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Chapter

Impacts of the Indoor Air Quality on the Health of the Employee and Protection against These Impacts

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Abstract

Workplace indoor factors are among the factor which affect the health of workers most in all sectors. Another important one of these factors is the air quality of the workplace. There are three main groups of workplace indoor pollutants: biological ones, chemical ones and particles (non-biological). They were grouped as asbestos, biological pollutants, carbon monoxide (CO), carbon dioxide (CO₂), formaldehyde/pressed wooden products, lead (Pb), nitrogen dioxide, (NO₂), Radon (Rn), indoor particle substances, environmental tobacco smoke, volatile organic compounds (VOCs), humidity, odor and wood smoke. The workplace indoor air pollutants are among the primary indoor air pollutants with serious effects on health and the potential to deteriorate the workers' health. Healthy indoor air quality is defined as the indoor air which does not contain hazardous substances and does not create sense of discomfort in at least 80% of the workers in the workplace. Poor indoor may result in a variety of health problems, from headache, dizziness and nausea, to asthma, cardiovascular diseases, cancer and death.

Keywords: air quality, worker, health effect, prevention, VOCs

1. Introduction

Oxygen is a basic need for the survival of human beings who can stand its deficiency only for a certain period of time which is shorter when compared with their other needs. Human beings receive oxygen from air through respiration. It is a right for them to have clean air around them. Pollution of air have adverse effects on the health of living things. The relation between health and air quality has been a fact acknowledged since Hippocrates. Indoor environments may pollute the air with the outdoor pollutants and indoor pollutants. Indoor air quality is of particular importance for people who spend 90% of their time in public or private indoors such as houses, schools, fitness centers, shopping malls, supermarkets, workplaces and transportation vehicles. The health risks accompanying exposure to indoor air pollution can be worse for many people when compared with those of the outdoor air pollution.

Unhealthy indoor air may be harmful particularly for risk groups, such as children, the elderly or the patients suffering chronic disorders. Workplace indoor air quality is equally important for those spending at least 1/3 of their lifetime in workplace [1, 2].

Workplace indoor factors are among the factor which affect the health of workers most in all sectors. Another important one of these factors is the air quality of the workplace. One of the focal points of occupational health is environmental effect on the workers working in the indoors of workplaces, when compared to those working in industrial workplaces, such as construction, mining and agricultural workplaces which are very dangerous or dangerous. Furthermore, workers working indoors are less prepared or experienced against environment risks in comparison to the ones working in industrial workplaces. Overview of relevant legislation shows control mechanisms used in such workplaces are not sufficient [3]. Workplace indoor air quality is an optimal indoor requirement which ensures health, comfort and well-being of workers and includes minimum air pollutants. Indoor air quality varies according to air temperature, relative humidity, air speed and chemicals at workplace [4]. In today's workplaces, materials, equipment, various cleaning products and chemical and particle emissions determine the indoor air quality. Indoor air quality affect workers' health, incidence of occupational accidents, nonattendance and productivity. For this reason, ensuring that the workplace indoor air quality conforms to the norms is of particular importance. Indoor air quality affects workers' health, emergence of occupational accidents, in attendance and productivity [5]. This article aims at shedding light on the adverse effects of workplace indoor air quality on the health of workers and also the measures which need to be taken for preventing such effects. For this reason, this part covers information on factors deteriorating indoor air pollution, health problems which might develop in workers as a result of the indoor air quality, workplace indoor air quality assessment criteria stemming from international and national source data, the measures to be taken to protect workers from indoor air pollution, indoor air quality and Covid-19.

2. Factors affecting workplace indoor air quality

Indoor air pollutants originating from environment/outdoor environment:

These are biological factors, industrial pollutants, fire products, ammonia, ozone, traffic pollutants such as nitrogen dioxide and particles, radon, methane and humidity.

Indoor air pollutants originating from workplace: They were grouped as asbestos, biological pollutants, carbon monoxide (CO), carbon dioxide (CO₂), formaldehyde/pressed wooden products, lead (Pb), nitrogen dioxide, (NO₂), Radon (Rn), indoor particle substances, environmental tobacco smoke, volatile organic compounds (VOCs), humidity, odor and wood smoke [6–8]. Workers working in the workplace indoor environment may be exposed to various air pollutants (both in gas form and particle form), including organic, inorganic and biological ones. The workplace indoor air pollutants are among the primary indoor air pollutants with serious effects on health and the potential to deteriorate the workers' health. Indoor air quality is affected by the tobacco and nicotine products, chemicals used for cleaning purposes, heating, construction materials and humidity. The pollutants in the indoor air can be present in the form of gas or particle and they may cause various diseases in the respiration system. The most important indoor air pollutant is the smoke of cigarette. The smoke produced by smokers includes many hazardous

substances, just like the smoldering cigarette. Most of them are carcinogenic. The people who are exposed to this smoke may develop serious diseases, although they do not consume these products. All workers are affected by the smoke of cigarette consumed in the environment. Limiting the act of smoking to particular rooms would not protect other workers. The particles of tobacco products hang in the air for five hours. Hookah, warmed up tobacco products and electronic cigarette consumption have the same effects on environment and people [6–8]. The construction materials, equipment and chemicals present in the workplace deteriorates the indoor air quality. There are sources of pollutants which deteriorates the indoor air quality and health of workers can be protected only if their effects are eliminated. There are three main groups of workplace indoor pollutants: biological ones, chemical ones and particles (non-biological):

Biological factors: They may stem from excessive bacteria, virus, fungus, dust mite, animal hair, pollen concentrations, insufficient maintenance and cleaning, water split, insufficient humidity control, condensation or leakages at the building envelope or water leakage caused by flood.

Chemical Factors: Chemical pollutants (gas and vapor), emissions stemming from the products used in the building (like floor or walls covering, office equipment, furniture, insecticide, cleaning products), accidental spillage of chemicals and products used for construction purposes, adhesives, paints and combustion products such as carbon monoxide, formaldehyde and nitrogen dioxide are included in this group.

Particle-associated factors (non-biological): Particles are substances which are light enough to hang in the air, in solid or liquid form, and they are non-biological. The building may extract dust, dirt or other substances. Particles may be produced by activities such as construction, wooden punching, drywall, printing, duplication, copying and operation equipment [9].

3. Health problems associated with workplace indoor air pollution

Healthy indoor air quality (IAQ) is defined as the indoor air which does not contain hazardous substances and does not create sense of discomfort in at least 80% of the workers in the workplace [8–10]. Poor indoor may result in a variety of health problems, from headache, dizziness and nausea, to asthma, cardiovascular diseases, cancer and death. The typical effect of some common indoor air pollutants on the health and wellbeing of the residents can be seen in **Table 1**. Poor air quality may also have adverse impact on workplace performance, learning at the education/training institutions and improvement of health services, in addition to being hazardous in terms of health and comfort. The impact of indoor air pollutants on the health of the people depends on the concentration of the concerned pollutant, exposure duration, age and gender of the people exposed to it. As for the industrial workplaces, most of the primary risks are evaluated in terms of use of personal protection equipment (PPE), exposure risk and local air conditioning [7–10].

EU-OFFICER research Project showed the association between the indoor chemicals in the office and sick building syndrome-SBS symptoms. The most expressed complaints are ocular irritation (dry eyes, watering eyes or itching, burning or irritation), headache, lethargy, extraordinary tiredness. The researchers also reported that xylene, ethylbenzene, α -pinene, d-limonene, styrene, formaldehyde, acrolein, propionaldehyde, hexane and ozone might increase in the incidence of the symptoms. They concluded by underlining the need for further research in order to better depict

Pollutant	Impact on health
Carbon monoxide (CO)	Carbon monoxide can cause headaches, dizziness, nausea and at very high levels, death. Elderly people, pregnant women, young children and people with heart disease and lung disease are more sensitive to the adverse effects of carbon monoxide.
Formaldehyde	Formaldehyde can cause eye, nose and throat irritation and is considered a potential human carcinogen.
Nitrogen dioxide (NO ₂)	Exposure to nitrogen dioxide can cause inflammation of the airways, respiratory illnesses and possibly increases the risk of lung infections. Young children and people with asthma are the most sensitive to NO ₂ . It plays a major role in the development of chronic obstructive pulmonary disease in adults which will affect more people than heart disease by 2020 (Environmentalist 2012). Long-term exposure may also affect lung function and can enhance responses to allergens in sensitized individuals.
Odor	Odorous discharges are subjective and cause nausea and irritation for some people.
Ozone (O ₃)	Ozone exposure can cause asthma, irritation and damage to the eyes, nose and airways. Prolonged exposure to high levels may result in damage to the lungs and airway linings.
Particulate matter	Inhalable particles have been linked with a number of respiratory illnesses, including asthma and chronic bronchitis. Long-term exposure to fine particles can cause premature death from heart disease and lung disease including cancer. Short-term exposure to higher levels of fine particle concentrations have also been linked with cardio-vascular problems and increased death rates. Exposure to fine particles has also been linked to prevalent anxiety and hypertensive disorders.
Volatile organic Compounds (VOCs)	Key symptoms associated with exposure to VOCs include eye irritation, nose and throat discomfort, headache and allergic skin reaction.

Table 1.
Typical health impacts of some common pollutants found indoors.

the complicated relationship between IAQ and health interaction symptoms [11]. A research conducted on the effects of indoor air quality on the health of workers in Middle East showed that the first most affected part of workers’ bodies is their respiratory system; the second most affected one is their cardiovascular system, and the third most affected one is their visual system [12].

4. Indoor air pollution for health professionals

People living in developed European and American countries are reported to be more exposed to airborne substances deriving from indoors where they spend most of their time (>90%) causing environmentally associated symptoms that should be evaluated by health professionals. However, this percentage is expected to be higher for infants and the elderly, chronically ill people and in urban settings [13]. Many pollutants present with higher concentrations indoor than outdoor, especially in case of longer and non-intermittent exposure like in the home, workplace and school. It should be taken into account that some of the signs and symptoms presented in the text may occur only in the case of significant exposures. However, lower or shorter exposures with milder or indeterminate symptoms, or atypical presentation (noted in the text) in younger aged children render the diagnosis more difficult. The cooperation of the

individual and the health care professional is essential for the correct diagnosis noting clues suggestive of indoor air pollution, like time patterns or location of occurrence by the help of a log or diary of symptoms. In the absence of this cooperation, the following questions in addition to the medical history may be useful.

- Start, duration and periodicity (diurnal, daily, weekly, seasonally) of symptom or complaints.
- Their relation with location under consideration (cessation when away or reoccurrence when returning)
- The work type, work place, any change including moving or decoration.
- Exposure to environmental tobacco smoke at work, school, home, etc.
- Place of residence including internal change or moving
- Exposure to a new hobby etc., a new pet.
- Similar problem in anybody in close contact at home or work (**Table 2**).

4.1 Health problems related to environmental tobacco smoke (ETS)

It is the most observed indoor air contaminants. It easily disperses and it is hard not be inhaled by workers in the workplace.

Key Signs/Symptoms in Adults; conjunctival irritation, headache, persistent cough, wheezing, rhinitis/pharyngitis, nasal congestion, exacerbation of chronic respiratory conditions.

Key Signs/Symptoms in Infants and Children; asthma onset, snoring, bronchitis, repeated pneumonia, persistent middle-ear effusion, frequent upper respiratory infections and/or episodes of otitis media, increased severity of, or difficulty in controlling, asthma.

ETS is also defined as Group A human carcinogen by the U.S. Environmental Protection Agency (EPA) and related to three thousand pulmonary cancers per year among people who do not smoke in the U.S [14–16]. Among very young children, the incidence of pneumonia, bronchitis, and bronchiolitis is reported to increase two-fold and the effects to be proportional with the frequency of smoking and smokers at the home [17].

The odor of ETS can be eliminated by ventilation, but not meaning that health risks are also removed as it is not possible to totally remove tobacco smoke [18]. The most effective remedy is strict smoking prohibition in the work-place or adapting special smoking rooms with separate ventilation to the outside [19].

4.2 Other combustible products causing health problems

Carbon monoxide is an odorless and colorless asphyxiant due to carboxyhemoglobin (COHb) resulting from CO binding to Hb, impeding oxygen transport.

Nitrogen dioxide (NO) and sulfur dioxide (SO₂) particularly irritate ocular, nasal, pharyngeal and respiratory tract mucosa. Acute bronchoconstriction by sulfur dioxide can be observed in asthma cases or as a hypersensitivity reaction. Continued exposure to elevated levels of nitrogen dioxide may result in acute or chronic bronchitis [20].

Signs and symptoms	Environmental tobacco smoke	Other combustion products	Biological pollutants	Volatile organics	Heavy metals	Sick building syndrome
Respiratory						
Rhinitis, nasal congestion	Yes	Yes	Yes	Yes	No	Yes
Epistaxis	No	No	No	Yes ¹	No	No
Pharyngitis, cough	Yes	Yes	Yes	Yes	No	Yes
Wheezing, worsening asthma	Yes	Yes	No	Yes	No	Yes
Dyspnea	Yes ²	No	Yes	No	No	Yes
Severe lung disease	No	No	No	No	No	Yes ³
Other						
Conjunctival irritation	Yes	Yes	Yes	Yes	No	Yes
Headache or dizziness	Yes	Yes	Yes	Yes	Yes	Yes
Lethargy, fatigue, malaise	No	Yes ⁴	Yes ⁵	Yes	Yes	Yes
Nausea, vomiting, anorexia	No	Yes ⁴	Yes	Yes	Yes	No
Cognitive impairment, personality change	No	Yes ⁴	No	Yes	Yes	Yes
Rashes	No	No	Yes	Yes	Yes	No
Fever, chills	No	No	Yes ⁶	No	Yes	No
Tachycardia	No	Yes ⁴	No	No	Yes	No
Retinal hemorrhage	No	Yes ⁴	No	No	No	No
Myalgia	No	No	No	Yes ⁵	No	Yes
Hearing loss	No	No	No	Yes	No	No

¹Associated especially with formaldehyde.
²In asthma.
³Hypersensitivity pneumonitis, Legionnaires' Disease.
⁴Particularly associated with high CO levels.
⁵Hypersensitivity pneumonitis, humidifier fever.
⁶With marked hypersensitivity reactions and Legionnaires' Disease.

Table 2.
Diagnostic quick reference.

Key Signs/Symptoms; nausea/emesis, dizziness, headache, fatigue, ocular and upper respiratory tract irritation, tachycardia, chronic cough, confusion wheezing, hypercarboxyhemoglobinemia, increased frequency of angina in cardiovascular patients.

Diagnostic Leads

- Types of heating, cooking or similar equipment and used combustion material (especially charcoal).
- Similar findings/symptoms among households in heating season.

- Odor felt during heating or any damage in the equipment, if they undergo periodic professional inspection.

Remedial Action.

All equipment should be periodically checked by specialized services, especially before each cold season. The ventilation of equipment (including kitchens) is required to be connected to the outdoor environment.

Health Problems Caused By Volatile Organic Compounds (VOCs).

Even at room temperature certain solids or liquids may emit VOCs like formaldehyde, benzene, perchloroethylene for different length of time. They have been observed indoors than outdoors up to 10 times in six locations of the United States as reported by the EPA, even where there were petrochemical plants in use [21].

Key Signs/Symptoms; conjunctival irritation, headache, dyspnea, allergic skin reaction, nausea, emesis, fatigue, epistaxis (formaldehyde), nose, throat discomfort, dizziness, declines in serum cholinesterase levels.

Diagnostic Leads

- Presence and quantity of pressed wood products at the resident.
- Exposure to VOCs at work, home, school.
- Exposure to pesticides, paints, or solvents.

Formaldehyde.

Formaldehyde is a possible human carcinogen (EPA). It may irritate ocular (burning or tingling sensations) or respiratory mucosa (dyspnea or wheezing). Formaldehyde vapor may result in hypersensitivity reactions including asthmatics [22].

Pesticides.

They are used in daily life as pesticides and harmful when inhaled or exposed to their vapors or contaminated dusts. Cephalgia, dizziness, muscular weakness, and nausea are the main symptoms. Some of them are considered possible human carcinogens [23].

Remedial Action.

A forced ventilation is required when such products are used. Avoid storage of opened containers of unused paints etc. at home or workplace and similar materials within home or office.

Health Problems Caused By Heavy Metals: Airborne Lead And Mercury Vapor.

Key Signs/Symptoms.

Lead Poisoning.

In Adults; headache, hearing loss, fatigue, weakness, personality changes, gastrointestinal discomfort/constipation/anorexia/nausea, tremor, coordination loss.

In Young Children; abdominal pain, irritability, seizures/loss of consciousness, ataxia, hyperactivity, reduced attention span, (chronic) learning deficits.

Key Signs/Symptoms of Mercury Poisoning; headache, tachycardia, muscle cramps or tremors, acrodynia, intermittent fever, neurological dysfunction, personality change.

Diagnostic Leads

- Housing or working in old or restored buildings or nearby busy highway or industrial area.

- Working with lead material (automobile radiators, solder etc.)
- Lead poisoning among people in close contact.
- Exposure to mercury in latex paints or in religious or cultural activities

Remedial Action.

The possible lead dust should be cleaned by wet-mopping. Professional intervention should be sought when handling paints containing lead and adequate protective gear and good-ventilation provided in work areas.

Health Problems Caused By SICK BUILDING SYNDROME.

Key Signs/Symptoms; headache, dizziness, nausea, sensitivity to odors, lethargy or fatigue, mucosal irritation.

Diagnostic Leads

- Temporal ceasing or aggravation of problems in relation to exposure frequency to suspected building, or seasonality
- Similar complaints in co-workers or peers.

Remedial Action.

The building, HVAC systems or possible conditions should be investigated and examined appropriately.

4.3 Health problems caused by two long-term risks: asbestos and radon

Asbestos and radon are among the most publicized indoor air pollutants. Both are known as carcinogens. Their carcinogenic effects are not immediate after prolonged exposure.

Asbestos.

Materials containing asbestos can lose its integrity with time releasing microscopic fibers into the environment. If they remain present in the lungs for many decades as in the case of heavy occupational exposure, they may lead to asbestos-caused pulmonary fibrosis, pulmonary, pleural or peritoneal (including gastrointestinal) carcinoma, or mesothelioma [24].

Radon.

- Radon is a naturally occurring radioactive gas resulting from the decay of radium, itself a decay product of uranium, follows smoking for causing pulmonary malignancies due to the emitted alpha-particles during the decay. It has no odor, color, and taste. Tobacco smoke has a synergistic effect to radon exposure putting smokers and ex-smokers in increased risk.

4.4 Health problems caused by animal dander, molds, dust mites, other biologicals

Every home, school, and workplace are subject to biological air pollutants. Some reside outdoor or in human (viruses and bacteria), some in animals or insects (allergens), and some indoor and in water reservoirs (fungi and bacteria), such as humidifiers. High relative humidity is the most important factor contributing to the growth and

dissemination of biological agents like house-dust mite populations or fungal growth on damp surfaces. They may cause infections by invading human tissues; hypersensitivity by activating the immune system; and toxicosis by direct effects of toxins [25].

Key Signs/Symptoms; rhinitis, dyspnea, cough, chest tightness, recurrent fever, recognized infectious disease, malaise, conjunctival inflammation, exacerbation of asthma.

Diagnostic Leads.

Infectious disease:

- Mounting evidence regarding the workplace, home, etc. as a source place (although very difficult) like presence of a reservoir or disseminator of biologicals
- Evidence of mold growth (visible growth or odors)?

Hypersensitivity disease:

- Relative humidity consistently above 50%.
- Presence of humidifiers or other water-spray systems, proper maintenance.
- History of flooding or leaks or other sources of surface wetting.
- Pets, cockroaches or rodents in the place.

Toxicosis and/or irritation:

- Appropriate ventilation with fresh air.
- Relative humidity consistently above 50% or below 30%.
- Presence of humidifiers or other water-spray systems.
- Evidence of mold growth (visible growth or odors)?
- Presence of bacterial odors (fishy or locker-room smells)?

Remedial Action

- Adequate outdoor air ventilation.
- Cleaning of water reservoirs and chlorination of potable water systems
- Repairing of leaks and seepage.
- Keeping relative humidity below 50%
- Controlling exposure to pets.
- Regular vacuuming of carpets and furniture.

- Covering of mattresses. Washing in hot water ($>54.4^{\circ}\text{C}$ to kill dust mites in soft materials)

Distinguishing whether indoor air pollution originates from the home or workplace. Some information may help to determine the presence of an indoor air quality problem at workplace:

- Symptoms observed to occur at workplace and to disappear when leaving the workplace, their temporal or locality pattern (day, season or location at work)
- Similar complaint in co-workers.
- Any diagnosis related to IAQ by a physician [26].

5. Criteria for workplace indoor air quality

There are some international guiding principles set for indoor air quality. The recommended guidelines define indoor air quality issues with legal standards. These guidelines are prepared and updated by professionals. There is limited information in the World, particularly on concentration guidelines and standards proposed for indoor air pollutants. Only in the United Kingdom and USA, there are concentration guidelines and standards proposed for indoor air pollutants.

- **World Health Organization:** WHO issued various guidelines aiming at protecting the public health from risks arising from some indoor pollutants such as benzene, carbon monoxide, formaldehyde, nitrogen dioxide, polycyclic aromatic hydrocarbon (PAH), benzo [α] pyrene, radon, trichloroethylene, tetrachloroethylene. Reference values offer basic information allowing assessor to decide whether lifelong exposure to these pollutants or exposure to them for a certain approximate period of time impose a significant risk for the health and wellbeing of people [7].
- Committee on the Medical Effects of Air Pollutants (COMEAP) issued “Report on the Impact of Air Pollution on Health for public institutions and agencies. It determined allowed amounts of indoor air pollutants (COMEAP-2004); formaldehyde, benzene, PAHs (as the equivalent of benzo[α]piren), NO_2 ve CO for indoors. Air Quality Strategy for England, Wales and Northern Ireland (DETR, 2000; Defra, 2007) sets out policies for the management of indoor air quality. These include air quality targets for ten basic air pollutants for protecting the health of people and the environment, without bearing unacceptable “economic and social costs. These are Particles (PM_{10} and $\text{PM}_{2.5}$), NO_2 , O_3 , Sulfur dioxide (SO_2), PAHs, benzene, 1,3 butadiene, carbon monoxide (CO) and lead. Health and Safety Executive (HSE) supports the regulatory framework for the workplace health and safety in England, Wales and Scotland, in line with the Occupational Health and Safety Law (HSE, 1974).
- Regulation on Control of Substances Hazardous on Health 2002 (HSE, 2002) set out Official Workplace Exposure Limits (WELs) for 500 substances which are listed in the EH40 document (HSE, 2011 and the following revisions), as an action against specific pollutants. These limits include maximum concentrations for short term (15 minutes) and long term (8 hours) exposure in any period of 24 hours.

Although it is mostly related about indoor emissions, exposure limits determine the indoor values which should not be exceeded, no matter what the source is. HSE does not set limits for continuous (24 hours) exposure. For this reason, WELs are not considered as safe concentrations for periods longer than those specified [7].

- A research conducted in Europe in 2005 collected formaldehyde, CO, NO₂, benzene and naphthalene under “Group 1: High Risk Chemicals”, as they can form in high concentration and impose a significant risk for the health of residents of the building (INDEKS, 2005). “Group 2” included acetaldehyde, toluene, xylene, styrene as the chemicals of second highest risk. These compounds may occur in high concentrations in indoors, but they require less urgent action under risk management practice [7]. Leading institutions regulating the national official rules are American Conference of Governmental Industrial Hygienists (ACGIH) and American Society of Heating and Air-Conditioning Engineers (ASHRAE) [8–10].

The focus point of EPA air quality is to protect the human health against outdoor air. The objective of this Standard is to control emissions of six pollutants during the release of large amounts of vehicle exhaust gas and industrial waste. These standards can be used for the indoor air quality researches as outdoor air quality offer potential contribution to the indoor exposure (**Table 3**) [8–10].

OSHA claims that it has jurisdiction in all workplace environments. These standards are concerned about indoor air quality at office buildings, industrial and construction workplaces. However, OSHA standards have limitations in terms of knowledge of pollutants and limited exposure limits, as OSHA’s standards are based on old limits issued by ACGIH in 1968. Original OSA exposure limits were developed out of ACGIH recommendations dated 1968. Up to now, only limits for some chemical pollutants (for example, asbestos and benzene) have been updated. For this reason, general tendency of industrial hygienists to prefer ACGIH Instructions to OSHA limits. Although backed up by federal laws, OSHA limits are rarely exceeded in office environments where one or more pollutant substances are correctly defined. The complicated nature of the indoor air quality is not supported by the OSHA limits [8–10].

Indoor air pollutants	Permissible concentrations
Carbon monoxide (CO)	< 9 ppm
Carbon dioxide (CO ₂)	< 800 ppm
Mold	Indoor and outdoor values should be the same
Formaldehyde (CH ₂ O)	< 20 µg/m ³ *
Total volatile organic compounds (VOC)	< 200 µg/m ³ *
4-Phenyl Cyclohexane (4-PC)	< 3 µg/m ³
Total particles (PM)	< 20 µg/m ³
Regular pollutants	< National indoor standard
Other pollutants	< 5% of the limit value

**Above outdoor air concentrations.*

Table 3.
EPA maximum indoor air standards.

ACGIH is a professional institution which revises and recommends user manuals used for evaluation of Professional workplace exposure by industrial hygienists every year. There are approximately 400 chemicals that are listed with exposure limits of 15 minutes and 8 hours. These directives were prepared to treat the workplace exposure. Professional exposure is generally limited with a period of 8 hour exposure for healthy individuals aged between 18 and 65. For this reason, ACGIH exposure rules do not apply for house exposure for which exposure parameters are different [7–10].

ASHRAE issued a revised mechanical ventilation standard namely “Ventilation for Acceptable Indoor Air Quality Standard” in 1981. ASHRAE developed consensus principles for the indoor air quality in public buildings. The Standard aims at “stating minimum ventilation rates and indoor air quality”. Health effects and acceptable exposure limits are based on specific authorized people and their recommendations. For this reason, ASRAE Standard “Ventilation for Acceptable Indoor Air Quality” has become the guideline which is most widely used for the evaluation of indoor air quality in commercial facilities and enterprises. ASHRAE previously issued Standard 62 which is a ventilation standard. This Standard was revised a few times in the following years. The amount of fresh air was specified for smokers and non-smokers separately in 1981. This value was 2,5 L/s foreseen for non-smokers and 10 L/s for smokers, which is four times higher than the one for nonsmokers. Cigarette monopolies prevented the recognition of this Standard by American National Standards Institute (ANSI) and its integration to the building regulations, by conducting intensive propagandas. Application of this Standard will increase the ventilation cost by four times in the buildings where smokers work. In 1989, the acceptable fresh air was accepted to be the amount for which 80% of the people did not express dissatisfaction. The dissatisfaction rate was increased to 20% of the people in the place.

ASHRAE’s Standard numbered 1989–2062 introduced the limit of 1000 ppm carbon dioxide for office workers. OSHA in USA defined a limit of 5000 ppm, on the condition that it does not exceed 40 hours a week. ASHRAE’s Standard 62 recognized that carbon dioxide is not a pollutant by itself, but it is one of the indicators of air polluted by people. This CO₂ amount was 280 ppm before the industrial revolution and it has been continuously increasing due to the combustion of fossil fuel. As a result, global warming caused by greenhouse effect has become a very important public problem. The rate of carbon dioxide in today’s air is around 390 ppm and it increases by 2 ppm every year [8–12]. Workplace Exposure Limits (WELs) apply to healthy people who are at working age and directly exposed to pollutants at their workplaces. Generally lower exposure limits are imposed for people who are not healthy or of working age or those who are older than the working age. These lower limits apply even if a person is exposed to a pollutant for a period which is significantly longer than 8 hours or even if the work activities do not directly include pollutant [7–10]. Attention should be paid to the selection of air quality standards applicable to a particular workplace during the selection of the most appropriate air quality standard and guideline. In schools and hospitals which are open to public Access, imposition of the targets set by the World Health Organization’s guidelines and the targets introduced by the United Kingdom Air Quality Strategy are more appropriate. As for the industrial environments, Health and Safety Executive (HSE) and Workplace Exposure Limits (WELs) are most appropriate (HSE, 2011) [8, 27]. HSE WELS defines official exposure limits for physically healthy people who are exposed for a nominal period of eight hours a day, five day a week in industrial workplaces. For this reason, the elderly, the young and the disabled who are sensitive to some pollutants should be excluded,

when the limits are determined. The people who work in the office environment including the ones who are physically less in form and talented, represent a wider proportion of society, when compared to the workers in the industrial environments. Furthermore, workers may not be aware of the fact that they are exposed to a pollutant, if they are not in contact with it as a direct part of the work they perform, and thus they may not take any measure to protect themselves. Her Majesty's Inspectorate of Pollution (MHIP) recommended that a part of the guidelines given in HSE WELs for the exposure of the general society (1993). In the light of this, it is more appropriate to apply lower outdoor air quality guidelines set by the World Health Organization and United Kingdom Air Quality Strategy (Defra 2007) for exposure of the general population also for the indoor environments. The limits determined by HMIP (1993) may be used for the pollutants which do not fall under this scope [8–12, 28].

6. Protection from indoor air pollution at workplaces

An employer should use a systematic approach is needed when treating the air quality at the workplace. The systematic approach to indoor air quality (IAQ) comprise commitment of the management, training, participation of employees, hazard definition, control and program inspection. A management coordinator needs to be assigned for IAQ and a management plan needs to be developed.

7. IAQ control methods

There are three main control methods used to decrease the concentration of the indoor air pollutants:

1. Source Management

It includes eliminating the pollutant or replacement of pollutant with a less hazardous one. It is the most effective control method in practice. For example, an employer may install temporary barriers in order to prevent pollutants during construction activity or impose negative pressure on the field in Ref. to the adjacent fields.

2. Engineering Controls

A. Local exhaust: Use of local exhaust, such as shading and fume hood are effective in eliminating pollutants which are very concentrated.

B. General ventilation: When designed, operated, maintained properly, general ventilation is a measure which control air pollutants of normal amount. A well designed and operating HVAC system ensures comfort, by controlling temperature and relative humidity levels, distributes the amount of air sufficient to meet the needs of ventilation for the building habitants and alleviate and eliminates odors and other pollutants.

C. Air cleaning: Firstly, it requires elimination of particles in the air when they pass through HVAC equipment. Generally, HVAC system filtering is used to

keep the dirt away from adjustable surfaces during the process of ensuring heat transfer effectiveness.

3. Management Controls

A. Working Chart: Managers may significantly decrease the amount of exposure to pollutants in their respective buildings, by using charts. For example, they can take the following actions:

1. Eliminate or decrease the duration in which one worker is exposed to a pollutant (in other words, programming the maintenance or cleaning work in the absence of inhabitants)
2. Decrease the amount of chemical substances used by workers or used near to workers (limit the amount of chemicals used by workers for maintenance or cleaning activities during the activity).
3. Control the place where the chemicals are used (conduct maintenance on moving equipment in a maintenance workshop or place equipment- printers, copy machines to a separate room).

B. Training: It is important to give IAQ training to workers. Workers need to be informed about the sources and effects of pollutants under their control and smooth operation of ventilation system. Employers can make warnings and/or take measures to decrease personal exposure.

Cleaning: Cleaning practices should contain preventing entry of dirt to the environment (using walking doormats), cleaning it when it enters the workplace, discharging the litter, storing the food properly and using minimum amount of cleaning products [7–9, 29].

8. Indoor air and coronavirus (COVID-19)

COVID-19 spreads through particles and droplets in the air. Individuals infected by COVID may release particles and droplets of inspiration liquids containing SARS CoV-2 virus to the air (by breathing, talking, singing, exercising, coughing and sneezing). Droplets- particles may continue to disseminate and accumulate indoors of workplaces. Infection may happen in case of inhaling the COVID-19 virus from air in a distance shorter than six feet. The particles from an infected person may move along all room or closed area. The particles may hang in the air for hours even after the person leaves the room. A worker may be exposed to it, if respiration liquids directly jump to the mucosa membrane and if it is sprayed on him or her. The following cases may increase the infection risk:

- a. Spending time indoors where the amount of outdoor air and ventilation is poor
- b. Performing activities which increases emission of respiration liquids, such as talking loudly, singing, exercising
- c. Long term exposure (longer than a few minutes)

- d. Spending time in crowded areas (especially without proper mask protection).

Measures to decrease the infection potential of COVID-19:

1. Layout, design of a building, occupancy state, heating, ventilation and acclimatization (HVAC) system may affect the spread potential of virus through air. Although improvements made on ventilation and air cleaning do not alone eliminate the risk of spread for the SARS-CoV-2 virus, EPA recommends that physical distance should be maintained and ventilation should be improved by using outdoor air and air filtering, as the important components of a strategy which includes hygiene and clothing.
2. Cloth masks, face guards or masks should be used. Attention should be paid to surface cleaning, hand washing, disinfection, personal and environment hygiene [8, 30].

9. Conclusion

- WHO/ILO Joint Estimates of the Work-related Burden of Disease and Injury (2000–2016: Global Monitoring Report) revealed that approximately 450,000 workers' deaths were associated with air pollution (particle substances, gas, smoke, etc.). This association was reported to be the second most important factor which comes after the factor of working for long hours among the risk factors causing death of workers. Workplace indoor air pollution can significantly increase the health risks of workers, including asthma, allergenic reactions, lung cancer and death as a result of occupational accident [1, 29].
- 1989 EPA Report showed that improved indoor air quality may result in higher productivity and less working day loss. EPA stated that the poor indoor air quality may bring a cost of tens of million dollars to the respective country, employer and the enterprise every year, due to the loss of productivity and medical care cost [8].
- Further research is needed to detect new indoor pollutants which are increasing in number and control their effects. Lifelong awareness, elimination of potential indoor hazards, increased awareness of health service providers and professionals are reported to be important to encourage long term lung health and wellbeing [1].
- Indoor air quality can be defined as an optimal indoor requirement specifying the possible minimum amount of air pollutants to ensure the health, comfort and wellbeing of majority of the workers in any closed workplace, at any given time. Temperature at the workplace depends on relative humidity and flow of air in industry. In addition, indoor air at industrial facilities is associated with the technological processes conducted and contents of the chemicals used. Workplace risk assessment is a means which helps creation of a safer environment and it is a process allowing determination of potential adverse effects imposed on the health of workers. The obligation to determine risk assessments which are both correct and simple led to the development of approaches to assess and control

risks, including COSHH (Control of Substances Hazardous to Health) and “Chemical Control Kit” designed to assess chemical risks. Enterprises developed Process Route Healthiness Index (PRHI) to analyze new processes which are not yet in implementation [3].

- It was seen that some people had health symptoms although concentrations of indoor air pollutants are below the indoor air quality guidelines. For this reason, further research is needed to better understand and explain the complicated relationships between IAQ and health symptoms [11].
- A multidisciplinary team comprising experts of occupational medicine, IAQ, building physics and toxicology is recommended for evaluation and management of IAQ problems [5].

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