The Effects of Outdoor Air on Indoor Air Quality and a Survey on Indoor Air Quality Standards

[1]Barbaros Batur [2]Mustafa Cem Çelik
[1]Faculty of Mechanical Engineering of Yıldız Technical University
[2]Faculty of Engineering of Marmara University

Abstract

First studies with the indoor air quality has begun in Scandinavia in the 1960's with the impacts of outdoor air pollutants on indoor air quality. They begun to calculate how much air quality which has direct impact on human health will shorten the average human life expectancy. Today, white-collar workers are spending more than 90% of their times indoors. Therefore , indoor air quality standards, as well as outdoor air quality standards are widely used in most densely populated places . Different countries have adopted standards with different values. In this paper a short information about the air quality will be given with the comparisons of the world standards

Key Words: Indoor air quality, outdoor air quality, air pollutants, air pollution, air pollution standards

Introduction

In medical scientific papers it can be observed that, diseases like chronic obstructive pulmonary disease, acute respiratory infections in childhood, low birth weight, increase in infant and prenatal mortality, pulmonary tuberculosis, nasopharyngeal, laryngeal cancer, asthma, cataract and specifically lung cancer, are related to the air quality and the exposure to the indoor air pollutants.

In recent years, white-collar workers spend more than 90% of their time in indoors. Working, housing and recreation activities are restricted the modern life in indoors. With the changes in technology and utilization of new materials, indoor environment changed dramatically over the last few decades. The impacts on human wellbeing and health conditions of indoor air quality started to draw more attention. The health problems caused by the indoor environment led to workforce loss, absenteeism of students and overall decline in wellbeing. Accordingly, the distinctive effects of major pollutants and exposure levels were investigated by the national and international level organizations. The improvements in high rise buildings, construction materials and ventilation practices introduced various new pollutants and problems. Hence, the internal air quality standards must be updated periodically and its implementation and execution must be evaluated decisively.

1. Air Pollution Diseases

These potentially adverse effects are further complicated by the fact that people are spending more time than ever indoors, up to 90 percent according to estimates by the U.S. Environmental Protection Agency (EPA). It is easy to understand why there is a growing concern about the quality of the air we breathe [1].

Human beings need a regular supply of food and water and an essentially continuous supply of air. The requirements for air and water are relatively constant (10–20 m^3 and 1–2 liters per day, respectively). That all people should have free access to air and water of acceptable quality is a fundamental human right.

*Corresponding author: Address: Faculty of Mechanical Engineering of Yıldız Technical University

According to the World Health Organization (WHO), 4.3 million deaths are attributable to the household air pollution. Among these deaths, 12% are due to pneumonia, 34% from stroke, 26% from ischemic heart disease, 22% from chronic obstructive pulmonary disease (COPD), and 6% from lung cancer [2].

2. Air Pollutants Sources

Indoor air pollutants emanate from a range of sources (Table 1). They are emitted by the fabric of buildings, and may also be a by-product of the activities that are undertaken within them. Sources can be broadly classified as being associated with the activities of building occupants and other biological sources, the combustion of substances for heating or fuel, and emissions from building materials. For some contaminants, infiltration from outside, either through water, air, or soil, can also be a significant source. [3]

Table 1 Major indoor pollutants and emission sources [4]

Pollutant	**Major emission sources**
Allergens	House dust, domestic animals, insects
Asbestos	Fire retardant materials, insulation
Carbon dioxide	Metabolic activity, combustion activities, motor vehicles in garages
Carbon monoxide	Fuel burning, boilers, stoves, gas or kerosene heaters, tobacco smoke
Formaldehyde	Particleboard, insulation, furnishings
Micro-organisms	People, animals, plants, air conditioning systems
Nitrogen dioxide	Outdoor air, fuel burning, motor vehicles in garages
Organic substances	Adhesives, solvents, building materials, volatilisation, combustion, paints, tobacco smoke
Ozone	Photochemical reactions
Particles	Re-suspension, tobacco smoke, combustion products
Polycyclic aromatic hydrocarbons	Fuel combustion, tobacco smoke
Pollens	Outdoor air, trees, grass, weeds, plants
Radon	Soil, building construction materials (concrete, stone)
Fungal spores	Soil, plants, foodstu!s, internal surfaces
Sulphur dioxide	Outdoor air, fuel combustion

It is important to note that outdoor sources may be the main contributors to indoor concentrations of a number of non-biological pollutants commonly found in indoor air. This is especially the case for contamination in buildings situated in urban areas and close to industrial zones or streets with heavy trace. The factors which determine the contribution of outdoor pollution to indoor air quality include the type of ventilation in use (natural or forced), the ventilation rate (air changes per hour), and the nature of the contaminants in question [5]. The major outdoor sources of important indoor air pollutants are given in Table 2. The USA EPATEAM studies have shown that reactive gasses such as ozone tend to occur at lower concentrations indoors than outdoors because they react rapidly with indoor surfaces [6]. Non-reactive gases may accumulate indoors and exposures there may be greater than outside.

EU can be seen as a contribution to target 10 of HEALTH21, the health for all policy framework for the WHO European Region as formulated in 1999 [7]. This target states that by the year 2015, people in the Region should live in a safer physical environment, with exposure to contaminants hazardous to health at levels not exceeding internationally agreed standards. The achievement of this target will require the introduction of effective legislative, administrative and technical measures for the surveillance and control of both outdoor and indoor air pollution, in order to comply with criteria to safeguard human health. Unfortunately, this ambitious objective is not likely to be met in the next few years in many areas of Europe. Improvement in epidemiological research over the 1990s and greater sensitivity of the present studies have revealed that people's health may be affected by exposures to much lower levels of some common air pollutants than believed even a few years ago. While the no-risk situation is not likely to be achieved, a minimization of the risk should be the objective of air quality management, and this is probably a major conceptual development of the last few years.

Various chemicals are emitted into the air from both natural and man-made (anthropogenic) sources. The quantities may range from hundreds to millions of tons annually. Natural air pollution stems from various biotic and abiotic sources such as plants, radiological decomposition, forest fires, volcanoes and other geothermal sources, and emissions from land and water. These result in a natural background concentration that varies according to local sources or specific weather conditions. Anthropogenic air pollution has existed at least since people learned to use fire, but it has increased rapidly since industrialization began. The increase in air pollution resulting from the expanding use of fossil energy sources and the growth in the manufacture and use of chemicals has been accompanied by mounting public awareness of and concern about its detrimental effects on health and the environment. Moreover, knowledge of the nature, quantity, physicochemical behavior and effects of air pollutants has greatly increased in recent years. Nevertheless, more needs to be known. Certain aspects of the health effects of air pollutants require further assessment; these include newer scientific areas such as developmental toxicity. The proposed guideline values will undoubtedly be changed as future studies lead to new information.

The impact of air pollution is broad. In humans, the pulmonary deposition and absorption of inhaled chemicals can have direct consequences for health. Nevertheless, public health can also be indirectly affected by deposition of air pollutants in environmental media and uptake by plants and animals, resulting in chemicals entering the food chain or being present in drinking water and thereby constituting additional sources of human exposure. Furthermore, the direct effects of air pollutants on plants, animals and soil can influence the structure and function of ecosystems, including their self regulation ability, thereby affecting the quality of life.

In recent decades, major efforts have been made to reduce air pollution in the European Region. The emission of the main air pollutants has declined significantly. The most pronounced effect is observed for sulfur dioxide: its total emission was reduced by about 50% in the period 1980–1995. Reduction of emission of nitrogen oxides was smaller and was observed only after 1990: total emission declined by about 15% in the period from 1990 to 1995 [8]. The reduction of sulfur dioxide emission is reflected by declining concentrations in ambient air in urban areas. Trends in concentrations of other pollutants in urban air, such as nitrogen dioxide or particulate matter, are less clear and it is envisaged that these pollutants still constitute a risk to human health [9]

Many countries of the European Region encounter similar air pollution problems, partly because pollution sources are similar, and in any case air pollution does not respect national frontiers. The subject of the transboundary long-range transport of air pollution has received increasing attention in Europe over the last decade. International efforts to combat emissions are undertaken, for instance within the framework of the Convention on Long-range

Transboundary Air Pollution established by the United Nations Economic Commission for Europe [10].

The task of reducing levels of exposure to air pollutants is a complex one. It begins with an analysis to determine which chemicals are present in the air, at what levels, and whether likely levels of exposure are hazardous to human health and the environment. It must then be decided whether an unacceptable risk is present. When a problem is identified, mitigation strategies should be developed and implemented so as to prevent excessive risk to public health in the most efficient and cost-effective way.

Analyses of air pollution problems are exceedingly complicated. Some are national in scope (such as the definition of actual levels of exposure of the population, the determination of acceptable risk, and the identification of the most efficient control strategies), while others are of a more basic character and are applicable in all countries (such as analysis of the relationships between chemical exposure levels, and doses and their effects). The latter form the basis of these guidelines. The most direct and important source of air pollution affecting the health of many people is tobacco smoke. Even those who do not smoke may inhale the smoke produced by others ("passive smoking"). Indoor pollution in general and occupational exposure in particular also contributes substantially to overall human exposure: indoor concentrations of nitrogen dioxide, carbon monoxide, respirable particles, formaldehyde and radon are often higher than outdoor concentrations [11].

Outdoor air pollution can originate from a single point source, which may affect only a relatively small area. More often, outdoor air pollution is caused by a mixture of pollutants from a variety of diffuse sources, such as traffic and heating, and from point sources. Finally, in addition to those emitted by local sources, pollutants transported over medium and long distances contribute further to the overall level of air pollution. The relative contribution of emission sources to human exposure to air pollution may vary according to regional and lifestyle factors. Although, as far as some pollutants are concerned, indoor air pollution will be of greater importance than outdoor pollution, this does not diminish the importance of outdoor pollution. In terms of the amounts of substances released, the latter is far more important and may have deleterious effects on animals, plants and materials as well as adverse effects on human health. Pollutants produced outdoors may penetrate into the indoor environment and may affect human health by exposure both indoors and outdoors.

Table 2 Outdoor sources of major indoor air pollutants [12]

Pollutant	Percentage of emissions associated with industry!	Percentage of emissions associated with transport
Benzene	32	65
Carbon monoxide (CO)	3	90
Lead (Pb)	31	60
Oxides of nitrogen (NO_x)	38	49
Particulates (PM_{10})	56	25
Sulphur dioxide (SO_2)	90	2
Volatile organic compounds (VOC_s)	52	34
Ozone (O_3)	Arises from atmospheric chemical reactions	

Where meaningful, typical indoor, outdoor concentration ratios of pollutants are provided. However, to discuss the full impact of outdoor pollutants on indoor air quality would require a detailed consideration of the chemistry and processes that operate within the outdoor environment. This is not the place for such a discussion, although the health effects of one outdoor pollutant, radon, are considered. Although radon arises from outside, it merits consideration as it only presents a significant risk to health when found inside buildings. Heating and cooking are often essential indoor activities but may produce smoke and gasses that present a problem of disposal. This difficulty is greatest in colder climates, where it is necessary to retain heat at the same time as removing combustion by-products [13]. A wide range of pollutants are associated with combustion. In the past, a high reliance on wood and coal for the production of heat meant that the indoor pollution profile was dominated by smoke from these sources [14]. In some countries, especially those of Eastern Europe and China, the use of these fuels still predominates [15]. In much of Western Europe and the USA, coal and wood have largely been replaced by natural gas and electricity [16], and approximately one-half of all American homes now use gas for cooking and heating [17]. If properly vented to the outside, most appliances are typically not major contributors to indoor air quality problems. However, the use of unvented appliances or those that are malfunctioning or improperly installed can generate severe problems [18]. Cigarette smoking is an important source of indoor combustion related pollution. Tobacco smoke is an aerosol containing several thousand substances that occur as particles, vapors, and gases. Exposure to cigarette smoke has been associated with a wide range of acute and chronic health impacts. Although the prevalence of smoking in western societies is much lower than it was in the 1950s and 1960s, tobacco smoke still contributes a significant proportion of the total indoor pollutant dose for many individuals. Materials that comprise the fabric of buildings are another important source of non-biological pollutants. A large number of the chemical compounds which are found in indoor air originate from paints, varnishes, solvents, and wood preservatives used in buildings [19]. Furthermore, deteriorating materials that comprise the fabric of a building can become friable and release contaminants into the air. Pollutants from these sources are often difficult to quantify because they are present in relatively low concentrations, and their sources are diffuse [6]. An additional complication arises where levels of contamination are mediated by climatic factors such as temperature and relative humidity. Hence, possible health risks of contaminants from building materials depend very much on the nature and concentration of the pollutants involved.

3. Air Quality Guidelines and Standards

Several guidelines and standards exist for ozone, nitrogen dioxide, and particulate matter in ambient air. The table lists the most recent air quality guidelines and standards recommended by WHO, the US Environmental Protection Agency, and the European Union (EU). The EU standards are targets to be reached in 2005 or 2010. The most remarkable difference lies in the annual value for nitrogen dioxide. The WHO and EU value is only 40% of the US value.

WHO has not proposed guidelines for particulate matter, arguing that it was unable to define a threshold below which no adverse effects are expected. Instead, dose response information was provided to help policy makers decide when setting a standard. The effect estimates given in the table were based on information as it was available until 1996. As described earlier, the newest large-scale studies 43, 48 tend to show somewhat smaller effects per unit particulate matter. For particulate matter, the proposed US standards for $PM_{2.5}$ are not very different from the EU 2010 annual average and the 2005 24-h average for PM_{10}, considering that $PM_{2.5}$

usually comprises about 60–70% of the PM_{10} concentration, and considering the number of exceedances allowed in the 24-h EU standard. All guidelines and standards mentioned in the table are subject to periodic revision when new scientific information becomes available. WHO has just recently started a process to re-evaluate the guidelines for these three pollutants (Table3) [20].

Table 3 WHO, US Environmental Protection Agency (EPA), and European Union (EU) air quality guidelines and standards for ozone, nitrogen dioxide, and particulate matter [20]

	Maximum concentration allowed when averaged over time			
	1 h	8 h	24 h	1 year
Ozone (μg/m³)				
WHO	..	120	..	..
EPA	235	157 (proposed)		
EU		120 (2010)		
Nitrogen dioxide (μg/m³)				
WHO	200			40
EPA				100
EU	200			40 (2010)
PM_{10} (μg/m³)				
WHO (mortality relative risk per 10 μg/m³)			1 007	1 10
EPA			150	50
EU			50 (2005) 50 (2010)	40 (2005) 20 (2010)
$PM_{2.5}$ (μg/m³)				
WHO (mortality relative risk per 10 μg/m³)			1 015	1 14
EPA			65 (proposed)	15 (proposed)

Comparison of regulation guidelines to indoor environments are summarized in Table 3.

Table 4. Comparison of regulation guidelines to indoor environments [21, 22]

	Enforceable and/or Regulatory Levels			Non-Enforced Guidelines and Reference Levels			
	NAAQS/EPA	OSHA	MAK	Canadian	WHO/Europe	NIOSH	ACGIH
Carbon dioxide		500ppm	5 000ppm 10 000 ppm [1h]	3 500 ppm		5 000 ppm 30 000 ppm [15 min]	5 000 ppm 30 000 ppm [15 min]
Carbon monoxide	9 ppm 35 ppm [1h]	50 ppm	30 ppm 60 ppm [30 min]	11 ppm [8h] 25 ppm [8h]	90 ppm [15min] 50 ppm [30min] 25 ppm [1h] 10 ppm [8h]	35 ppm 200 ppm [C]	25 ppm
Formaldehyde		0,75 ppm 2 ppm [15min]	0,3ppm 1ppm*	0,1ppm [L] 0,05ppm [L]	0,081ppm	0,016ppm 0,1ppm [15min]	0,3ppm[C]
Lead	1,5 µg/m^3	0,05 mg/m^3	0,05 mg/m^3 0,05 mg/m^3 [30min]	Yaygın kullanımda minimize edilir	0,5 µg/m^3 [1year]	0,05 mg/m^3	0,05 mg/m^3
Nitrogen dioxide	0,05ppm [1yıl]	5ppm[C]	5ppm 10ppm[5min]	0,05ppm 0,25ppm [1h]	0,1 [1h] 0,02 [1yıl]	1ppm [15min]	3ppm 5ppm [15min]
Ozone	0,12ppm [1h] 0,08ppm	0,1ppm		0,12ppm [1h]	0,064ppm (120 µg/m^3)[8h]	0,1ppm [C]	0,05ppm 0,08ppm 0,1ppm 0,2ppm
Particles < 2,5µm	15 µg/m^3[1yıl] 35 µg/m^3[24h]	5 mg/m^3	1,5 mg/m^3 <4µm	1 mg/m^3[1h] 0,04mg/ m^3[L]			3 mg/m^3[L]
Particles < 10µm	150 µg/m^3[24h]		4 mg/m^3				10 mg/m^3
Radon				800Bq/m^3[1year]			
Sulfur dioxide	0,03ppm[1year] 0,14ppm[24h]	5ppm	0,5ppm 1ppm*	0,38ppm[5min] 0,019ppm	0,48ppm[24saat] 0,012ppm[1year]	2ppm 5ppm [15min]	2ppm 5ppm [15min]
Total Particles		15mg/m^3					

4. Discussion

1- Without proper indoor air conditioning it is needless to consider indoor air quality.
2- OAQ figures directly effects IAQ parameters.
3- The limits of indoor air quality parameters and exposure levels must be determined according to the medical studies.
4- IAQ standards and regulations of WHO and EU are applied in (Spain and in) Turkey as well.
5- IAQ parameters and regulations are going to be controlled more vigorously in more various indoor spaces.
6- The increasing need for clean air, decreasing energy prices and technological advances in HVAC industry are expected to lead better IAQ performances.

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