JOURNAL OF HEALTH AND SOCIAL SCIENCES

Journal of Health and Social Sciences (JHSS)
The Italian Journal for Interdisciplinary Health and Social Development *EDIZIONI FS Publishers*

Viewpoint in Occupational and Public Health

Indoor Air Quality and Indoor Environmental Quality: The role of occupational health surveillance and the cooperation between public and occupational health stakeholders

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Abstract

This viewpoint emphasizes the growing significance of Indoor Air Quality (IAQ) in improving health and comfort in indoor environments, a crucial concern given that individuals spend approximately 90% of their time indoors. It conducts a comprehensive review of IAQ, highlighting its profound impact on overall health and quality of life, often exceeding outdoor environmental pollution. Our paper identifies various risks associated with IAQ, particularly for vulnerable groups such as children, the elderly, and those with chronic health conditions. It details the dual nature of indoor pollutants—external sources like traffic, heating and cooling of buildings, industrial emissions, and internal sources including combustion for food preparation and heating, building materials and furnishing, paints, cleaning products materials, and human activities. These pollutants, ranging from very volatile organic-VVOC, volatile-VOC, semi-volatile organic-SVOC compounds, particulate matter-PM_{10}, $PM_{2.5}$, and biological entities, necessitate extensive interdisciplinary research.

The viewpoint discusses the severe implications of IAQ, especially in developing countries, where it contributes significantly to the global disease burden. It introduces the concept of Indoor Environmental Quality (IEQ), expanding the focus from just air quality to encompass lighting, acoustics, thermal comfort, and water quality. This holistic approach to IEQ is vital for ensuring health and well-being in indoor spaces.

Furthermore, the paper explores the interconnection between IAQ and global health crises, such as climate change and the COVID-19 pandemic, and emphasizes the importance of maintaining good IAQ and visual and thermal comfort in workplaces. These factors are linked to improved health, productivity, and sustainable practices.

The role of occupational stakeholders, employers, and medical professionals in creating a healthy work environment is critically examined. We argue for their collaboration in promoting health initiatives, ergonomic designs, and effective health surveillance. This collective approach aims to address the complexities of modern workplaces, fostering a healthier, more productive, and sustainable workforce.

Take-home message: Enhancing Indoor Air and Environmental Quality lies in the collaboration between public and occupational health stakeholders. Together, they must promote healthy practices, ergonomic designs, and effective health surveillance to create spaces that support well-being, productivity, and sustainability, thereby contributing to a healthier society.

Key words: IAQ; IEQ; occupational health; occupational physicians; public health; occupational health surveillance.

Cite this paper as: Chirico F, Settimo G, Magnavita N. Indoor Air Quality and Indoor Environmental Quality: The role of occupational health surveillance and the cooperation between occupational and public health stakeholders. J Health Soc Sci. 2023;8(4):262-269. Doi: 10.19204/2023/NDOO1.

Received: 15 November 2023; Accepted: 15 December 2023; Published: 15 December 2023

INTRODUCTION

Over recent years, the focus on Indoor Air Quality (IAQ) has significantly grown among scientists globally, political bodies, and environmental authorities, emphasizing its importance in enhancing the health, comfort, and welfare of those inside buildings. Numerous research efforts have documented qualitative and quantitative changes in IAQ over time, highlighting a rise in the presence and concentrations of chemical and biological pollutants [1].

Estimates suggest that individuals typically spend around 90% of their time in various indoor settings, including homes, workplaces, healthcare facilities, universities, banks, educational institutions, shopping centres, fitness centres, and transportation modes. Consequently, IAQ significantly affects overall health and life quality. In fact, for a substantial portion of the population, the health hazards associated with indoor air pollution might exceed those posed by outdoor environmental pollution [2].

"This commentary aims to elucidate the multifaceted relationship between IAQ and Indoor Environmental Quality (IEQ), emphasizing the pivotal role of occupational health surveillance and the synergistic cooperation between public and occupational health stakeholders in enhancing health outcomes, mitigating the global disease burden and fostering sustainable practices in indoor environments.

DISCUSSION

Indoor Air Quality and health

Particularly, substandard IAQ poses risks to sensitive demographics like children, adolescents, the elderly, and those with chronic respiratory or heart disorders [3,4].

Indoor settings are often affected by a combination of external pollutants, primarily from traffic heating and cooling of buildings and industrial operations, which can penetrate through leaks or be introduced by natural and mechanical air ventilation systems. Additionally, indoor pollutants arise from sources within the building itself. These include emissions from combustion sources (like fuel, coal, wood and biomass burning, gas stoves, tobacco product use; and candle burning), releases from construction materials and furniture, paints, cleaning products, air fresheners, heating and cooling systems, humidifying devices, moisture-related processes, electronic devices, pets, and occupant activities such as smoking, cooking, and painting [1-5].

IAQ is influenced by a diverse array of chemical substances, encompassing like very volatile (VVOCs), volatile organic compounds (VOCs), semi volatile organic compounds (SVOC), carbon monoxide (CO), nitrogen oxides (NO_2), ozone (O_3), particulate matter (PM_{10}, $PM_{2.5}$), ultrafine particles (UFP), fibres, both inorganic pollutants (metals), and biological entities including bioaresol, virus, bacteria, fungi, and pollen, and radon. Various factors impacting IAQ result in a broad spectrum of research and scholarly articles published across several scientific fields, such as chemistry, medicine, environmental science, and more [4]. IAQ is an essential, although not the only, element for ensuring

an optimal indoor work environment, to which all employers must pay the utmost attention not only for the prevention of building-associated diseases (Building-Related Illness (BRI)- such as Legionnaires' disease or for the prevention of symptoms of Sick Building Syndrome (SBS) but also and above all for promoting the health and psycho-physical well-being of the worker [5-9].

Indoor Air Quality and global burden of diseases

Indoor air pollution, stemming from the widespread use of solid fuels like biomass (including wood, animal dung, and crop waste) and coal, presents a significant challenge to global health. This form of pollution is associated with a variety of health issues, such as different respiratory diseases, tuberculosis, asthma, cardiovascular diseases, and adverse perinatal health outcomes. Notably, in children under five, there is a significant concern regarding pneumonia and acute lower respiratory infections (ALRI). At the same time, adults are at increased risk of chronic obstructive pulmonary disease (COPD) and lung cancer, mainly due to coal combustion. In 2012, indoor air pollution was responsible for more than 3.3 million deaths. In developing countries with high mortality rates, its impact was even more pronounced, accounting for 3.7% of the disease burden, following closely behind malnutrition, the HIV/AIDS epidemic, and inadequate access to clean water and sanitation. Indoor air pollution disproportionately impacts women and children, who typically spend more time near the household hearth [3,4,10-12].

While there has been a notable decrease in the disease burden associated with Household Air Pollution (HAP) from 1990 to 2019, it still constitutes a considerable risk factor. The use of solid fuels for cooking, which leads to HAP, continues to be one of the primary risk factors for the global disease burden. In the realm of environmental risk factors, the impact of HAP on the disease burden is only exceeded by the influence of ambient particulate matter pollution PM_{10}, $PM_{2.5}$ [11,12].

From Indoor Air Quality to Indoor Environmental Quality (IEQ)

Our perception of the health implications associated with indoor environments has significantly developed over the last ten years. Earlier, the concept of IEQ was primarily centred around the constituents of IAQ, focusing mainly on particles (PM_{10}, $PM_{2.5}$, UFP), chemicals (VVOCs, VOCs, SVOCs), and bioaerosols, along with factors affecting comfort, such as temperature, airflow, and relative humidity [13,14]. However, in recent times, the perspective has shifted to a more intricate understanding that views the interaction between humans and the built environment as a dynamic relationship. This relationship encompasses the characteristics of building occupants, including their activities and identities, and a wide array of physical, chemical, biological, and architectural elements [15,16].

This progressive understanding has crucial repercussions for how we approach building design and operation. It influences the utilization of these structures and plays a pivotal role in preventing and managing health issues that may arise among individuals who inhabit or use these buildings. The evolving comprehension of IEQ underscores the need for a holistic approach that integrates all these factors, ensuring that the spaces we inhabit or work in are not only structurally sound and aesthetically pleasing but also contribute positively to our health and well-being [17].

IEQ refers to the quality of the indoor environment within buildings, impacting the well-being, health, and productivity of those residing or working there, and encompasses various factors contributing to air quality, lighting, acoustics, thermal comfort, and water quality [18,19].

IAQ pertains to the purity of the air inside a building concerning pollutants like PM_{10}, $PM_{2.5}$, UFP, VVOCs, VOCs, SVOCs, mould, allergens, and harmful gases (NO_2, CO, O_3). Good IAQ prevents respiratory issues, allergies, and other diseases. Lighting involves the amount and quality of light in a building. Proper natural and artificial lighting is essential for visual comfort and the psychological well-being of individuals. Acoustics refers to the noise level inside a building, where appropriate acoustics help reduce background noise and provide a peaceful and comfortable environment. Thermal comfort includes internal environment temperature, humidity, and ventilation. Adequate thermal comfort ensures individuals feel comfortable, impacting productivity and overall well-being. Finally, water quality concerns the quality and safety of drinking water used in buildings. Good water quality is vital to avoid health issues related to contaminated potable water. Although

sometimes overlooked in environmental comfort studies, it is integral to overall health and safety [14,17,18].

IEQ aims to create a healthy, safe, and comfortable indoor environment. This requires careful design, construction, and maintenance of buildings and proper management of facilities and resources. Good IEQ can enhance building occupants' productivity, satisfaction, and health in homes, offices, hospitals, schools, or other indoor spaces [18-21].

The relationship between IAQ and global health emergencies

It is also essential to consider the relationship between climate change and indoor air quality. Climate and weather changes significantly impact allergy and asthma, with increased temperatures and carbon dioxide-CO_2 levels leading to longer pollen seasons and more potent allergens, exacerbating asthmatic conditions. The 2019 Report from the Work Group Report of the AAAI Environmental Exposure and Respiratory Health Committee also highlights the anticipated rise in indoor air pollution due to climate change, such as mould growth from flooding and emissions from burning fossil fuels, underscoring the urgency of community efforts to reduce air pollution and protect at-risk patients [22].

Climate change and indoor and outdoor air pollution interact to exacerbate respiratory allergies, with extreme weather conditions like high temperatures directly affecting the respiratory system and leading to allergic respiratory diseases. Additionally, thunderstorms and floods modify aeroallergen patterns, while wildfires and dust storms heighten air pollution indoors and outdoors, indirectly increasing health hazards. Rising temperatures and CO_2 levels are projected to boost pollen, moulds, and spores, heightening the risk of allergic respiratory conditions, and the combined effects of extreme heat and aeroallergens amplify the harmful impact of air pollutants indoors and outdoors, further enhancing the allergenic potential of these aeroallergens [23,24].

The COVID-19 pandemic has further underscored the critical role of IAQ in public health, highlighting how airborne pathogens can significantly impact health in indoor spaces. Enhanced air filtration and ventilation systems have emerged as vital tools that must be part of the multi-level organic strategy to reduce virus transmission, demonstrating the need to improve IAQ standards in the post-pandemic world [3]. COVID-19 continues to circulate globally, and the pandemic has heightened public awareness regarding the importance of environmental hygiene worldwide [24,25].

Moreover, this heightened focus on IAQ presents an unprecedented opportunity to advocate for and implement comprehensive IAQ improvements, not only as a response to COVID-19 but also as a long-term strategy to safeguard against future airborne health threats and to enhance overall public health resilience [26,27].

The cooperation between occupational and public health stakeholders

In supervising those who work indoors, the occupational physician must keep in mind the environmental problems. Indeed, it is known that the presence of pollutants, poor IAQ, or ergonomically unfavorable environmental conditions can induce health problems for workers [8,14]. On the contrary, good IAQ positively affects workers' well-being, the working climate, and productivity [9,14].

The World Health Organization reported as early as the 1980s that a significant proportion of workers in indoor environments have environment-related complaints and physical symptoms [7]. Occupational doctors have been actively monitoring this topic in Italy since the early 1990s [8,9]. In the impossibility of identifying a single cause of the phenomenon, which appears to be related to various physical, chemical, and psychosocial agents, it was chosen to classify the building where this phenomenon occurs as "sick." The term "Sick Building Syndrome" (SBS) is thus used to describe a building in which the frequency of symptoms is higher than could reasonably be expected [29], but also to refer to the clinical case or "sick building patient" [30], i.e., the presence in a worker of irritative symptoms in the respiratory system and eyes (stuffy or dry nose, rhinitis, cough, sore throat, difficulty in breathing, burning or redness of the eyes), skin (burning and redness) and general and neuropsychological symptoms (fatigue, headache, sense of confusion), associated with working or

residing in a particular environment. This type of problem is inevitably associated with those related to working at the video terminal, as was clear to those who first dealt with the phenomenon [31,32].

The competent doctor has a very valid tool available to investigate air quality problems and related disorders: the MM040 (Miljomedicin 040) questionnaire, also known as the IAQ questionnaire. The questionnaire comprises 40 questions relating to four sections: the first relating to the work environment, the second to work organization, the third to symptoms, and the fourth to the worker's allergic history. The MM040/IAQ has been validated in Italian [9]. Compilation takes no more than five minutes, and the correction is very simple. The 12 questions on the work environment have answers graded according to a Likert scale from "no, never" to "yes, often, every week." The examiner can simply collect these last answers and study their distribution, or he/she can calculate an environmental discomfort score by adding the answers to the 12 questions. Symptoms are also graded on a Likert scale from “no, never” to “yes, often, and I think this is due to the work environment.” Once again, the examiner can calculate an overall symptom score or consider only the symptoms that workers attribute to the work environment.

Visual comfort, IAQ, and Thermal Comfort (TC) significantly impact Visual Display Terminals (VDTs) users and office workers. Proper lighting and visual comfort reduce eye strain and fatigue, enhancing focus and productivity. Good IAQ is crucial in preventing respiratory issues and improving cognitive function, while optimal TC maintains comfort and concentration, reducing discomfort and distraction from too hot or cold temperatures. Together, these elements contribute to a healthier and more efficient work environment. Good IAQ and environmental quality reduce visual and musculoskeletal disturbances in workers, limit the spread of infectious diseases transmitted through the air, increase levels of attention, concentration, satisfaction, and productivity of the occupants of the building, reduce levels of work-related stress, improve the company's image and productivity and reducing direct and indirect costs for individuals, companies, and the entire community [32-35]. Therefore, IAQ and, more generally, the quality of indoor work environments represent a strategic asset for all companies [14,17].

Additionally, prioritizing IAQ, visual comfort, and TC in office environments aligns with sustainable practices that benefit both the environment and the workforce. Implementing energy-efficient lighting and HVAC systems considered good IAQ improves health [36], enhances visual and thermal comfort, and reduces energy consumption, contributing to a lower carbon footprint. Sustainable practices in maintaining IAQ, such as using eco-friendly cleaning products and incorporating green spaces, can improve air quality while minimizing environmental impact.

This sustainable approach that must increasingly be worker-centred can foster a healthier and more productive workplace and aligns with broader environmental goals, making it a crucial consideration for companies committed to social responsibility and environmental stewardship [25,27].

Thus, integrating health and environmental sustainability in workplace design and maintenance represents a strategic company asset and a vital step towards a more sustainable and responsible future. Identifying, correctly attributing, and preventing problems related to IAQ and those deriving from the organization of office work is far from a simple task but one within the reach of the occupational doctor [6]. He/she can have a tool proven by many decades of application, such as the IAQ questionnaire, an indispensable aid in controlling subjectivity referred to the environment [7].

Since workers spend a significant part of their daily lives in the workplace, the role of occupational stakeholders becomes crucial in promoting a healthy working environment. Employers have a responsibility to promote workplace health initiatives by developing an action plan on IAQ, addressing issues such as the intelligent choice of different products and materials that are used in cleaning, paints, insulation, furniture, or how rooms/spaces are ventilated, product inventory, training and information activities, smoking and other harmful habits that may affect individual health and general workplace well-being. Initiatives such as anti-smoking campaigns, wellness programmes, and mental health support can contribute significantly to a healthier workforce.

Furthermore, the design of ergonomic workplaces is vital. Employers should ensure that the physical setup of the workplace supports the comfort and well-being of employees. This includes providing ergonomic and low-emission VOCs furniture, air changes (L/s/p), ensuring adequate space for movement, and designing workstations that minimize strain and fatigue. Such ergonomic considerations enhance employee comfort, reduce the risk of musculoskeletal disorders, and improve productivity and job satisfaction.

By integrating these health promotion activities and ergonomic design principles, employers can create a workplace that supports their employees' physical and mental well-being and fosters a more engaged and productive workforce. This proactive approach by occupational stakeholders is essential for building a sustainable, health-oriented work culture that benefits both the individual and the organization [36-38].

The role of occupational health surveillance

In addition to the strategies mentioned above, the role of the competent doctor is pivotal in maintaining a healthy workplace. Through medical examinations, including those requested on demand, these professionals play a crucial role in identifying vulnerable workers who may be more susceptible to risks associated with IAQ and workplace factors such as using Visual Display Terminals (VDTs). Their expertise in health surveillance, grounded in thorough risk assessments, enables them to provide vital feedback for the continuous improvement of the risk assessment process. This proactive approach ensures that prevention and protection measures are in place, effectively addressing workers' needs and risks. The competent doctor's role in verifying the effectiveness of these measures is essential in safeguarding the psycho-physical well-being of employees in indoor environments [39-41].

CONCLUSION

In conclusion, collaboration between workplace actors, employers, and physicians is key to creating a sustainable, health-focused work environment. By promoting workplace health activities, designing ergonomic workplaces with good IAQ, and ensuring effective health surveillance and risk assessments, we can promote a workplace that increases employee productivity and satisfaction and prioritizes each individual's holistic well-being. Such a comprehensive cultural approach is key to addressing the intricate challenges of the modern workplace, helping to create a healthier, more productive, sustainable workforce.

Author Contributions: Draft writing: FC. Reviewing: GS and NM.
Funding: This research received no external funding.
Institutional Review Board Statement: Not applicable.
Informed Consent Statement: Not applicable.
Acknowledgments: None.
Conflicts of Interest: The first author is this journal's Editor-in-Chief. Other than this, the authors declare no other conflicts of interest.
Publisher's Note: Edizioni FS stays neutral with regard to jurisdictional claims in published maps and institutional affiliation.

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