	■			■			■		■		■	■	■	■	■	■	■	■						■		13
PM_{10}	■	■	■	■		■			■		■	■		■	■	■	■	■						■		14
Radon	■	■	■				■			■												■			■	7
Sulfur dioxide		■																								1
Styrene	■			■	■			■			■		■	■	■		■		■		■	■				12
Tetrachloroethylene	■		■	■				■	■			■	■	■	■			■			■	■				12
Tetradecane					■																					1
Toluene	■	■			■			■	■			■	■	■	■		■	■			■	■				13
TVOC		■	■		■		■	■	■						■	■	■	■			■			■		12
Trichloroethylene	■		■	■					■			■	■	■			■	■			■					10
Xylenes		■			■																	■				3

The reference values of acetaldehyde are listed in Table 3.

Table 3. Reference values for acetaldehyde.

Region		Reference Value (μg/m³)			
		General	1 h	1 Day	Long Term
AS	India	-	-	-	140 (1 y) [1]
	Japan	48 (30 ppb)	-	-	-
EU	France	-	3000	-	160 (>1 y)
NA	Canada	-	1420 (795 ppb)	280 (157 ppb)	-

[1] The values are displayed in "reference value (value in ppm or ppb) (average period if they have) (additional information if they have)", in which the average period refers to "m" for minutes, "h" for hours, "d" for days, and "y" for years. Values are displayed in the same way in the following tables.

As Table 3 shows, the value from Japan (48 μg/m^3 and 30 ppb) is far lower than the others, probably because the value was assessed based on exposure effects on the nasal olfactory epithelium in the rats' respiratory tract as criteria, which was adapted from the work published by Appelman et al. in 1986 [90]. Although the final update time of the Japanese document was in 2019, this value was proposed on 22 Jan. 2002 [91] based on the research mentioned above in 1986, and there are no more updates on it.

For the values from Canada, among the comparisons, those values are usually slightly lower (for short- and long-term exposures) than the others, not only in acetaldehyde but also in the following tables, meaning higher requirements in the IAQ. This may be due to the better local natural habitats, as well as the developed social and economic context. Since the deviations of these values from Canada are not so far from those from other regions, they are still considered adaptable values for other regions, but not the first choice.

The reference value to be adopted in the international scenario can be related to the following:

- 1420 μg/m^3 for the 1-h average and 280 μg/m^3 for 1-day average as the short-term value, as Canada [24] suggests.
- 140–160 μg/m^3 for the 1-year average as the long-term value, as India [50] and France suggest [17,71–78].

3.2.2. Benzene

Benzene is an aromatic hydrocarbon with a pungent and sweet smell that evaporates in the air very quickly, as do all volatile organic compounds (VOCs), and it is a highly flammable substance. It is listed as a Group 1 carcinogen by the IARC.

Lower levels of concentration can cause dizziness, drowsiness, increased heart rate, tremors, confusion, and unconsciousness. Prolonged concentrations over time can impair memory and some psychic abilities, as well as cause disturbances and irritant effects on skin and mucous membranes; it is also a human carcinogen.

It comes from cigarette smoke; incomplete combustion of domestic coal and oil; and vapors released from products that contain it, such as glues, paints, furniture and floor wax, cleaning agents, etc. [92].

The reference values of benzene are listed in Table 4.

From the comparison in Table 4, the data from China (110 μg/m^3 for 1 h average) and Lithuania 100 μg/m^3 for 1-day average) are quite higher than the others, maybe because of the local emission source in the past, and the last updated time of these two documents was in 2002 from China [26] and 2007 from Lithuania [79].

Table 4. Reference values for benzene.

Reference		Reference Value ($\mu g/m^3$)					
		General	1 h	8 h	Days	Long Term	Additional Info
INT	WHO	NSL [1]	-	-	-	-	0.17 [2] 1.7 [3]
AS	China	-	110	-	-	-	-
	India	3	-	-	-	-	-
EU	Belgium	0.4	-	-	-	-	20 IV [4]
	France	-	-	-	30 (1–14 d)	20 (14 d–1 y) 2 (> 1 y)	0.2 [2] 2 [3]
	Lithuania	-	-	-	100	-	-
	Netherlands	20	-	-	-	-	-
	Poland	-	-	20 PO [5]	10 R [5]	-	-
	Portugal	-	-	5	-	-	-
	UK	NSL [1]	-	-	-	-	0.17 [2] 1.7 [3]

[1] NSL means No Safe Level. [2] An excess lifetime risk UR/lifetime of 10^{-6} at this value. [3] An excess lifetime risk UR/lifetime of 10^{-5} at this value. [4] IV means Intervention Value. [5] PO means Public Offices; R means Residential buildings.

Meanwhile, the values from India (3 $\mu g/m^3$), Belgium (0.4 $\mu g/m^3$), and Portugal (5 $\mu g/m^3$ for 8 h average) are relatively lower than the others, especially in Belgium. These values can be adapted for the future stage, according to the local emission condition.

For the value from Belgium, 20 $\mu g/m^3$ for continuous condition is the Intervention Value, and the 0.4 $\mu g/m^3$ is set for the target value, which is why the value is far lower than the others. The proposed values from Belgium are similar in the following tables.

Although currently there is not a specific guideline value for Benzene, as indicated by the WHO [39], the reference value to be adopted can be related to the following:

- 20 $\mu g/m^3$ for 1-day average, as the short-term value, as The Netherlands [80] and Poland [83] suggest.
- 2 $\mu g/m^3$ for 1-year average, as the long-term value, as France [17,71–78] suggests.

Moreover, the value refers to the Unit Risks (URs) evaluated by the following:

- 1.7 $\mu g/m^3$ (UR/lifetime) 10^{-6}—WHO values.
- 17 $\mu g/m^3$ (UR/lifetime) 10^{-5}—WHO values [39].

The Unit Risk factors are toxicity values used for carcinogens, which estimate the increased risk of getting cancer that is associated with the concentration of the chemical in the air. A cancer risk of less than one in a million is usually considered to be negligible.

3.2.3. Benzo[a]pyrene (BaP)

Benzo[a]pyrene, is a crystalline aromatic hydrocarbon consisting of five fused benzene rings and formed during the incomplete combustion of organic matter. It is mainly found in gasoline and diesel exhaust, cigarette smoke, coal tar and coal tar pitch, charcoal-broiled foods and certain other foods, amino acids, fatty acids and carbohydrate pyrolysis products, soot smoke, creosote oil, petroleum asphalt, and shale oils [93].

It is listed as a Group 1 carcinogen by the IARC. In the 18th century, a scrotal cancer of chimney sweepers, the chimney sweep's carcinoma, was already known to be connected to soot.

The reference values of Bap are listed in Table 5.

Table 5. Reference values for BaP.

Region		Reference Value (ng/m^3)			
		General	8 h	1 Day	Additional Info
INT	WHO	-	-	-	0.012 [1] 0.12 [2]
AS	China	-	-	1 (1 d)	-
	Hong Kong (China)	-	1.2	-	-
EU	Lithuania	-	-	1 (1 d)	-
	Netherland	1.2	-	-	-

[1] An excess lifetime risk of 10^{-6} at this value. [2] An excess lifetime risk of 10^{-5} at this value.

From the comparison, generally, apart from those from the WHO, the four values of BaP are close: 1 ng/m^3 for 1-day average from China and Lithuania, and 1.2 ng/m^3 from Hong Kong and The Netherlands. These are all for short-term exposure, no matter whether they are for 8 h or 1 day, and there are no long-term values found in the documents so far.

Missing currently specific guidelines values from the WHO, the reference value to be adopted can be related to the following:

- 1 ng/m^3 for 1-day average, as China [26] and Lithuania [79] suggest.

The value refers to the Unit Risks evaluated by the following:

- 0.012 ng/m^3 (UR/lifetime) 10^{-6}—WHO values.
- 0.12 ng/m^3 (UR/lifetime) 10^{-5}—WHO values [39].

3.2.4. Carbon Dioxide [94]

Carbon dioxide (CO_2) is one of the common gaseous substances in the atmosphere. The latest observations reported by the WMO [95] show that globally averaged surface mole fractions for carbon dioxide (CO_2) reached 415.7 $\pm$ 0.2 ppm in 2021.

Apart from the listed regions in Table 1, the reference value of CO_2 is also included in the documents for indoor environment and ventilation in other regions, including Brazil (1800 mg/m^3–1000 ppm), South Korea (1800 mg/m^3–1000 ppm), and Taiwan (China) (1800 mg/m^3–1000 ppm). Moreover, in the US, different organizations published different values on CO_2; for example, CDC has 1440 mg/m^3 and 800 ppm, ASHRAE has 1800 mg/m^3–1000 ppm for the reference value and 1260 mg/m^3–700 ppm for the acceptable value [49], and Illinois has 1800 mg/m^3 and 1000 ppm [96].

Since CO_2 does not have any direct toxicity, the reference value is usually set to improve the working efficiency in the school and office [87]. The values at 1000 ppm and 1800 mg/m^3 are the Intervention Value in most regions; the working environments higher than this value require ventilation for fresh air.

The reference values of carbon dioxide are listed in Table 6.

Generally, from the comparison, the values vary between 1440 and 2180 mg/m^3 and between 800 and 1200 ppm, with the most mentioned value at 1800 mg/m^3 and 1000 ppm, no matter whether it is for 8 h, 1 day, or as a general value. In addition, 3600 mg/m^3 and 2000 ppm are applied as the Intervention Value, such as in Germany and UK.

Table 6. Reference values for carbon dioxide.

Region		**Reference Value (mg/m^3)**			
		General	**8 h**	**1 Day**	**Additional Info**
AS	China	0.1% [1]	-	-	-
	Hong Kong (China)	1440 (800 ppm) EC [2] 1800 (1000 ppm) GC [2]	-	-	
	Malaysia	1800 (1000 ppm)	-	-	-
	Singapore	1000 ppm	700 ppm	-	-
EU	Belgium	-	1620 (900 ppm) (8 h)	-	-
		-	2160 (1200 ppm) (8 h)	-	-
	Finland	1350 (750 ppm) S1 [3]	1710 (950 ppm) S2 [3]	-	-
	France	1440 (800 ppm)	1800 (1000 ppm)	-	-
	Germany	1800 (1000 ppm)	-	-	<1800 (1000 ppm) (harmless) 1800–3600 (1000–2000 ppm) (high) >3600 (2000 ppm) (unacceptable)
	Netherlands	2160	1710 (School)	-	-
	Norway	1800	-	-	-
	Portugal	1800 (1000 ppm) 2250 (1250 ppm)	2250	-	-
	Spain	1440 (800 ppm) 1800 (1000 ppm)	1800	-	-
	UK [4]	1000 ppm 1500 ppm 2000 ppm	-	-	1800 (1000 ppm) (ESB); 2700 (1500 ppm) (RB); 1800 (1000 ppm) (S) occupation; 2700 (1500 ppm) (S) 20 consecutive minutes; 3600 (2000 ppm) (S) (20 m) NE
NA	Canada	-	-	1800 (1000 ppm)	-
OC	Australia	-	850 ppm	-	-
	New Zealand	1800 (1000 ppm) (continuous)	-	-	-

[1] 0.1% is 1000 ppm and 1800 mg/m^3. [2] For Hong Kong, "EC" refers to "Excellent Class", and "GC" refers to "Good Class". [3] S1 for individual indoor environment, and S2 for good indoor environment. [4] For the UK, "ESB" refers to "Energy Saving Buildings"; "RB" refers to "Refurbished Buildings"; "S" refers to "Schools with natural ventilations".

The reference value of CO_2 as a real-time level to be adopted can be related to the following:

- 1800 mg/m^3 and 1000 ppm, as many of the documents mentioned above suggest;
- 3600 mg/m^3 and 2000 ppm as an Intervention Value (IV), as Germany [18] and the UK [31,32,87] suggest.

3.2.5. Carbon Monoxide

Carbon monoxide (CO), which is an odorless, colorless, and tasteless gas that is highly toxic at low concentrations, causing fatigue and pains in the chest for heart patients; at moderate concentrations, it causes coordination problems, headaches, nausea, dizziness, etc.; and, at very high concentrations, it is lethal. The sources that generate it are the incomplete combustion of materials containing carbon or biomass (for heating issues); the malfunction of the gas heating systems, stoves, furnaces, and fireplaces; inadequate ventilation; and also the proximity to roads with high vehicular traffic, as well as garage and parking lots, which can cause a significant impact on the gas concentrations in confined environments [39].

The reference values of carbon monoxide are listed in Table 7.

Table 7. Reference values for carbon monoxide.

Region		Reference Value (mg/m^3)						
		General	**15 min**	**30 min**	**1 h**	**8 h**	**1 Day**	**Additional Info**
INT	WHO	-	100	-	35	10	7	-
AS	China	-	-	-	10	-	-	-
	Hong Kong (China)	-	-	-	-	2 EC 7 GC	-	-
	Malaysia	-	-	-	-	10 ppm	-	-
	Singapore	-	-	-	31 ppm	9 ppm	-	-
EU	Belgium	8	-	-	30 IV	-	5.7	-
	Finland	7	-	-	-	-	-	Instant value
	France	-	100	60	30	10	-	-
	Germany	-	-	6 RWI	-	1.5 RWI [1]	-	-
		-	-	60 RWII	-	15 RWII [2]	-	-
	Lithuania	-	-	5	-	-	3	-
	Netherlands	-	100	60	30	10	-	-
	Norway	-	-	-	25	10	-	-
	Poland	-	-	-	25 R	10 PO	-	-
	Portugal	-	-	-	-	10	-	-
	Russia	-	-	-	-	-	3	-
	UK	-	100 (90 ppm)	60 (50 ppm) (30 m)	30 (25 ppm)	10 (10 ppm)	-	-
NA	Canada	-	-	-	28.6 (25 ppm)	-	11.5 (10 ppm)	-
OC	Australia	-	100 (90 ppm)	50 ppm (30 m)	25 ppm	10 ppm	-	For Class 234,569 building
		100 ppm (NE) [3]	90 ppm	-	60 ppm	30 ppm	-	For Class 7a building

[1] Guide Value I (RW I—precautionary guideline value) describes the concentration of a pollutant in the indoor air, which, according to the current state of research, is not expected to have any adverse health effects if the level is maintained or not reached, even with lifelong exposure. [2] Guide Value II (RW II—hazard guide value) is an effect-related value that is based on the current toxicological and epidemiological knowledge of the effect threshold of a pollutant. [3] NE means No Exceedance.

From the comparison, most values are in a small range for each average period: 100 mg/m^3 and 90 ppm for 15 min average; 60 mg/m^3 and 50 ppm for 30 min average; 25–35 mg/m^3 and 25–31 ppm for 1 h average; 10 mg/m^3 and 9–10 ppm for 8 h average; and 3–7 mg/m^3 for 1-day average.

There are several exceptions that are higher or lower than the range mentioned above, for example, Belgium (8 mg/m^3), Lithuania (5 mg/m^3 for 20–30 min average), Germany (6 mg/m^3 for 30 min and 1.5 mg/m^3 for 8 h for RWI), and Hong Kong (2 mg/m^3 for 8 h EC), which are relatively lower than the others in the same average period.

The 20–30 min values from Lithuania are the one-time maximum permissible concentration (vienkartinė cheminių medžiagų -teršalų- didžiausia leidžiama koncentracija (DLK)), which is defined to be the concentration of a chemical substance (pollutant) that does not harm human health after exposure for 20–30 min [79], and there is no other citation or interpretation of the values from Lithuania. The 5 mg/m^3 for 20–30 min average from the document is much lower, so maybe it is proposed based on the local context and is not a suitable value for other regions, which are similar in the following tables, such as Table 11 for nitrogen dioxide and Table 18 for tetrachloroethylene.

For the values for RWI from Germany, they are much lower than the others because the RWI (Guide Value I) values are proposed to have no adverse health effect if levels are not reached, even after lifelong exposure. Thus, these values are not so helpful to be compared with other values since the meaning and purpose are different, and these values for RWI are the same in the comparison among the following tables.

For Hong Kong, the value of 2 mg/m^3 for 8 h is pretty low because it is classified as EC (Excellent Class), adapted from a report from Finland published in 2001 [97], and is implemented as the high-level target. The values for EC from Hong Kong are similar in the following tables and are excluded from the comparison among the general requirements. Moreover, the other value of 7 mg/m^3 for 8 h was described to be adapted from the WHO [39], but it should be a value for the 24-h average, as listed in Table 7, which probably was a mistake.

For Australia, there are values of 60 ppm for the 1-h average and 30 ppm for the 8-h average for Class 7a buildings. These less stringent requirements are proposed because Class 7a buildings in Australia are defined as buildings with car park space, so the CO value is allowed to be a bit higher than that in other spaces in the regulation [23].

For carbon dioxide, the 1-day average is considered as the long-term value due to its toxicity, and there is no other long-term average value found in the documents for days or the 1-year average.

The reference values to be adopted can be related to the following:

- 100 mg/m^3 for 15 min average; 25 mg/m^3 for the 1-h average; 10 mg/m^3 for the 8-h average as the short-term value, as the WHO [39], Malaysia [59], Belgium [67–70], France [98], The Netherlands [80], Norway [81,82], Poland [83], Portugal [84,85], the UK [31,32,87], and Australia [23] suggest.
- 7 mg/m^3 for 1-day average as long-term value, as the WHO [39] suggests.

3.2.6. Dichloromethane

Dichloromethane (DCM), or methylene chloride, is a volatile, colorless liquid with a chloroform-like odor. It is extensively used in numerous industrial settings, such as paint stripping and pharmaceutical and paint remover manufacturing. It irritates the skin and eyes by preventing evaporation, and long-term exposure will cause chemical burns. The main toxic effects of DCM are reversible central nervous system depression (neurophysiological and neurobehavioral disturbances) and carboxyhemoglobin formation extending up to hepatic, renal, cardiovascular, and hematological parameters [99].

The reference values of dichloromethane are listed in Table 8.

From the comparison in Table 8, we can see that the short-term values are from 2000 to 3000 μg/m^3 for the 1-day average and 450 μg/m^3 for the 7-day average. The long-term value can be 200 μg/m^3 for the 1-year average.

The mean outdoor concentrations of DCM are generally below 5 μg/m^3, and only in certain conditions, the indoor concentration of DCM can reach a high level (up to 4000 μg/m^3), such as when using paint stripping solutions or with other outdoor industrial emission sources [37]. Moreover, the WHO [37] indicated that acute inhalation exposure at levels exceeding 1050 mg/m^3 (300 ppm) for short durations will cause impairment of behavioral or sensory responses in humans, and the effects are transient, which is much higher than the normal concentration. Thus, unless it is in a specific working space, such as in a factory, the 1-day average value range of 2000–3000 μg/m^3 is more representative than the 30 min value from Lithuania.

Table 8. Reference values for dichloromethane.

Region		Reference Value (μg/m^3)				
		30 min	1 Day	7 Day	Long Term	Additional Info
INT	WHO	-	3000	450	-	0.012 [1] 0.12 [2]
EU	Germany	-	200 RWI	-	-	-
		-	2000 RWII	-	-	-
	Lithuania	8800	3000	-	-	-
	Netherlands	-	-	-	200 (1 y)	-

[1] An excess lifetime risk of 10^{-6} at this value. [2] An excess lifetime risk of 10^{-5} at this value.

The reference value to be adopted can be related to the following:

- 3000 μg/m^3 for the 1-day average and 450 μg/m^3 for the 7-day average, as the short term, as the WHO suggests [37,39];
- 200 μg/m^3 for the 1-year average, as the long-term value, as The Netherlands [80] suggests.

3.2.7. Formaldehyde

Formaldehyde is a colorless gas with a characteristic pungent odor and a strong irritating power to mucous membranes, eyes, and the respiratory system. It causes conjunctivitis, asthma, contact dermatitis, fatigue, anxiety, headaches, nausea, drowsiness, and dizziness; it is mutagenic and carcinogenic. It is attributable to furniture; fabrics; construction materials; tobacco smoke; and in many everyday products, such as detergents, dyes, disinfectants, plastics, glues, and paint materials [39].

The reference values of formaldehyde are listed in Table 9.

Table 9. Reference values for formaldehyde.

Region		Reference Value (μg/m^3)						
		General	30 min	Hours	8 h	1 Day	Long Term	Additional Info
INT	WHO	-	100	-	-	-	-	-
AS	China	-	-	100	-	-	-	-
	Hong Kong (China)	-	70 EC 100 GC	-	30 EC 100 GC	-	-	-
	India	-	-	-	30	-	-	-
	Japan	100 (80 ppb)	-	-	-	-	-	-
	Malaysia	-	-	-	100 ppb	-	-	-
	Singapore	-	100 (80 ppb)	-	-	-	-	-
	Austria	-	100	-	-	60 (24 h)	-	-
	Belgium	-	10	-	-	-	-	100 (30 m) IV
	Denmark	100	-	-	-	-	-	-
	Finland	-	100	-	-	-	50 (1 y)	-
	France	100 (continuous)	-	50 (2 h)	-	-	10 (1 y)	10 (valid from 2023)
	Germany	120	-	-	-	-	-	-

Table 9. *Cont.*

Region		Reference Value (μg/m³)						
		General	**30 min**	**Hours**	**8 h**	**1 Day**	**Long Term**	**Additional Info**
EU	Lithuania	-	100	-	-	10 (1 d)	-	-
	Netherlands	-	120	-	-	-	10 (1 y)	1.2 (long term)
	Norway	-	100	-	-	-	-	-
	Poland	-	-	-	100 PO	50 (24 h) R	-	-
	Portugal	-	-	-	100	-	-	-
	Russia	-	-	-	-	-	10 (1 y)	-
	UK	-	100	-	-	-	10 (1 y)	-
NA	Canada	-	-	123 (100 ppb)	50 (40 ppb)	-	-	-
OC	Australia	-	100	-		-	-	-

From the comparison in Table 9, in the short-term average period, we can see that the values are mostly in the range of 70–120 μg/m^3, in which 100 μg/m^3 is mentioned in most of the documents, no matter whether it is for the 30 min average or 1-to-8 h average values. For the 1-day average, an intermedium value in the range of 50–60 μg/m^3 was proposed. For the long-term value, 10 μg/m^3 for the 1-year average is the most mentioned value, although The Netherlands [80] highlights reaching a value of 1.2 for the long term.

The regulation from Denmark did not provide a value on formaldehyde but quoted 0.1 mg/m^3 from the WHO. Moreover, this WHO value was adapted to the 8-h average value in the document from Hong Kong.

The reference values to be adopted can be related to the following:

- 100 μg/m^3 for the 30 min average as the short-term value, as the WHO [39], Singapore [33], Austria [60–66], Finland [19–21], Lithuania [79], Norway [81,82], the UK [32], and Australia [23] suggested.
- 10 μg/m^3 for 1-year average, as France, The Netherlands, Russia, and the UK suggest [17,29,31,72–78,80].

3.2.8. Naphthalene

Naphthalene is a two-ring aromatic hydrocarbon isolated from coal tar, the volatile organic compound (VOC) polycyclic aromatic hydrocarbon (PAH) with a gas-phase part of 90–100%. Its indoor sources are consumer products such as multipurpose solvents, lubricants, herbicides, charcoal lighters, hair sprays, unvented kerosene heaters/tobacco smoke, rubber materials, naphthalene insect repellents (mothballs), and so on. The outdoor naphthalene sources mainly originate from fugitive emissions and motor vehicle exhaust [39].

The reference values of naphthalene are listed in Table 10.

From the comparison in Table 10, apart from the adjacent regions, including Germany, The Netherlands, and Poland, which mentioned the higher values from 25 to 30 μg/m^3, other regions proposed values within the range from 3 to 10 μg/m^3, no matter whether they are for the short term or long term, with 10 μg/m^3 being applied in most of them.

For the value from the UK (3 μg/m^3 for 1-year average), in the document, it is mentioned that this value was adapted from a webpage of the Agency for Toxic Substances & Disease Registry (ATSDR), USA, in 2005, but the page is no longer available. Instead, another document found in the database of ATSDR about the toxicological profile of naphthalene was published in 2005 [100], which provided a review of previous research on the naphthalene measurement, but neither reference values nor the indoor air value was proposed in the document. Thus, this value will be excluded from the comparison before the source is verified.

Table 10. Reference values for naphthalene.

Region		Reference Value (µg/m^3)					
		General	**30 min**	**1 h**	**8 h**	**1 day**	**Long Term**
INT	WHO	-	-	-	-	-	10 (1 y)
AS	Hong Kong (China)	-	-	-	10	-	-
	India	-	-	-	9	-	-
EU	Finland	10	-	-	-	-	-
	France	-	-	-	-	-	10 (1 y)
	Germany	10 (RWI)	-	-	-	-	-
		30 (RWII)	-	-	-	-	-
	Lithuania	-	3	-	-	3	-
	Netherlands	25		-	-	-	-
	Poland	-		-	150 PO	100 R	-
	UK	-		-	-	-	3 (1 y)
NA	Canada	-		-	-	10 (1.9 ppb)	-

Another point to note is that the WHO and UK proposed only the long-term values due to the lack of reliable human data for long-term inhalation toxicity available, as mentioned in references [32,39]. For the value from Canada, although the value is for a 24-h average, it is defined as the long-term exposure limit, which is set for health problems that can occur from continuous or repeated exposure over several months or years. The value from Hong Kong is adapted from the WHO [39], but it was adapted from annual data to the 8-h average value [27].

The reference values to be adopted can be related to the following:

- 10 µg/m^3 for 1-year average, for long-term value, as the WHO and UK (10 µg/m^3) suggest [31,39].

3.2.9. Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a toxic gas with yellow-red color and a strong and pungent odor; it is a highly reactive and corrosive oxidant, and, with great irritant power, it causes disturbances to the lower respiratory system and susceptibility to infections, especially in people with lung diseases. It is generated by high-temperature combustion processes (cooking stoves, heating systems with internal boilers, etc.). The proximity to roads with high vehicular traffic and parking garages can significantly affect gas concentrations in indoor environments because NO_2 is contained in the exhaust gases of motor vehicles [39].

The reference values of nitrogen dioxide are listed in Table 11.

In the new guideline from the WHO in 2021, a value of 10 µg/m^3 was proposed as the recommended AQG level, also with three interim target values of 40 µg/m^3, 30 µg/m^3, and 20 µg/m^3 respectively. Moreover, for the short term (24-h average), 25 µg/m^3 was proposed as the recommended AQG value, with two interim target values of 120 µg/m^3 and 50 µg/m^3 [4].

Nitrogen dioxide is also mentioned in the building regulation from Denmark as oxides of nitrogen in general, but there is no reference value given. Because it is a building regulation and is considered to be related to kitchen and gas supply, details are included in Danish Gas Regulations.

Table 11. Reference values for nitrogen dioxide.

Region		Reference Value (μg/m³)						
		30 min	1 h	8 h	1 Day	7 Day	Long Term	Additional Info
INT	WHO	-	25	-	-	-	10 (1 y)	-
AS	China	-	240	-	-	-	-	-
	Hong Kong (China)	-	100 EC 200 GC	40 EC 150 GC	-	-	-	-
	India	-	-	-	-	-	-	<40 Class A three-time days (18 results for y) <80 Class B three-time days (6 results for y)
	Singapore	-	-	40	-	-	-	-
EU	Belgium	-	20 (1 h) 40	-	-	-	-	200 (1 h) IV
	France	-	200	-	-	-	40 (1 y)	20 (>1 y)
	Germany	350	-	-		60 (7 d)	-	Both for RWII
	Lithuania	85	-	-	40	-	-	-
	Netherlands	-	200	-	-	-	40 (1 y)	-
	Norway	-	200	-	100	-	-	-
	Russia	-	-	-	-	-	40 (1 y)	-
	UK	-	288 (150 ppb)	-	-	-	40 (20 ppb) (1 y)	-
NA	Canada	-	170 (90 ppb)	-	20 (11 ppb)	-	-	-
OC	Australia	-	200 (98.7 ppb)	-	-	-	40 (19.7 ppb) (1 y)	-

Apart from the WHO, in the comparison, it can generally be included in the range from 170 to 288 μg/m^3 for the 1-h average, with more values at 25 μg/m^3 as the short-term value, and there can be an intermedium value in the range of 60–100 μg/m^3 for a daily average. Moreover, for long-term values, 40 μg/m^3 is the most proposed value for the 1-year average. The ranges of values, no matter whether they are for the for short term or for the long term, are at the level of the interim value 1, which is acceptable for the current scenario, but the AQG value from the WHO can be adapted as the target value for the future scenario.

The reference value to be adopted can be related to the following:

- 25 μg/m^3 for the 1-h average as the short-term value, as the WHO's new guidelines 2021 [39] suggest; 10 μg/m^3 for the 1-year average as the long-term value, as the WHO [39] suggests.

3.2.10. Ozone

Ozone (O_3) is a poisonous gas, with a penetrating odor and pale blue color. It is present in the troposphere and contributes to air pollution; it is harmful to humans and the environment. As a powerful oxidant, it attacks the organic tissues of the respiratory system, causing breathing disturbances and aggravating asthma episodes. It is emitted by photocopiers, laser printers, ultraviolet lamps, and some air purifiers [101].

For ozone, 100 μg/m^3 equals 49.27 ppb at 15 °C, 50.12 ppb at 20 °C, and 50.98 ppb at 25 °C, under a pressure of 1 atmosphere. Thus, generally, in regard to ozone, most documents put forward 100 μg/m^3 and 50 ppb, except for Canada and India, which have a lower level, and China, which has a higher level.

The reference values of ozone are listed in Table 12.

Table 12. Reference values for ozone.

Region		Reference Value (μg/m^3)				
		General	1 h	8 h	Long Term	Additional Info
INT	WHO	-	-	100 *	60 (1 y) **	-
AS	China	-	160	-	-	-
	Hong Kong (China)	-	-	50 EC 120 GC	-	-
	India	-	-	-	-	<50 Class A three-time days (18 results for y) <80 Class B three-time days (6 results for y)
	Malaysia	-	-	50 ppb	-	-
	Singapore	-	-	50 ppb	-	-
EU	UK	100	-	-	-	-
NA	Canada	-	-	40 (20 ppb)	-	-
OC	Australia	-	-	100	-	-
	New Zealand	100 (50 ppb) (continuous)	-	-	-	-

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

As Table 12 shows, for the ozone, 50 ppb is around 98.16 μg/m^3 in 25 °C and 1 atmosphere conditions. Thus, in the comparison, the short-term values are similar at around 100 μg/m^3 and the 50 ppb level for the 8-h average, except for China and Canada, with 160 (1 h) μg/m^3 and 40 (20 ppb) (8 h), respectively. Moreover, for the long-term value, only the WHO proposed a value of 60 μg/m^3 for the 1-year average.

The value from China is higher because it is averaged for 1 h, but not 8 h like other values; however, unfortunately, there is no other value to be compared at this average period.

The reference value to be adopted can be related to the following:

- 100 μg/m^3 for the 8-h average, for the short-term value, as the WHO [39], Malaysia [59], Singapore [33], and Australia [23] suggest.
- 60 μg/m^3 for the 1-year average, for the long-term value, as the WHO [39] suggests.

3.2.11. Particulate Matters ($PM_{2.5}$ and PM_{10})

PM_{10} and $PM_{2.5}$ are constituted by all those solid, liquid, and aerosol particles, with an adequate diameter and weight to remain suspended in the air. It may cause irritating and harmful effects on the respiratory system, obstruction of the pulmonary alveoli, heart diseases, and the possibility of inducing alterations in the immune system. It is generated by cigarette smoking, burning, outdoor environment, spraying, cooking food, bacteria, spores, pollen, and human activities [102,103].

According to the definition, $PM_{2.5}$ includes particles with a diameter smaller than 2.5 μm, and PM_{10} are those smaller than 10 μm, so basically PM_{10} included $PM_{2.5}$ in the concentration measured, and its reference values are also higher than $PM_{2.5}$.

The reference values of $PM_{2.5}$ and PM_{10} are listed in Tables 13 and 14 respectively.

Table 13. Reference values for $PM_{2.5}$.

Region		Reference Value (μg/m^3)			
		8 h	**1 day**	**Long Term**	**Additional Info**
INT	WHO	-	15	5 (1 y)	-
AS	India	-	-	-	<15 Class A three-time days (18 results for y) <25 Class B and C three-time days (6 results for y)
	Singapore	-	37.5	-	-
EU	Belgium	-	10–25	15 (1 y)	-
	Finland		25	-	-
	France	-	20	10 (1 y)	-
	Germany	-	24	-	-
	Lithuania	-	40	-	-
	Netherlands	-	25	10 (1 y)	-
	Norway	40	-	-	-
	Poland	40 R	-	-	-
	Portugal	25	-	-	-
OC	Australia	-	25	10 (1 y)	-

Table 14. Reference values for PM_{10}.

Region		Reference Value (μg/m^3)			
		8 h	**1 Day**	**Long Term**	**Additional Info**
INT	WHO	-	45	15 (1 y)	-
AS	China	-	150	-	-
	Hong Kong (China)	20 EC 100 GC	-	-	-
	India	-	-	-	<50 Class A three-time days (18 results for y) <100 Class B and C three-time days (6 results for y)
	Malaysia	150	-	-	-
EU	Belgium	-	40	15 (1 y)	-
	Finland	-	50	-	-
	France	-	50	25 (1 y)	-
	Lithuania	500	50 150	-	-
	Netherlands	-	50	20 (1 y)	-
	Norway	90	-	-	-
	Poland	90	-	-	-
	Portugal	50	-	-	-
OC	Australia	-	50	20 (1 y)	-

From the comparison in Table 13, for the short-term value, the values are in the range of 20–40 μg/m^3 for 8-h and 1-day averages, among which 40 μg/m^3 for 8-h and

25 μg/m^3 for 1-day are the most mentioned values. For the long-term value, 10 μg/m^3 is the most used value, apart from the WHO and Belgium.

The WHO values are lower than those in all the other documents, which can be adapted for the future scenario as the final target.

The reference value for $PM_{2.5}$ to be adopted can be as follows:

- 40 μg/m^3 for 8-h average and 25 μg/m^3 for 1-day average as the short-term value, as Norway [81,82] and Poland [83] state;
- 10 μg/m^3 for 1-year average as the long-term value, as France [17,71–78], The Netherlands [80], and Australia [23] suggest.

For the future scenario, the WHO values can be applied as the final target:

- 15 μg/m^3 for 1-day average, for the short term;
- 5 μg/m^3 for 1-year average, for the long term [37,39].

In addition, apart from the $PM_{2.5}$, the document by Singapore adds a reference value for respirable suspended particles [33], as Table 15 shows. The given definition of this value from the document is for the particles sampled with a median cut-point of 4 μm, which is different from the definition of $PM_{2.5}$ and PM_{10}. Theoretically, they are not comparable, so it is listed separately.

Table 15. Reference values for respirable suspended particles.

Pollutant	Region	Reference Value (μg/m^3)
Respirable suspended particles	Singapore	50 (24 h)

As Table 15 shows, in the document from Malaysia, although the value is under the name of respirable suspended particles, the given definition is suspended airborne particles with an aerodynamic diameter of 10 μm or less, the same as PM_{10}.

From the comparison, except for the values from China (150 μg/m^3 for 1 day) and Lithuania (500 μg/m^3 for 8 h and 150 μg/m^3 for 1 day), others are inside the range of 50 to 150 μg/m^3 for the 8-h average and 40–50 μg/m^3 for the 1-day average as the short-term value, as well as 15–25 μg/m^3 for the 1-year average as the long-term values.

The reference value for PM_{10} to be adopted can be as follows:

- 90 μg/m^3 for 8-h average and 50 μg/m^3 for 1-day average as the short-term values, as Norway [81,82], Poland [83], France [17,71–78], The Netherlands [80], and Australia [23] suggest;
- 20 μg/m^3 for 1-year average as the long-term value, as The Netherlands [80] and Australia [23] suggest.

For the future scenario, the WHO values can be adapted:

- 45 μg/m^3 (1-day), for the short term;
- 15 μg/m^3 (1-year), for the long term [37,39].

3.2.12. Radon

Radon, which has several isotopes, is a naturally occurring colorless and odorless radioactive noble gas. It is also an important source of ionizing radiation of natural origin and a major contributor to the ionizing radiation dose received by the general population. It is a member of the uranium-238 (238Ur) decay series and its immediate parent is radium-226 (226Ra), which is around 1–3 ppm in all rocks [39].

The main source of indoor radon is the radon produced by the decay of radium in the soil subjacent to a house. Meanwhile, building materials with high concentrations of radium, such as alum shale concrete, and Water supply from the underground water are the potential indoor source of radon [39].

The reference values of radon are listed in Table 16.

Table 16. Reference value for radon.

	Region	Reference Value (Bq/m^3)			
		General	8 h	Long Term	Additional Info
INT	WHO	-	-	-	0.6 [1] 15 [2]
AS	China	400 IV	-	-	-
	Hong Kong (China)	-	150 (8 h) EC 167 (8 h) GC	-	-
	Singapore	-	100 (8 h)	-	-
EU	Denmark [3]	100–200 EB 100 NB			200 IV
NA	Canada	200	-	-	-
OC	New Zealand	-	-	100 (1 y)	-

[1] An excess lifetime risk of 10^{-6} at this value. [2] An excess lifetime risk of 10^{-5} at this value. [3] For Denmark, "EB" refers to "Existing Building"; "NE" refers to "New Building to be constructed".

From the comparison on Table 16, we can see that the values are in the range of 100 to 200 Bq/m^3. The value of 400 from China is an Intervention Value (IV) when the intervention is urgently needed.

The reference value to be adopted can be as follows:

- 100 Bq/m^3 for 8-h and 1-year averages as short- and long-term values, as Singapore [33] and New Zealand [25] suggest.

The value refers to the Unit Risks evaluated by the following:

- 0.6 Bq/m^3. (UR/lifetime) 10^{-6}—WHO values.
- 15 Bq/m^3. (UR/lifetime) 10^{-5}—WHO values [39].

3.2.13. Styrene

Styrene is primarily a synthetic chemical pollutant that is used extensively in the manufacture of plastics, rubber, and resins. The health effects of styrene include irritation of the skin, eyes, and upper respiratory tract. Acute exposure may also result in gastrointestinal effects. Chronic exposure affects the central nervous system, showing symptoms such as depression, headache, fatigue, and weakness, and may cause minor effects on kidney function [104].

Styrene present in residential indoor air can arise from multiple indoor and outdoor sources, such as automobile exhaust; tobacco smoke; certain consumer, office, and household products; and building and furnishing materials. Moreover, apart from the natural existence inside food, it can be intake from the packaging of the food and drinking water with a certain level of styrene [105].

The reference values of styrene are listed in Table 17.

As Table 17 shows, for the value from the WHO, the 70 $\mu g/m^3$ for 30 min was based on sensory effects or annoyance reactions, with the given recognition threshold to the smell of styrene at around 210–280 $\mu g/m^3$. The document added that these values were set to protect the public from the smell, and it is lower than the level which can cause adverse effects to health; and the value of 260 $\mu g/m^3$ for 7-day average is defined as the level at the lowest concentration at which adverse effects are observed [37].

Table 17. Reference values for styrene.

Region		Reference Value (μg/m³)						
		General	30 min	1 h	8 h	1 Day	7 Days	Long Term
INT	WHO	-	70 [1]	-	-	-	260 [2]	-
AS	India	-	-	-	-	-	-	900 (1 y)
	Japan	220 (50 ppb)	-	-	-	-	-	-
EU	Austria	-	-	10	-	-	40	-
	Finland	40	-	-	-	-	-	-
	Germany	-	-	-	-	-	30 RWI	-
		-	-	-	-	-	300 RWII	-
	Lithuania	-	40	-	-	2	-	-
	Netherlands	900	-	-	-	-	-	-
	Poland	-	-	-	30 PO	20 R	-	-
	Russia	2	-	-	-	-	-	-
	UK	-	-	-	-	-	-	850 (1 y)
NA	Canada	850	-	-	-	-	-	-

[1] This value is based on sensory effects or annoyance reactions. [2] This value is based on effects other than cancer or odor/annoyance.

The value from Canada (850 μg/m^3) [52] was adapted from the Toxicological Profile for Styrene [106], which was published by ATSDR in 2010, but this value of 850 μg/m^3 is not found in the ATSDR document. Instead, other American national regulations on the styrene in the air were listed together, including values from ACGIH, American Industrial Hygiene Association (AIHA), USEPA, NIOSH, and OSHA. The details of them can be seen in the document from ATSDR [106]. Just taking the EPA value as an example, Acute Exposure Guideline Levels (AEGL)-1,2,3, three levels were provided as a reference, in which the AEGL-1 provided the lowest values among the three levels, and the value for this level is 85 mg/m^3 for all average periods, far higher than the 0.26 mg/m^3 from the WHO.

Meanwhile, the value from the UK (850 μg/m^3 for 1 year) was adapted from Canada, which means the origin is also from ATSDR [106].

The value from India was not interpreted with much additional information in the document from ISHRAE [50]; instead, the document mentioned that the sampling methods were based on ISO16000-5. Since there is no another citation for this value, it is presumed to be proposed according to the local research in the Indian context. Moreover, similar to styrene, other VOCs' values from India that are shown in the following table with large variations may be due to this reason.

The reference value to be adopted can be related to the following:

- The range between 40 and 70 μg/m^3 for 30 min average as the short-term value to avoid the smell, as the WHO [39], Lithuania [79], and Austria [60–66] suggest;
- 260 μg/m^3 for 7-day average as the long-term value for health, as the WHO [39] suggests.

3.2.14. Tetrachloroethylene

Tetrachloroethylene (PCE) is a readily volatile, colorless liquid with an ether-like smell. The major industrial applications of PCE are as a synthetic raw material of hydrochlorofluorocarbon, a dry-cleaning agent, a degreaser for manufactured metal parts, and an industrial solvent, as well as consumer products for dry cleaning, drinking water, and food [39].

By breathing in the air containing a large amount of tetrachloroethylene, people will feel dizzy or sleepy, develop headaches, and become uncoordinated; or they can become unconscious. Long-term exposure may have changes in mood, memory, attention, reaction time, or vision [107].

The reference values of tetrachloroethylene are listed in Table 18.

Table 18. Reference values for tetrachloroethylene.

Region		Reference Value (μg/m^3)						
		General	30 min	1 h	8 h	1 Day	Days	Long Term
INT	WHO	-	8000 [1]	-	-	-	-	250 (1 y) [2]
AS	Hong Kong (China)	-	-	-	250	-	-	-
	India	-	-	-	-	-	-	35 (1 y)
EU	Austria	-	-	-	-	-	250 (7 d)	-
	Belgium	100	-	-	4–38	-	-	-
	France	-	-	-	-	-	1380 (1–14 d)	250 (1 y)
	Germany	-	-	-	-	-	100 (7 d) RWI 1000 (7 d) RWII	-
	Lithuania	-	500	-	-	60	-	-
	Netherlands	250	-	-	-	-	-	-
	Portugal	-	-	-	250	-	-	-
	UK	-	-	-	-	40	-	-
NA	Canada	40	-	-	-	-	-	-

[1] This value is based on sensory effects or annoyance reactions. [2] This value is based on effects other than cancer or odor/annoyance.

Similar to the value of styrene, as Table 18 shows, the values from the WHO apply to different conditions: 8 mg/m^3 for 30 min applies to the smell recognition with the given recognition threshold to the smell of tetrachloroethylene at around 24–32 mg/m^3, and the value of 250 μg/m^3 is applied as the level at the lowest concentration at which adverse effects are observed [37].

For the value from France, 1380 μg/m^3 is proposed for the acute health effect during 1 to 14 days, and this value is adapted from ATSDR as the short-term value. Moreover, the 250 μg/m^3 for 1-year average is adapted from the WHO document, and the value for RWII from Germany is based on the toxicological and epidemiological knowledge of the effective threshold of a pollutant; thus, the value is close to that of France.

For the values of 40 μg/m^3 from the UK and Canada, the document of the UK is cited from Canada and USEPA [28], but the value is only found in the document from Canada [52]. Then the document of Canada is adapted from USEPA and ASTDR [108]. Similar to the condition for styrene, the value is also not found from ATSDR, but there are many other American organizations listed, which are not comparable.

The reference value to be adopted can be related to the following:

- 1000 μg/m^3 for 7-day average, as short-term value, as Germany [18] suggests;
- 250 μg/m^3 for 1-year average, as long-term value, as the WHO [37] and France [17,71–78] suggest;
- In addition, the value of 8000 μg/m^3 for 30 min average to avoid sensory effects, as the WHO [37,39] suggests.

3.2.15. Toluene

Toluene is a clear, colorless liquid with a distinctive smell. Toluene occurs naturally in crude oil and the tolu tree. It is also produced in the process of making gasoline and other fuels from crude oil and coke from coal. Toluene is used in making paints, paint thinners, fingernail polish, lacquers, adhesives, and rubber and in some printing and leather-tanning processes. The primary effect of toluene on the nervous system can cause tiredness, confusion, weakness, drunken-type actions, memory loss, nausea, and loss of appetite at low-to-moderate levels [109].

For generic people, the primary route of exposure for the general population is from inhalation of vehicle exhaust, and possible exposure with the use of paints, varnishes, lacquers, shoe polishes, and cigarette smoke. The occupational people who are exposed frequently to vehicles and work in nail salons, gasoline service stations, paint stripping, the printing industry, or other occupations that use toluene may be exposed to higher concentrations [109].

The reference values of toluene are listed in Table 19.

Table 19. Reference values for toluene.

Region		Reference Value (μg/m³)						
		General	**30 min**	**1 h**	**8 h**	**1 Day**	**7 Day**	**Long Term**
INT	WHO	-	1000 [1]	-	-	-	260 [2]	-
AS	China	-	-	200	-	-	-	-
	Japan	260 (0.07 ppm)	-	-	-	-	-	-
EU	Austria	-	-	75	-	-	-	-
	Belgium	5000–140,000	-	-	-	-	-	-
	France	20,000	-	-	-	-	-	-
	Germany	300 RWI	-	-	-	-	-	-
		3000 RWII	-	-	-	-	-	-
	Lithuania	-	600	-	-	600	-	-
	Netherlands	-	-	-	-	-	-	200 (1 y)
	Poland	-	-	-	250 PO	200 R	-	-
	Portugal	-	-	-	250	-	-	-
	UK	-	-	-	15,000	2300	-	-
NA	Canada	-	-	-	15,000 (4.0 ppm)	2300 (0.6 ppm)	-	-

[1] This value is based on sensory effects or annoyance reactions. [2] This value is based on effects other than cancer or odor/annoyance.

As Table 19 shows, the values from the WHO, similar to the previous section, are 1000 μg/m^3 for sensory effects with the given recognition threshold to the smell at around 10 mg/m^3 and 260 μg/m^3 for adverse effects on health [37].

The value from France (20,000 μg/m^3) is defined for both the short term and long term [71], because TRV (valeurs toxicologiques de référence) for 24 h and the chronic are 21 and 19 mg/m^3, respectively, which are practically equivalent [98]. Moreover, these values were adapted from the research by Kobald et al. in 2015 [110] for the short term and Zavalic et al. in 1998 [111,112] for the long term, even if the measured values are always far lower than these levels. In addition, the document also mentioned 1000 μg/m^3 as the olfactory threshold.

Furthermore, the values from the UK and Canada are also not comparable due to the reason for adaptation from USEPA mentioned in Section 3.2.14.

Apart from the values mentioned above, which vary a lot, the others are inside the range from 200 to 260 μg/m^3, with 600 μg/m^3 from Lithuania and 75 μg/m^3 from Austria.

The reference value to be adopted can be related to the following:

- 260 μg/m^3 (7 days), for the long-term, as the WHO [37,39] suggests.

3.2.16. Total Volatile Organic Compounds (TVOCs)

Volatile organic compounds (VOCs) are compounds emitted as gases from certain solids or liquids that have a high vapor pressure and low water solubility, including a variety of chemicals, some of which may have short- and long-term adverse health effects [113]. Since there are too many types of VOCs, for the monitoring of air quality, TVOC is applied to sum up the total concentration of VOCs.

Generally, the pollutant mentioned in previous chapters, including acetaldehyde, benzene, BaP, dichloromethane, formaldehyde, naphthalene, styrene, toluene, trichloroethylene, and tetrachloroethylene, as well as other organic air pollutants list in Section 3.3.1, can also be included in the list of VOCs. Some organic pollutants are well-studied and highly related to the generic population, so they are proposed with a suitable reference value for IAQ intervention. However, there are still many other compounds that are not proposed with values or listed in addition to non-compulsory regulations or standards, because of the local industries, research focus, and progress.

The reference values of TVOC are listed in Table 20.

Table 20. Reference values for TVOC.

Region		Reference Value (μg/m³)			
		General	1 h	8 h	Long Term
AS	China	-	-	600	-
	Hong Kong (China)	-	-	200 EC 600 GC	-
	Japan	400	-	-	-
	Singapore	-	-	1000 ppb	-
EU	Austria [1]	300 R 1000 Z	-	-	-
	Belgium	-	300	-	1000
	Netherlands	-	-	-	200 (1 y)
	Norway	400	-	-	-
	Poland	400 R	-	-	-
	Portugal	-	-	600	-
	UK	-	-	300	-
OC	Australia	-	500	-	-

[1] For Austria, "R" refers to "Richtwert" as the reference value; "Z" refers to "Zielwert" as the target value.

Because TVOCs contain multiple pollutants and their composition of them varies a lot according to the local emission condition and the specific usage of indoor spaces, the values from different regions may not be comparable.

As Table 20 shows, for the value from Singapore (1000 ppb for 8-h average), in the document, the given information indicates the measured TVOCs are photo-ionizable (10.6 eV) calibrated to the isobutylene equivalent, which has the molecular weight of 56.106 g/mol. In this way, 1000 ppb can be converted to around 2290 μg/m^3 at 25 °C and 1 atmosphere condition, and this value is still quite higher than the others.

From the comparison, and according to EN ISO 16000—Part 6, the values to be adopted can be related to a range of 200–600 μg/m^3, but it is not possible to use/recommend any reference value because the reference values do not take into account the toxicological effects of the different substances.

The reference values of trichloroethylene are listed in Table 21.

Table 21. Reference values for trichloroethylene.

Region		Reference Value (μg/m^3)							
		General	30 min	1 h	8 h	1 Day	7 Day	Long Term	Additional Info
INT	WHO	-	-	-	-	-	-	-	2.3 [1] 23 [2]
AS	Hong Kong (China)	-	-	-	230	-		-	-
	India	-	-	-	-	-		600 (1 y)	-
EU	Belgium	0.2–2.5	-	-	-	-		-	-
	France	-	-	50	-	-		800 (14 d–1 y)	2 [1] 20 [2]
	Germany	-	-	-	-	-	1000 RWII 100 RWI	-	-
	Lithuania	-	4000	-	-	1000		-	-
	Poland	-	-	-	200 PO	150 R		-	-
	Portugal	-	-	-	25	-		-	-
	UK	-	-	-	-	-		-	2.3 [1] 23 [2]

[1] An excess lifetime risk of 10^{-6} at this value. [2] An excess lifetime risk of 10^{-5} at this value.

3.2.17. Trichloroethylene

Trichloroethylene (TCE) is a widely used industrial solvent. It is a volatile, colorless liquid with a sweet ethereal (chloroform-like) smell. The main indoor sources are groundwater and drinking water: water ingestion/dermal absorption when showering; breathing indoor air—use of wood stains, varnishes, finishes, lubricants, adhesives, typewriter correction fluid, paint removers, and certain cleaners, where TCE is used as a solvent; and food with TCE as the solvent [39].

As Table 21 shows, for Hong Kong, since there is no guideline value from the WHO, the value of 230 μg/m^3 was adapted from the value with an excess lifetime cancer risk of 1:10,000.

The value from Belgium [70] is adapted from USEPA [114], in which The RfC (inhalation reference concentration) of 0.0004 ppm (0.4 ppb or 2 μg/m^3) was proposed based on route-to-route extrapolated results from oral studies for the critical effects of heart malformations (rats) and immunotoxicity (mice) for noncancer effects [114].

For the document from France about trichloroethylene, there is one confusing point about the lifetime risk value: the given values are 2 and 20 μg/m^3 in the summary and conclusion, but in Chapter 7, "Conclusions of the working group" ("Conclusions du groupe de travail"), the values are 2.3 and 23 μg/m^3 [115]. Since there is no particular reason declared in the document, and the values did not vary much, it may be an adaptation.

The value to be adopted can be related to the following:

- A range between 600 and 800 μg/m^3 as the long-term value as India [50] and France [17,71–78] state.

Due to missing currently a specific guideline value from the WHO [39], the values of Unit Risks can be those from France, which is more restrictive.

- 2 μg/m^3 (UR/lifetime) 10^{-6},
- 20 μg/m^3 (UR/lifetime) 10^{-5}, as France [17,71–78] suggests.

3.3. Other Pollutants

3.3.1. Organic Pollutants Listed but Only in Limited Documents

Apart from the listed values in Table 22, in other countries or regions, there are also lists of reference values on the detailed organic pollutants, such as in Germany [18] and Lithuania [79]. However, considering many other documents included in TVOC, rather than listed separately, the detailed values are not listed in this paper.

Table 22. Reference values for organic pollutants.

Pollutant	Region	Reference Value (μg/m^3)	
Acrolein	France	6.9 (1 h)	0.8 (>1 y)
	Canada	38 (1 h)	0.44 (24 h)
Ammonia	China	200 (1 h)	-
Chlordane	New Zealand	5/0.3 ppb (continuous)	-
Chlorpyrifos	Japan	1.0 (0.07 ppb)	0.1 (0.007 ppb) (Children)
Diazinon	Japan	0.29 (0.02 ppb)	-
Di-n-butyl phthalate	Japan	17 (1.5 ppb)	-
Di-2-ethylhexyl phthalate	Japan	100 (6.3 ppb)	-
Ethylbenzene	France	22,000 (24 h)	15,000 (>1 y)
	Japan	3800 (880 ppb)	-
Fenobucarb	Japan	33 (3.8 ppb)	-
Nicotine	Singapore	<0.01 (8 h)	-
Paradichlorobenzene	Japan	240 (40 ppb)	-
Polycyclic aromatic hydrocarbons	WHO	No threshold	-
Xylenes	China	200 (1 h)	-
	Japan	200 (50 ppb)	-
	Canada [88]	7200 (1 h)	150 (24 h)

As Table 22 shows, although polycyclic aromatic hydrocarbons (PAHs) are included in this list and the WHO did not propose a reference value for it, BaP and naphthalene are both inside the definition of PAH with proposed values (see Tables 5 and 10, respectively).

3.3.2. Less Common Indoor Pollutants

- Asbestos

Asbestos is the name given to six minerals that occur naturally in the environment as bundles of fibers that can be separated into thin, durable threads for use in commercial and industrial applications. When asbestos fibers are breathed in, they may get trapped in the lungs and remain there for a long time. Over time, these fibers can accumulate and cause scarring and inflammation, which can affect breathing and lead to serious health problems like shortness of breath, coughing, and permanent lung damage [116].

The reference values of asbestos are listed in Table 23.

Table 23. Reference value for asbestos.

Pollutant	Region	Reference Value
Asbestos	Singapore	0.01 fiber/cm^3 (8 h)
	Finland	0.01 fiber/cm^3 [1]

[1] 1cc equals 1 cm^3.

As Table 23 shows, asbestos is also mentioned in the regulation from Denmark [22], which remarked that "Materials containing asbestos are not to be used", with no value provided.

- Sulfur dioxide

Sulfur dioxide (SO_2) is a colorless and nonflammable gas that is highly soluble in water; it has a pungent smell; it irritates the skin, eyes, and mucous membranes; and it contributes to asthma, bronchitis, and tracheitis. This gas is also produced by combustion processes. The value of sulfur dioxide is only found in the document from China, maybe because it is more of a typical outdoor air pollutant with less indoor sources in generic spaces. Table 24 shows the value defined by China.

Table 24. Reference values for sulfur dioxide.

Pollutant	Region	Reference Value (μg/m^3)
Sulfur dioxide	China	500 (1 h)

The reference values of sulfur dioxide are listed in Table 24.

- Hydrocyanic acid (HCN)

Hydrogen cyanide, whose solution in water is called hydrocyanic acid or prussic acid, is a metabolic poison [117]. At atmospheric pressure, it occurs over the temperature range from −14 °C to +26 °C; it is a colorless gas or bluish-white liquid [118]. Its toxins ultimately act by blocking electron transfer to molecular oxygen during the oxidative phosphorylation of adenosine triphosphate (ATP), leading to a decrease in the unloading gradient for oxyhemoglobin [119].

It causes dyspnea and headache at a low level; immediate and progressive sense of warmth (due to vasodilation) with visible flushing; prostration, followed by nausea, vomiting, headache, difficulty in breathing, and a feeling of tightness around the chest at a medium level; loss of consciousness; and pain in the back of the neck and chest at the high level [118].

As Table 25 shows, although it is mentioned in the document from France [71], no reference value was proposed, probably due to its high toxicity.

Table 25. Reference values for hydrocyanic acid.

Pollutant	Region	Reference Value
Hydrocyanic acid	France	No short-term IAQGs proposed

4. Conclusions: Trends and Perspectives

4.1. Sum Up of the Current Trends and Reference Values for Common Perspectives

The pollutant can be put up with a reference value in the higher requirement for current and future scenarios.

In conclusion, supported by existing norms and guideline values by the WHO and international scenarios, a summary table of the main chemical guideline values can be synthesized, as Table 26 lists.

Table 26. Guidelines' values for chemical compounds for generic environments.

Pollutant	Reference Value		Reference	Additional Info
	Value	Period		
Acetaldehyde	1420 (1 h) µg/m^3	Short term	[24]	
	280 (1 d) µg/m^3			
	140–160 µg/m^3	Long term	[17,50,71–78]	
Benzene	20 (1 d) µg/m^3	Short term	[17,71–78,80,83]	1.7 µg/m^3 (UR/lifetime) 10^{-6} 17 µg/m^3 (UR/lifetime) 10^{-5}
	2 (1 y) µg/m^3	Long term	[17,71–78]	
Benzo[a]pyrene	1 (1 d) ng/m^3		[26,79]	0.012 ng/m^3 (UR/lifetime) 10^{-6} 0.12 ng/m^3 (UR/lifetime) 10^{-5}
Carbon dioxide	1000 ppm		[18,31,32,37,87], etc.	2000 ppm as Intervention Value
Carbon monoxide	100 (15 m) mg/m^3	Short term	[23,31,32,39,59,67–70,80–85,87,98]	
	25 (1 h) mg/m^3			
	10 (8 h) mg/m^3			
	7 (1 y) mg/m^3	Long term	[39]	
Dichloromethane	3000 (1 d) µg/m^3	Short term	[37,39]	
	450 (7 d) µg/m^3			
	200 (1 y) µg/m^3	Long term	[80]	
Formaldehyde	100 (30 m) µg/m^3	Short term	[19–21,23,32,33,39,60–66,79,81,82]	
	10 (1 y) µg/m^3	Long term	[17,29,31,72–78,80]	
Naphthalene	10 (1 y) µg/m^3	Long term	[31,39]	
Nitrogen dioxide	25 (1 h) µg/m^3	Short term	[39]	
	10 (1 y) µg/m^3	Long term		
Ozone	100 (8 h) µg/m^3	Short term	[23,33,39,59]	
	60 (1 y) µg/m^3	Long term	[39]	
$PM_{2.5}$	40 (8 h) µg/m^3	Short term	[81–83]	For the future scenario: 15 (1 d) µg/m as short term 5 (1 y) µg/m^3 as long term
	25 (1 d) µg/m^3			
	10 (1 y)µg/m^3	Long term	[17,23,71–78,80]	
PM_{10}	90 (8 h) µg/m^3	Short term	[17,23,71–78,80–83]	For the future scenario: 45 (1 d) µg/m as short term 15 (1 y) µg/m^3 as long term
	50 (1 d) µg/m^3			
	20 (1 y) µg/m^3	Long term	[23,80]	
Radon	100 (8 h) Bq/m^3	Short term	[33]	0.6 Bq/m^3. (UR/lifetime) 10^{-6} 15 Bq/m^3. (UR/lifetime) 10^{-5}
	100 (1 y) Bq/m^3	Long term	[25]	
Styrene	40–70 (30 m) µg/m^3	Short term	[39,60–66,79]	
	260 (7 d) µg/m^3	Long term	[39]	
Tetrachloroethylene	1000 (7 d) µg/m^3	Short term	[18]	8000 µg/m^3 (30 m) for sensory effects
	250 (1 y) µg/m^3	Long term	[17,37,71–78]	
Toluene	260 (7 d) µg/m^3	Long term	[37,39]	1000 µg/m^3 (30 min) for sensory effects
TVOC	No Safe Level			Highly depending on the regions
Trichloroethylene	600–800 µg/m^3	Long term	[17,50,71–78]	2 µg/m^3 (UR/lifetime) 10^{-6} 20 µg/m^3 (UR/lifetime) 10^{-5}

4.2. Limitations and Next Steps

In the current research stage, there are several limits to the comparison result. One aspect is that only the parts of documents from several countries and regional governments are referred to. Some guidelines for green buildings or institutions for ventilation are also instructive. However, it is not clear if these guidelines or standards are officially applied to the in situ evaluation or not.

On the other hand, even though all the collected reference values are compared together in this work, the best reference values for each region are depending on the local condition, including geographical environments, local industries, native cultures and lifestyles, etc. The values collected from the near regions during the comparison may be more suitable depending on the readers' regions, and the proposed reference value is provided as a reference for better practice, such as for healthcare requirements.

Although these documents have been published for many years in their regions, more efforts are still needed to implement those reference values into the actual living space with the intervention to the IAQ deterioration in many regions. For example, in China, the IAQ standard has been published since 2002; however, there is no specific benchmark or regulation about how the IAQ should be evaluated and intervened for improvement in real situations. In this way, even if the architects, the designers, the construction teams, the manager of buildings, the occupants of the indoor space, etc., are different stakeholders in this problem, none of them is required to take this responsibility due to the lack of related regulations on IAQ. Eventually, only the real users, who have less awareness of IAQ, are exposed to those "designed spaces" without a single evaluation during the whole occupied time. Thus, how these reference values can benefit the generic living space is an essential question to be considered. In the evaluations, it is necessary not to stop at the comparison with the specified guide or reference value but to take into account the conditions of use, frequency, age, etc.

A few values from the documents are found to be adapted or cited from other documents or some previous research. However, during the adaptation, the values were exactly maintained, but the average period or the application condition changed. There is no indication if it is adapted according to the local condition or if it is just a human error. For this reason, the reference values have to be updated, especially those published more than 2 or 3 decades ago.

Some values, such as those for benzene and trichloroethylene from Belgium and styrene from Lithuania and Russia, have a quite large deviation from the values proposed by other documents, but unfortunately, there is no detailed information or explanation found in their sources. They are worth deep research on the reason why and how those values were set in the past.

Different from thermal comfort and energy consumption, the poor IAQ consumes users in an invisible and unperceivable way through long-term exposure. Thus, the application of those reference values to the IAQ monitoring is necessary to raise users' awareness of the IAQ and further lead to ABs improving it.

In addition, it is worth considering European reference documents drafted by (inter) national accreditation institutions (ISO, CEN, AFNOR, and UNI). Such organizations have been involved in the definition of strategies and technical solutions regarding the methods for conducting monitoring, analysis, and assessments. Currently, EN norms define monitoring methods and strategies for air pollution dilution. The main norms for the monitoring activity of IAQ parameters are 33, as shown in Table 2 [34].

The study and knowledge of the indoor air levels of different pollutants are important to identify possible solutions and strategies to improve mitigation and prevention interventions. In addition, it is important to remember that there is a constant evolution of the data by the states concerning the health status of populations. The authors' aim is to refer to the general strategies of the WHO and to be more and more conservative with the scope of guaranteeing healthier living, working, etc., spaces.

Author Contributions: Conceptualization, G.S., M.G. and Y.Y.; methodology, G.S., M.G. and Y.Y.; validation, M.B. and S.C.; formal analysis, G.S. and Y.Y.; investigation, G.S. and Y.Y.; resources, G.S. and Y.Y; data curation, G.S., M.G. and Y.Y.; writing—original draft preparation, G.S., M.G. and Y.Y.; writing—review and editing, M.G., M.B. and S.C.; supervision, M.G., M.B. and S.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Klepeis, N.E.; Nelson, W.C.; Ott, W.R.; Robinson, J.P.; Tsang, A.M.; Switzer, P.; Behar, J.V.; Hern, S.C.; Engelmann, W.H. The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *J. Expos. Anal. Environ. Epidemiol.* **2001**, *11*, 231–252. [CrossRef]
2. Künzli, N.; Oglesby, L. *Air Pollution Exposure Distributions of Adult Urban Populations in Europe "EXPOLIS"*; Intermediate Scientific Report for the Federal Office for Education and Sciences (BBW): Basel, Switzerland, 1997. Available online: https://ec.europa.eu/commission/presscorner/detail/en/IP_03_1278 (accessed on 31 December 2022).
3. Air Quality. Available online: https://atmosphere.copernicus.eu/air-quality (accessed on 22 November 2022).
4. World Health Organization (WHO). *WHO Global Air Quality Guidelines: Particulate Matter (PM2.5 and PM10), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide*; World Health Organization: Geneva, Switzerland, 2021.
5. Brunekreef, B.; Holgate, S.T. Air pollution and health. *Lancet* **2002**, *360*, 1233–1242. [CrossRef] [PubMed]
6. Capolongo, S.; Settimo, G. Indoor Air Quality in Healing Environments: Impacts of Physical, Chemical, and Biological Environmental Factors on Users. In *Indoor Air Quality in Healthcare Facilities*; Capolongo, S., Settimo, G., Gola, M., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 1–11. [CrossRef]
7. Settimo, G.; Gola, M.; Capolongo, S. The Relevance of Indoor Air Quality in Hospital Settings: From an Exclusively Biological Issue to a Global Approach in the Italian Context. *Atmosphere* **2020**, *11*, 361. [CrossRef]
8. Gola, M.; Settimo, G.; Capolongo, S. No Impacts on Users' Health: How Indoor Air Quality Assessments Can Promote Health and Prevent Disease. In *Integrating IoT and AI for Indoor Air Quality Assessment*; Saini, J., Dutta, M., Marques, G., Halgamuge, M.N., Eds.; Springer International Publishing: Cham, Switzerland, 2022; pp. 43–54. [CrossRef]
9. Kallawicha, K.; Wongsasuluk, P.; Chao, H.J. Modern Solutions for Indoor Air Quality Management in Commercial and Residential Spaces. In *Integrating IoT and AI for Indoor Air Quality Assessment*; Saini, J., Dutta, M., Marques, G., Halgamuge, M.N., Eds.; Springer International Publishing: Cham, Switzerland, 2022; pp. 73–88. [CrossRef]
10. Gola, M.; Settimo, G.; Capolongo, S. Chemical Pollution in Healing Spaces: The Decalogue of the Best Practices for Adequate Indoor Air Quality in Inpatient Rooms. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4388. [CrossRef] [PubMed]
11. Gola, M.; Signorelli, C.; Buffoli, M.; Rebecchi, A.; Capolongo, S. Local health rules and building regulations: A survey on local hygiene and building regulations in Italian municipalities. *Ann. Ist. Super. Sanita* **2017**, *53*, 223–230. [CrossRef]
12. D'Alessandro, D.; Buffoli, M.; Capasso, L.; Fara, G.M.; Rebecchi, A.; Capolongo, S. Green areas and public health: Improving wellbeing and physical activity in the urban context. *Epidemiol Prev.* **2015**, *39* (Suppl. 1), 8–13. [PubMed]
13. Buffoli, M.; Rebecchi, A.; Gola, M.; Favotto, A.; Procopio, G.P.; Capolongo, S. Green SOAP. A Calculation Model for Improving Outdoor Air Quality in Urban Contexts and Evaluating the Benefits to the Population's Health Status. In *Integrated Evaluation for the Management of Contemporary Cities*; Springer International Publishing: Cham, Switzerland, 2018; pp. 453–467. [CrossRef]
14. Bianchi, C.L.; Gatto, S.; Pirola, C.; Naldoni, A.; Di Michele, A.; Cerrato, G.; Crocellà, V.; Capucci, V. Photocatalytic degradation of acetone, acetaldehyde and toluene in gas-phase: Comparison between nano and micro-sized TiO2. *Appl. Catal. B Environ.* **2014**, *146*, 123–130. [CrossRef]
15. Signorelli, C.; Odone, A.; Buffoli, M.; Capolongo, S. Building codes and public health on both sides of the Atlantic. *J. Public Health Policy* **2016**, *37*, 385–387. [CrossRef]
16. Settimo, G.; Manigrasso, M.; Avino, P. Indoor air quality: A focus on the european legislation and state-of-the-art research in Italy. *Atmosphere* **2020**, *11*, 370. [CrossRef]
17. Légifrance. Arrêté du 27 décembre 2022 Modifiant L'arrêté du 1er Juin 2016 Relatif aux Modalités de Surveillance de la Qualité de l'air Intérieur Dans Certains Établissements Recevant du Public. [Order of December 27, 2022 Amending the Order of June 1, 2016 Relating to the Procedures for Monitoring Indoor Air Quality in Certain Establishments Open to the Public]. Légifrance, 2022. Available online: https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000046829603 (accessed on 30 December 2022).

18. Zur Gesundheitlichen Bewertung der Innenraumluft Setzt der AIR Richtwerte, Hygienische Leitwerte Sowie Risikobezogene Leitwerte Fest. [For the Health Assessment of Indoor Air, the AIR Determines Guideline Values, Hygienic Conductivity Values and Risk-Related Conductivity Values.]. Available online: https://www.umweltbundesamt.de/themen/gesundheit/kommissionen-arbeitsgruppen/ausschuss-fuer-innenraumrichtwerte#ausschuss-fur-innenraumrichtwerte-air (accessed on 23 February 2023).
19. Ministry of the Environment Department of Built Environment. *Decree of the Ministry of the Environment on Indoor Climate and Ventilation of Buildings*; Ministry of the Environment Department of Built Environment: Helsinki, Finland, 2012.
20. Ministry of Social Affairs and Health (STM). Sosiaali- ja Terveysministeriön Asetus Asunnon ja Muun Oleskelutilan Terveydellisistä Olosuhteista sekä Ulkopuolisten Asiantuntijoiden Pätevyysvaatimuksista. [Decree of the Ministry of Social Affairs and Health on the Health Conditions of Apartments and Other Living Spaces and on the Qualification Requirements of External Experts]. Ministry of Social Affairs and Health (STM) 545/2015, 2015. Available online: https://www.finlex.fi/fi/laki/alkup/2015/20150545 (accessed on 1 December 2022).
21. VV.AA. Finnish Society of Indoor Air Quality and Climate. In *Classification for indoor Environment 2018*; The Building Information Foundation RTS sr: Helsinki, Finland, 2018.
22. Danish Building Regulations. Executive Order Amending the Executive Order on Publication of the Danish Building Regulations 2010 (BR10). Danish Building Regulations, 2010. Available online: https://historisk.bygningsreglementet.dk/file/256900/bkg_909_af_180811.pdsf (accessed on 5 March 2023).
23. Commonwealth of Australia and States and Territories of Australia (CASTA). *Indoor Air Quality*; Australian Building Codes Board: Canberra, Australia, 2021.
24. Indoor Air Quality Resources for Professionals. Available online: https://www.canada.ca/en/health-canada/services/air-quality/residential-indoor-air-quality-guidelines.html (accessed on 27 April 2022).
25. *NZS 4303:1990*; Ventilation for Acceptable Indoor Air Quality. Standards New Zealand: Weelington, New Zealand, 1990.
26. *GBT 18883-2002*; Indoor Air Quality Standard. Ministry of Ecology and Environment of the People's Republic of China (MEE): Beijing, China, 2002.
27. The Government of the Hong Kong Special Administrative Region Indoor Air Quality Management Group. 2019. Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places. Available online: https://www.iaq.gov.hk/wp-content/uploads/2021/04/gn_officeandpublicplace_eng-2019.pdf (accessed on 28 December 2022).
28. 室内空気中化学物質の室内濃度指針値について About the Indoor Concentration Guideline Value of Chemical Substances in Indoor Air. Available online: https://www.mhlw.go.jp/web/t_doc?dataId=00tc3866&dataType=1&pageNo=1 (accessed on 27 April 2022).
29. Де-партамент госсанэпиднадзора Министерства России. САНИТАРНО-ЭПИДЕМИОЛОГИЧЕСКИЕ ПРАВИЛА И НОРМАТИВЫ. [Sanitary and Epidemiological Rules And Regulations]. Д.-п. г. М. России 2.1.2.1002-00., 2001. Available online: https://docs.cntd.ru/document/1200008512 (accessed on 27 February 2023).
30. Settimo, G.; Avino, P. The dichotomy between indoor air quality and energy efficiency in light of the onset of the COVID-19 pandemic. *Atmosphere* **2021**, *12*, 791. [CrossRef]
31. Government of the United Kingdom (HM Goverment). *The Building Regulations 2010 Materials and Workmanship Approved document 7*; The Ministry of Housing, Communities and Local Government: London, UK, 2021.
32. Public Health England. Indoor Air Quality Guidelines for Selected Volatile Organic Compounds (VOCs) in the UK. 2019. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831319/VO__statement_Final_12092019_CS__1_.pdf (accessed on 28 February 2023).
33. *SS 554: 2016*; SINGAPORE STANDARD Code of Practice for Indoor Air Quality for Air-Conditioned Buildings. Singapore Standard Council (SSC): Singapore, 2016.
34. Settimo, G. Existing Guidelines for Indoor Air Quality: The Case Study of Hospital Environments. In *Indoor Air Quality in Healthcare Facilities*; Capolongo, S., Settimo, G., Gola, M., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 13–26. [CrossRef]
35. World Health Organization (WHO). *Indoor Air Pollutants Exposure and Health Effects Report on a WHO Meeting: EURO Reports and Studies*; World Health Organization: Copenhagen, Denmark, 1982.
36. World Health Organization (WHO). Copenhagen Regional Office for Europe. In *Indoor Air Quality Research*; WHO: Copenhagen, Denmark, 1986.
37. World Health Organization (WHO). Regional Office for Europe. In *Air Quality Guidelines for Europe*, 2nd ed.; European Series; World Health Organization. Regional Office for Europe: Copenhagen, Denmark, 2000.
38. Suess, M.J. The indoor air quality programme of the WHO Regional Office for Europe. *Indoor Air* **1992**, *2*, 180–193. [CrossRef]
39. World Health Organization (WHO). *WHO Guidelines for Indoor Air Quality: Selected Pollutants*; World Health Organization. Regional Office for Europe: Copenhagen, Denmark, 2010.
40. World Health Organization (WHO). Regional Office for Europe. In *WHO Guidelines for Indoor Air Quality: Dampness and Mould*; World Health Organization. Regional Office for Europe: Copenhagen, Denmark, 2009.
41. European Environment Agency (EEA). The European Environment-State and Outlook 2010: Synthesis. 2010. Available online: http://www.eea.europa.eu/soer/synthesis/ (accessed on 31 December 2022).

42. European Environment Agency (EEA). Report No 5., JRC Report. 2013. Available online: http://www.eea.europa.eu/publications/environment-and-human-health/download (accessed on 31 December 2022).
43. Oberti, I. Environmentally Friendly and Low-Emissivity Construction Materials and Furniture. In *Indoor Air Quality in Healthcare Facilities*; Capolongo, S., Settimo, G., Gola, M., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 73–81. [CrossRef]
44. Gola, M.; Settimo, G.; Capolongo, S. How can design features and other factors affect the indoor air quality in inpatient rooms? Check-lists for the design phase, daily procedures and maintenance activities for reducing the air concentrations of chemical pollution. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4280. [CrossRef]
45. Signorelli, C.; Capolongo, S.; Buffoli, M.; Capasso, L.; Faggioli, A.; Moscato, U.; Oberti, I.; Petronio, M.G.; D'Alessandro, D. Documento di indirizzo della Società italiana di igiene (SItI) per una casa sana, sicura e sostenibile. *Epidemiol. Prev.* **2016**, *40*, 265–270. [CrossRef]
46. Riva, A.; Rebecchi, A.; Capolongo, S.; Gola, M. Can Homes Affect Well-Being? A Scoping Review among Housing Conditions, Indoor Environmental Quality, and Mental Health Outcomes. *Int. J. Environ. Res. Public Health* **2022**, *19*, 15975. [CrossRef]
47. Gola, M.; Settimo, G.; Capolongo, S. Indoor air in healing environments. *Facilities* **2019**, *37*, 600–623. [CrossRef]
48. WHO Releases Country Estimates on Air Pollution Exposure and Health Impact. Available online: https://www.who.int/en/news-room/detail/27-09-2016-who-releases-country-estimates-on-air-pollution-exposure-and-health-impact (accessed on 9 January 2023).
49. American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE). *Ventilation for Acceptable Indoor Air Quality*; ASHRAE: Peachtree Corners, GA, USA, 2019.
50. Indian Society of Heating Refrigerating and Air Conditioning Engineers (ISHRAE). *Indoor Environment Quality Standard*; ISHRAE: New Delhi, India, 2019.
51. Acute Exposure Guideline Levels for Airborne Chemicals. Available online: https://www.epa.gov/aegl (accessed on 22 February 2023).
52. Indoor Air Reference Levels. Available online: https://www.canada.ca/en/health-canada/services/publications/healthy-living/indoor-air-reference-levels.html (accessed on 21 February 2023).
53. Introduction to Indoor Air Quality. Available online: https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality#:~:text=Indoor%20pollution%20sources%20that%20release,pollutants%20out%20of%20the%20area. (accessed on 21 February 2023).
54. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). *Indoor Air Quality Guide. American Society of Heating, Refrigerating and Air-Conditioning Engineers*; ASHRAE: Peachtree Corners, GA, USA, 2010. Available online: https://www.ashrae.org/technical-resources/bookstore/indoor-air-quality-guide (accessed on 31 December 2022).
55. American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE). ANSI/ASHRAE Standard 62.1-2022, Ventilation and Acceptable Indoor Air Quality. In *American Society of Heating Refrigerating and Air-Conditioning Engineers*; ASHRAE: Peachtree Corners, GA, USA, 2022.
56. American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE). ANSI/ASHRAE Standard 62.2-2022 Ventilation and Acceptable Indoor Air Quality in Residential Buildings. In *American Society of Heating Refrigerating and Air-Conditioning Engineers*; ASHRAE: Peachtree Corners, GA, USA, 2022.
57. Chou, C.M. Characterization of Indoor Air Quality in Public Area of Taiwan. *Int. Conf. Energy Environ. Sci.* **2013**, *54*, 12–15. [CrossRef]
58. Taiwan Environmental Protection Administration (Taiwan EPA). *Guidelines for Indoor Air Quality*; Taiwan EPA: Taipei, Taiwan, 2013.
59. Department of Occupational Safety and Health Ministry of Human Resources Malaysia (DOSH). Industry Code of Practice on Indoor Air Quality 2010. Available online: https://www.dosh.gov.my/index.php/legislation/codes-of-practice/chemical-management (accessed on 15 November 2022).
60. Ad-Hoc-Arbeitsgruppe. Richtwerte für die Innenraumluft: Basisschema. Erarbeitet von der Ad-hoc-Arbeitsgruppe der Innenraumlufthygiene-Kommission (IRK) des Umweltbundesamtes und des Ausschusses für Umwelthygiene der AGLMB. *Bundesgesundheitsblatt* **1996**, *39*, 422–426.
61. Ad-Hoc-Arbeitsgruppe. Richtwerte für die Innenraumluft: Erste Fortschreibung des Basisschemas. *Bundesgesundheitsblatt* **2012**, *55*, 279–290. [CrossRef] [PubMed]
62. VV.AA. Stellungnahme der Ad-hoc-Arbeitsgruppe Innenraumrichtwerte der IRK/AOLG (unveröffentlicht). Entwurf des AGÖF-Leitfadens „Gerüche in Innenräumen—Sensorische Bestimmung und Bewertung", Berlin, Germany, 2010. Available online: https://www.umweltbundesamt.de/sites/default/files/medien/1/dokumente/stellungnahme_der_ad_hoc_ag_zur_geruchsbewertung.pdf (accessed on 26 March 2023).
63. Ad-Hoc-Arbeitsgruppe. Gesundheitlich-hygienische Beurteilung von Geruchsstoffen in der Innenraumluft mithilfe von Geruchsleitwerten. *Bundesgesundheitsblatt* **2014**, *57*, 148–153. [CrossRef]

64. AGÖF. AGÖF-Leitfaden. Gerüche in Innenräumen–Sensorische Bestimmung und Bewertung. presented at the Umwelt, Gebäude & Gesundheit: Schadstoffe, Gerüche & schadstoffarmes Bauen; Ergebnisse des 10. Fachkongresses der Arbeitsgemeinschaft Ökologischer Forschungsinstitute (AGÖF) am 24. und 25.10.2013 in Nürnberg, 2013. Available online: https://www.agoef.de/fileadmin/user_upload/dokumente/orientierungswerte/AGOEF-Geruchsleitfaden-2013.pdf (accessed on 26 March 2023).
65. AGÖF. AGÖF-Orientierungswerte für flüchtige organische Verbindungen in der Raumluft 2013. presented at Available online: The Umwelt, Gebäude & Gesundheit: Schadstoffe, Gerüche & schadstoffarmes Bauen; Ergebnisse des 10. Fachkongresses der Arbeitsgemeinschaft Ökologischer Forschungsinstitute (AGÖF) am 24. und 25.10.2013 in Nürnberg, 2013. Available online: https://www.agoef.de/fileadmin/user_upload/dokumente/orientierungswerte/AGOEF-VOC-Orientierungswerte-2013-11-28.pdf (accessed on 26 March 2023).
66. Federal Ministry of Agriculture Regions and Tourism (BMLFUW). *Richtlinie zur Bewertung der Innenraumluft*; BMLFUW: Wien, Austria, 2011.
67. Federale Overheidsdienst Werkgelegenheid Arbeid en Sociaal Overleg. Koninklijk Besluit tot Wijziging van de Codex over Het Welzijn op het Werk Inzake de Binnenluchtkwaliteit in Werklokalen. [2 May 2019.-Royal Decree Amending the Codex on Well-Being at Work Regarding Indoor Air Quality in Workplaces]. 2019. Available online: https://www.ejustice.just.fgov.be/eli/besluit/2019/05/02/2019201857/staatsblad (accessed on 28 February 2023).
68. Vlaamse Overheid. *Besluit van de Vlaamse Regering tot Wijziging van Diverse Bepalingen van het Binnenmilieubesluit van 11 Juni 2004 en tot Opheffing van het Ministerieel Besluit van 16 Maart 2006 tot Vaststelling van het Modelformulier en de Procedure Voor Aanvragen van een Onderzoek van het Binnenmilieu. [13 July 2018.-Decree of the Flemish Government Amending Various Provisions of the Indoor Environment Decree of 11 June 2004 and Repealing the Ministerial Decree of 16 March 2006 Establishing the Model form and the Procedure for Requesting an Investigation of the Indoor Environment]*; Vlaamse Overheid: Brussels, Belgium, 2018. Available online: https://www.ejustice.just.fgov.be/cgi/article_body.pl?language=nl&caller=summary&pub_date=18-09-07&numac=2018013405 (accessed on 28 February 2023).
69. FPS Public Health Food Chain Safety and Environment. *6 Nov. 2022.-Loi Relative à L'amélioration de la Qualité de l'air Intérieur Dans les Lieux Fermés Accessibles au Public (1)*; [Nov. 6, 2022.-Law on Improving Indoor Air Quality in Closed Places Accessible to the public (1)]; FPS Public Health Food Chain Safety and Environment, 2022. Available online: http://www.ejustice.just.fgov.be/eli/loi/2022/11/06/2022034199/moniteur (accessed on 28 February 2023).
70. Superior Health Council. *Indoor aiq Quality in Belgium*; Superior Health Council: Bruxelles, Belgium, 2017. Available online: https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/shc_8794_advice_iaq_.pdf (accessed on 28 February 2023).
71. Indoor Air Quality Guidelines (IAQGs). Available online: https://www.anses.fr/en/content/indoor-air-quality-guidelines-iaqgs (accessed on 28 April 2022).
72. Gouvernement de la République française. *LOI n° 2010-788 du 12 Juillet 2010 Portant Engagement National Pour L'environnement. [Law No. 2010-788 of July 12, 2010 on the National Commitment to the Environment]*; Gouvernement de la République française: Paris, France, 2010. Available online: https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000022470434 (accessed on 28 February 2023).
73. Gouvernement de la République française. *Décret n° 2011-1727 du 2 Décembre 2011 Relatif aux Valeurs-Guides pour l'air Intérieur Pour le Formaldéhyde et le Benzène. [Decree No. 2011-1727 of December 2, 2011 Relating to Indoor Air Guide Values for Formaldehyde and Benzene]*; Gouvernement de la République française: Paris, France, 2011. Available online: https://www.legifrance.gouv.fr/eli/decret/2011/12/2/DEVP1116199D/jo/texte (accessed on 28 February 2023).
74. Gouvernement de la République française. *Décret n° 2015-1000 du 17 août 2015 Relatif aux Modalités de Surveillance de la Qualité de l'air Intérieur Dans Certains Établissements Recevant du Public. [Decree No. 2015-1000 of August 17, 2015 Relating to the Procedures for Monitoring Indoor Air Quality in Certain Establishments Open to the Public]*; Gouvernement de la République française: Paris, France, 2015. Available online: https://www.legifrance.gouv.fr/eli/decret/2015/8/17/DEVP1406204D/jo/texte (accessed on 28 February 2023).
75. Gouvernement de la République française. *Décret n° 2015-1926 du 30 Décembre 2015 Modifiant le Décret n° 2012-14 du 5 Janvier 2012 Relatif à L'évaluation des moyens D'aération et à la Mesure des Polluants Effectuées au Titre de la Surveillance de la Qualité de l'air Intérieur de Certains Établissements Recevant du Public*; Gouvernement de la République française: Paris, France, 2015. Available online: https://www.legifrance.gouv.fr/loda/id/JORFTEXT000031741934 (accessed on 28 February 2023).
76. Gouvernement de la République française. *Arrêté du 1er Juin 2016 Relatif aux Modalités de Surveillance de la Qualité de l'air Intérieur dans Certains Établissements Recevant du Public. [Order of 1 June 2016 Relating to the Procedures for Monitoring Indoor Air Quality in Certain Establishments Open to the Public]*; Gouvernement de la République française: Paris, France, 2016. Available online: https://www.legifrance.gouv.fr/loda/id/JORFTEXT000032630331 (accessed on 28 February 2023).
77. Gouvernement de la République française. *Décret n° 2022-1689 du 27 décembre 2022 Modifiant le code de L'environnement en Matière de Surveillance de la Qualité de l'air Intérieur. [Decree No. 2022-1689 of December 27, 2022 Amending the Environment Code with Regard to Indoor Air Quality Monitoring]*; Gouvernement de la République Française: Paris, France, 2022. Available online: https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000046829320 (accessed on 28 February 2023).

78. Gouvernement de la République française. *Décret n° 2022-1690 du 27 Décembre 2022 Modifiant le Décret n° 2012-14 du 5 Janvier 2012 Relatif* à *L'évaluation des Moyens D'aération et* à *la Mesure des Polluants Effectuées au Titre de la Surveillance de la Qualité de L'air Intérieur de Certains Établissements Recevant du Public. [Decree No. 2022-1690 of December 27, 2022 Amending Decree No. 2012-14 of January 5, 2012 Relating to the Evaluation of Ventilation Means and the Measurement of Pollutants Carried Out for Air Quality Monitoring Interior of Certain Establishments Open to the Public]*; Gouvernement de la République française: Paris, France, 2022. Available online: https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000046829352 (accessed on 28 February 2023).
79. Lietuvos Respublikos Sveikatos Apsaugos Ministras. Įsakymas dėl Lietuvos Higienos Normos Hn 35:2007 "Didžiausia Leidžiama Cheminių Medžiagų (Teršalų)Koncentracija Gyvenamosios Aplinkos Ore" Patvirtinimo. [Order on the Approval of the Lithuanian Hygiene Norm Hn 35:2007 "Maximum Permitted Concentration of Chemical Substances (Pollutants) in the Air of the Living Environment"]. 2007. Available online: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.297779?jfwid= (accessed on 28 February 2023).
80. Health Council of The Netherlands. *Indoor Air Quality in Primary Schools: And the Value of Carbon Dioxide as an Indicator of Air Quality*; Health Council of The Netherlands: Amsterdam, The Netherlands, 2010. Available online: https://www.healthcouncil.nl/documents/advisory-reports/2010/04/29/indoor-air-quality-in-primary-schools (accessed on 15 November 2022).
81. Ministry of Labour and Social Inclusion. *Regulations Concerning the Design and Layout of Workplaces and Work Premises (The Workplace Regulations)*; Ministry of Labour and Social Inclusion: Oslo, Norway, 2013. Available online: https://lovdata.no/dokument/SFE/forskrift/2011-12-06-1356 (accessed on 26 March 2023).
82. VV.AA; Rundskriv, N.R. *IK-39/91 91/06422/1/EWI Normer for Inneluft-Kvalite [Regulations Concerning the Design and Layout of Workplaces and Work Premises]*; Ministry of Labour and Social Inclusion: Oslo, Norway, 1991.
83. Minister of Health and Social Welfare. *Ordinance of the Minister of Health and Social Welfare of March 12, 1996 on Acceptable Concentrations and Intensity of Adverse to Health Agents, Secreted by Construction Materials, Equipment and Fittings in Rooms Designed to Accommodate People*; Minister of Health and Social Welfare: Kracov, Poland, 1996. Available online: https://www.ilo.org/dyn/natlex/natlex4.detail?p_lang=en&p_isn=99664 (accessed on 28 February 2023).
84. Ministério das Obras Públicas Transportes e Comunicações. Decreto-Lei n.° 79/2006, de 4 de abril. [Decree-Law No. 79/2006, of April 4]. 2006. Available online: https://dre.pt/dre/detalhe/decreto-lei/79-2006-672459 (accessed on 15 November 2022).
85. Ministério da Economia e do Emprego. Decreto-Lei n.º 118/2013, de 20 de Agosto. [Decree-Law No. 118/2013, 20th August]. Ministério da Economia e do Emprego. 2013. Available online: https://dre.pt/dre/detalhe/decreto-lei/118-2013-499237?_ts=1674172800034 (accessed on 15 November 2022).
86. Instituto Nacional de Seguridad y Salud en el Trabajo (INSST). La Ventilación Como Medida Preventiva Frente al Coronavirus SARS-CoV-2. [Ventilation as a Preventive Measure against the Coronavirus SARS-CoV-2]. INSST. 2021. Available online: https://www.insst.es/el-instituto-al-dia/la-ventilacion-como-medida-preventiva-frente-al-coronavirus-sars-cov-2#:~:text=Considerando%20esta%20v%C3%ADa%20de%20transmisi%C3%B3n,de%20la%20Salud%20(OMS) (accessed on 28 November 2022).
87. Education & Skills Funding Agency. Building Bulletin 101. In *Guidelines on Ventilation, Thermal Comfort and Indoor Air Quality in Schools: Government Response to Public Consultation*; Education & Skills Funding Agency: Coventry, UK, 2018. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/735652/BB101_Consultation_response.pdf (accessed on 31 December 2022).
88. Goverment of Canada. *Residential Indoor Air Quality Guidelines for Xylenes*; Goverment of Canada: Ottowa, ON, Canada, 2022. Available online: https://www.canada.ca/en/health-canada/services/publications/healthy-living/residential-indoor-air-quality-guidelines-xylenes.html (accessed on 31 December 2022).
89. Acetaldehyde. Available online: https://www.dcceew.gov.au/environment/protection/npi/substances/fact-sheets/acetaldehyde (accessed on 18 January 2023).
90. Appelman, L.M.; Woutersen, R.A.; Fcron, V.J.; Hooftman, R.N.; Notten, W.R.F. Effect of variable versus fixed exposure levels on the toxicity of acetaldehyde in rats. *J. Appl. Toxicol.* **1986**, *6*, 331–336. [CrossRef]
91. シックハウス（室内空気汚染）問題に関する検討会中間報告書ー第 8 回～第 9 回のまとめについて [Investigative Committee on the Problem of Sick House (Indoor Air Pollution) Interim Report-Summary of the 8th and 9th]. Available online: https://www.mhlw.go.jp/houdou/2002/02/h0208-3.html#:~:text=%E5%AE%A4%E5%86%85%E7%A9%BA%E6%B0%97%E6%B1%9A%E6%9F%93%E3%81%AB%E4%BF%82%E3%82%8B%E3%82%AC%E3%82%A4%E3%83%89%E3%83%A9%E3%82%A4%E3%83%B3%E3%81%AB%E3%81%A4%E3%81%84%E3%81%A6%E2%80%95%E5%AE%A4%E5%86%85%E6%BF%83%E5%BA%A6%E3%81%AB%E9%96%A2%E3%81%99%E3%82%8B,0.03ppm%EF%BC%89%E3%81%A8%E8%A8%AD%E5%AE%9A%E3%81%97%E3%81%9F%E3%80%82 (accessed on 17 February 2023).
92. Manzoli, L.; Flacco, M.E.; Ferrante, M.; La Vecchia, C.; Siliquini, R.; Ricciardi, W.; Marzuillo, C.; Villari, P.; Fiore, M.; The, I.W.G. Cohort study of electronic cigarette use: Effectiveness and safety at 24 months. *Tob. Control.* **2017**, *26*, 284–292. [CrossRef]
93. Benzo[a]pyrene. Available online: https://pubchem.ncbi.nlm.nih.gov/compound/Benzo_a_pyrene (accessed on 18 January 2023).
94. Settimo, G.; Baldassarri, L.T.; Brini, S.; Lepore, A.; Moricci, F.; Martino, A.d. And per il Gruppo di Studio Nazionale sull'Inquinamento Indoor. In *Presenza di CO_2 e H_2S in Ambienti Indoor: Conoscenze Attuali e Letteratura Scientifica in Materia; [Presence of CO_2 and H_2S in Indoor Environments: Current Knowledge and Scientific Literature on the Subject]*; Istituto Superiore di Sanità: Rome, Italy, 2016. Available online: http://www.iss.it/binary/publ/cont/16_15_web.pdf (accessed on 28 February 2023).

95. World Meteorological Organization (WMO). *WMO Greenhouse Gas Bulletin (GHG Bulletin)-No.18: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2021*; World Meteorological Organization (WMO): Petteri Taalas, Finland, 2022. Available online: https://library.wmo.int/index.php?lvl=notice_display&id=22149#.Y-zOMXbMKM8 (accessed on 28 February 2023).
96. Settimo, G.; Bertinato, L.; Martuzzi, M.; Inglessis, M.; D'Ancona, F.P.; Soggiu, M.E.; Brusaferro, S. Monitoraggio della CO_2 per prevenzione e gestione negli ambienti indoor in relazione alla trasmissione dell'infezione da virus SARS-CoV-2. [CO_2 monitoring for prevention and management in indoor environments in relation to the transmission of the SARS-CoV-2 virus infection]. In *Nota Tecnica ad Interim*; Istituto Superiore di Sanità: Rome, Italy, 2022.
97. VV.AA. Finnish Society of Indoor Air Quality and Climate. In *Classification of Indoor Climate 2000: Target Values, Design Guidance and Product Requirements*; FISIAQ: Espoo, Finland, 2001.
98. Agence Nationale de Sécurité Sanitaire de L'alimentation de L'environnement et du Travai (ANSES). *Proposition de Valeurs Guides de Qualité d'air Intérieur Le Toluène Avis de l'Anses Rapport D'expertise Collective. [Proposal for Indoor Air Quality Guide Values Toluene Opinion of ANSES Collective Expert Report]*; ANSES: Maisons-Alfort, France, 2018. Available online: https://www.anses.fr/fr/system/files/AIR2016SA0043Ra.pdf (accessed on 31 December 2022).
99. Yang, N. Dichloromethane. In *Encyclopedia of Toxicology*, 3rd ed.; Wexler, P., Ed.; Academic Press: Cambridge, MA, USA, 2014; pp. 99–101. [CrossRef]
100. Agency for Toxic Substances & disease Registry (ATSDR). *Toxicological Profile For Naphthalene, 1-Methylnaphthalene, and 2-Methylnaphthalene. Agency for Toxic Substances & Disease Registry*; ATSDR: Atlanta, GA, USA, 2005. Available online: https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=240&tid=43 (accessed on 28 November 2022).
101. Huang, Y.; Yang, Z.; Gao, Z. Contributions of indoor and outdoor sources to ozone in residential buildings in nanjing. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2587. [CrossRef] [PubMed]
102. Bessonneau, V.; Mosqueron, L.; Berrubé, A.; Mukensturm, G.; Buffet-Bataillon, S.; Gangneux, J.-P.; Thomas, O. VOC Contamination in Hospital, from Stationary Sampling of a Large Panel of Compounds, in View of Healthcare Workers and Patients Exposure Assessment. *PLoS ONE* **2013**, *8*, e55535. [CrossRef] [PubMed]
103. Settimo, G.; Musmeci, L.; Marzocca, A.; Cecinato, A.; Cattani, G.; Fuselli, S.; per il Gruppo di Studio Nazionale sull'Inquinamento Indoor. Strategie di monitoraggio del materiale particellare PM10 e PM2,5 in ambiente indoor. In *Caratterizzazione dei Microinquinanti Organici e Inorganici; [Monitoring strategies for PM10 and PM2.5 Particulate Matter in an Indoor Environment. Characterization of Organic and Inorganic Micropollutants.]*; Istituto Superiore di Sanità: Rome, Italy, 2016. Available online: http://www.iss.it/binary/publ/cont/16_16_web.pdf (accessed on 15 September 2022).
104. Styrene. Available online: https://www.osha.gov/styrene#:~:text=Styrene%20is%20primarily%20a%20synthetic,are%20potentially%20exposed%20to%20styrene. (accessed on 17 January 2023).
105. Styrene Exposure. Available online: https://styrene.org/styrene-exposure/ (accessed on 17 January 2023).
106. Agency for Toxic Substances and Disease Registry (ATSDR). *Toxicological Profile for Styrene Agency for Toxic Substances and Disease Registry*; ATSDR: Atlanta, GA, USA, 2010. Available online: www.atsdr.cdc.gov/toxprofiles/tp53.pdf (accessed on 28 January 2023).
107. Agency for Toxic Substances and Disease Registry. *Tetrachloroethylene. Agency for Toxic Substances and Disease Registry*; ATSDR: Atlanta, GA, USA, 2015. Available online: https://www.atsdr.cdc.gov/sites/toxzine/docs/tetrachloroethylene_toxzine.pdf (accessed on 3 March 2023).
108. Agency for Toxic Substances and Disease Registry (ATSDR). *Toxicological Profile for Tetrachloroethylene*; Agency for Toxic Substances and Disease Registry: Atlanta, GA, USA, 2014. Available online: https://www.atsdr.cdc.gov/toxprofiles/tp18.pdf (accessed on 3 March 2023).
109. U.S. Department of Health and Human Services; Public Health Service; Agency for Toxic Substances and Disease Registry. *ToxGuide for Toluene (C7H8) CAS# 108-83-3*; Agency for Toxic Substances and Disease Registry: Atlanta, GA, USA, 2017. Available online: https://www.atsdr.cdc.gov/toxguides/toxguide-56.pdf (accessed on 28 November 2022).
110. Kobald, S.O.; Wascher, E.; Blaszkewicz, M.; Golka, K.; van Thriel, C. Neurobehavioral and neurophysiological effects after acute exposure to a single peak of 200 ppm toluene in healthy volunteers. *Neurotoxicology* **2015**, *48*, 50–59. [CrossRef] [PubMed]
111. Zavalić, M.; Mandić, Z.; Turk, R.; Bogadi-Sare, A.; Plavec, D. Quantitative assessment of color vision impairment in workers exposed to toluene. *Am. J. Ind. Med.* **1998**, *33*, 297–304. [CrossRef]
112. Zavalic, M.; Mandic, Z.; Turk, R.; Bogadi-Sare, A.; Plavec, D.; Gomzi, M.; Skender, L.J. Assessment of colour vision impairment in male workers exposed to toluene generally above occupational exposure limits. *Occup. Med.* **1998**, *48*, 175–180. [CrossRef]
113. What are Volatile Organic Compounds (VOCs)? Available online: https://www.epa.gov/indoor-air-quality-iaq/what-are-volatile-organic-compounds-vocs (accessed on 1 December 2022).
114. United State Environmental Protection Agency (USEPA). *Toxicological Review Of Trichloroethylene: In Support Of Summary Information On The Integrated Risk Information System (Iris)*; USEPA: Washington, DC, USA, 2011. Available online: https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/0199tr/0199tr.pdf (accessed on 28 November 2022).
115. Agence Nationale de Sécurité Sanitaire de L'alimentation de L'environnement et du Travai (ANSES). *Valeurs Guides de Qualité d'air Intérieur: Le Trichloroethylene; [Indoor Air Quality Guideline Values: Trichlorethylene]*; ANSES: Maisons-Alfort, France, 2009. Available online: www.anses.fr/fr/system/files/AIR2004etVG006Ra.pdf (accessed on 15 November 2022).

116. Asbestos Exposure and Cancer Risk. Available online: https://www.cancer.gov/about-cancer/causes-prevention/risk/substances/asbestos/asbestos-fact-sheet (accessed on 17 January 2023).
117. Britannica, T. Editors of Encyclopaedia. Hydrogen cyanide. In *Encyclopedia Britannica*; Britannica, T., Ed.; Encyclopedia Britannica: Chicago, IL, USA, 2022. Available online: https://www.britannica.com/science/hydrogen-cyanide (accessed on 15 December 2022).
118. Hydrogen Cyanide Fact Sheet. Available online: https://www.emro.who.int/ceha/information-resources/hydrogen-cyanide-fact-sheet.html (accessed on 18 January 2023).
119. Krieger, G.R.; Philips, S.D. Blood. In *Encyclopedia of Toxicology*, 2nd ed.; Wexler, P., Ed.; Elsevier: Amsterdam, The Netherlands, 2005; pp. 323–329. [CrossRef]