# Indoor Air Quality and Health: Impact on Respiratory and Cardiovascular System

**Tsaloglidou A., Koukourikos K., Pantelidou P., Kourkouta L.**

*Abstract*— **Introduction: Various air pollutants are found in several interior environments, sometimes at increased concentrations, and they negatively affect the indoor air quality. Exposure to these pollutants often contributes to structural degradation and building failures within their indoor environment and can lead to numerous immediate and long-term health problems. Aim: This retrospective study provides a comprehensive review of the new evidence linking indoor air quality with its impact on respiratory and cardiovascular system. It also refers to the principal pollutants found in indoor environments and associated with harmful effects on health. Method: A review of the Greek and international literature on the issue was performed through the electronic databases Pubmed, Google Scholar, Scopus and scientific journals, using the following key words: Indoor Air Quality, Indoor Air Pollution, Cardiovascular disease, Respiratory disease, Risk factors Results: Indoor air pollution increases the risk of chronic obstructive pulmonary disease, causes or contributes to the development of acute respiratory infections, lung cancer, and chronic lung diseases such as asthma and it has also been associated with many cardiovascular diseases. Conclusion: The indoor air quality is a significant factor in maintaining good health. Understanding of the harmful effects induced by indoor air pollution will help us to take all the appropriate preventive measures to reduce the possible health risks. Key-words: Indoor Air Quality, Indoor Air Pollution, Cardiovascular Disease, Respiratory Disease, Risk factors.**

*Index Terms*—**Air Quality, air pollutants, retrospective study, Indoor Air Quality, Indoor Air Pollution**

## I. INTRODUCTION

People spend the majority of their time indoors, where there is a great possibility to face significant health risks due to repeated exposure to air pollutants in both private and public indoor environments as homes, workplaces, schools and transport systems. Some **indoor air pollutants** come from the outside, but most are released inside the buildings. Exposure to these pollutants often contributes to structural degradation and building failures within their indoor environment and can lead to numerous immediate and long-term health problems [1].

**Tsaloglidou Areti,** MSc, PhD, Clinical Professor, Nursing Department, Alexandrion Technological Institute of Thessaloniki, Thessaloniki, Greece, Phone: +30 2310 200378, Mobile: +30 6948 377619.

**Koukourikos Konstantinos,** MSc, Clinical Professor, Nursing Department, Alexandrion Technological Institute of Thessaloniki, Thessaloniki, Greece, Mobile: +30 6977220814.

**Pantelidou Parthenopi,** RN, MSc, PhD, Infection Control Nurse, AHEPA University Hospital, Thessaloniki, Greece, Mobile: +30 6942 989590.

**Kourkouta Lambrini,** MSc, PhD, Professor, Director of the Nursing Department, Alexandrion Technological Institute of Thessaloniki, Thessaloniki, Greece, Mobile: +30 684565953.

Various air pollutants, such as tobacco smoke, fireplace smoke, paint, furniture, draperies, floor coverings, adhesives, cleaning products and volatile organic compounds (VOCs) are found in several indoor environments, sometimes at increased concentrations, and they negatively affect the indoor air quality. Biological pollutants, such as mold, pollen, dust mites and animal dander are also shown to influence indoor air quality (IAQ) [2]. Furthermore, heating and cooking practices from solid fuels (wood, coal, charcoal, dung and crop wastes) burned in open fires and traditional stoves, coupled with generally inadequate ventilation lead to high levels of indoor air pollution that is severely damaging to health and contributes significantly to the global burden of mortality and morbidity [3]-[5].

Volatile organic compounds (VOCs), some of the worst indoor pollutants, are a large group of carbon-based chemicals that easily evaporate at room temperature. The emissions of volatile organic compounds (VOCs) and formaldehyde from building materials or products used in buildings can lead to high indoor concentrations, odors, and adverse effects on occupants. Some of them can be recognized by that "new furniture" or "new paint" smell, but odor does not indicate the level of risk from inhalation of this group of chemicals [2],[6].

Generally, the poor indoor air quality increases the risk of Chronic Obstructive Pulmonary Disease, causes or contributes to the development of acute respiratory infections, lung cancer, and chronic lung diseases such as asthma and it has also been associated with many cardiovascular diseases.[1],[7]-[8]. Furthermore, it can cause dry eyes, nasal congestion, throat irritation, dizziness, headaches, fatigue, nausea/vomiting [2]. According to WHO, 4.3 million people a year die prematurely from illness due to indoor air pollution caused by the inappropriate use of solid fuels (2012 data). Among these deaths 12% are due to pneumonia, 34% from stroke, 26% from ischaemic heart disease, 22% from chronic obstructive pulmonary disease (COPD), and 6% from lung cancer [9].

## II. "GREEN BUILDINGS" AND INDOOR AIR QUALITY

Last decades, in an effort to construct energy-efficient, cost-effective buildings, the vital issue of their indoor air quality (IAQ) is often overlooked. This can lead to an unhealthy indoor environment and as a result to difficult health conditions such as sick building syndrome (SBS) or other building related illnesses (BRI) [10].

Sick building syndrome (SBS) consists of a group of mucosal, skin, and general symptoms and it describes a situation whereby people experience symptoms of ill health that seem to be related to working in particular buildings. The cause of the syndrome is connected with the building or its services, and as a result the workers appear the relevant

symptoms [11]-[12]. The development of SBS includes environmental as well as personal risk factors. Environmental risk factors such as ventilation, high room temperature, ineffective cleaning routines, indoor chemicals, mold, and dust mite allergens, poor lighting, smoking in the workplace, air conditioning, low humidity are associated with SBS. As it is reported by previously implemented research works, indoor chemicals are the main contributors to subjective symptoms associated with SBS. Psychological factors, such as stress and poor staff morale, are also included in the syndrome.[13],[14].

Building-related illness is an illness in which worker complains more commonly than it is usually expected for ill health in a particular building. Attack rates vary considerably and can reach 80% of inhabitants. Building-related illnesses, such as asthma and hypersensitivity pneumonitis, have symptoms that may be worsened by building occupancy, but they also persist away of the building. Examples are recognized diseases, often infections (eg, Legionnaires' disease) or tuberculosis, caused by being in a building. [15],[16].

## III. EFFECTS OF INDOOR AIR QUALITY ON RESPIRATORY SYSTEM

Most indoor air pollutants directly affect the respiratory system and cause multiple respiratory diseases. The intensity and the duration of exposure as well as the health status of the population exposed affect the severity of the upcoming diseases symptoms.

### *Chronic obstructive pulmonary disease (COPD)*

Chronic obstructive pulmonary disease (COPD) is a common progressive lung disease that causes obstructed airflow from the lungs. Symptoms include breathing difficulty, cough, sputum production and wheezing can be affected by multiple environmental factors. Although it is well established in the literature that direct smoking is the most significant cause of Chronic Obstructive Pulmonary Disease COPD, the results of recent studies show that there are also other factors from the indoor environment, such as second hand smoking (SHS) and combustion of wood or charcoal for heating or cooking at home, that affect the clinical course of the disease and contribute to COPD morbidity [17], [18].

In less economically developed countries a large proportion of residents use solid fuel as the primary fuel for covering everyday needs. It is estimated that between different types of fuel, the exposure to wood smoke for domestic work presents a greater risk of development of COPD and chronic bronchitis than other fuels. In addition, women have a greater risk from the exposure to solid fuel as they spent more time at home than men [19].

Second hand smoking (SHS) exposure is another significant factor generally associated with greater COPD severity and poorer health status. The impact of SHS on fine particulate pollution ($PM_{2.5}$) is examined in several studies. It is reported that indoor levels of $PM_{2.5}$ (both the maximum and average levels of $PM_{2.5)}$ are significantly higher in environments with smokers [20],[21]. It is characteristic that in a study in which indoor $PM_{2.5}$ levels were measured after the implementation of a workplace smoking ban, an 83% reduction in $PM_{2.5}$ and an 80.2% reduction in benzene concentration in the bars were reported. The above mentioned smoking ban resulted not only in a significant reduction in air pollution in pubs, but also in a significant improvement in respiratory health of the staff, as it is apparent from the improved measured pulmonary tests and the significant reductions in self-reported symptoms and exposure levels in nonsmoking participants after the ban [22].

### *Asthma*

Except from the influence of indoor pollutants on COPD patients, they have also a negative influence on other respiratory diseases. Exposure to indoor air pollutants can cause a series of health effects ranging from sneezing and coughing to outcomes such as cancer and exacerbation of chronic respiratory disorders such as asthma. Asthma severity is modified by indoor environmental factors, like PM, nitrogen oxides, SHS, airborne allergens and endotoxin as well as allergens from pests, pets, and molds. [23],[24]. Asthma and its symptoms are also closely related to indoor exposure to Volatile Organic Compounds (VOCs), irritants that are included in solvents, floor adhesive, paint, cleaning products, furnishings, polishes, and room fresheners [25].

In addition, SHS exposure has been strongly linked with exacerbation of pre-existing asthma, especially in children. It is one of the key factors that has as a result the increase of respiratory symptom severity, greater medication use, impaired health-related quality of life, patient's general health status worsening, and more frequent hospitalizations for asthma [26]. According to other researchers, the prevalence of asthma among elderly men and women is closely associated with the exposure to cooking smoke, but it is not linked to SHS [27].

### *Acute Respiratory Infections*

Acute respiratory infections (ARI) are a leading cause of death among children and are closely associated with exposure to pollutants from domestic biomass fuels especially in low- and middle- income countries [28],[29]. A large proportion of population in these countries uses mixture of biomass fuel like wood, crop-residue, caw-dung, leaves etc for cooking purpose [30]. Indoor air pollution caused by using cooking fuel other than liquid petroleum gas (LPG) and socio- economic factors are significantly linked to ARI [31]. There are also numerous other risk factors that affect ARI rates in young children, such as malnutrition, lack of breast feeding, and the incidence of other diseases. [29] Furthermore, the use of mosquito's coils, poor living space, ventilation rates and the varying emission rates affect ARI,

especially among children in the age group 0-5 years [30], [32].

*Lung Cancer*

According to WHO approximately 4.3 million deaths and 17% of premature lung cancer deaths in adults were attributed to household air pollution in 2012 [33]. Cancers that have been associated with Indoor Air Pollution (IAP) include cancers of the lung, upper aero-digestive tract, and cervix. IAP–cancer (IARC) based its determination on the suggestion that household exposure to coal combustion by-products causes lung cancer in humans. Lung cancer prevalence is linked with increased amount of coal used and the duration of a coal stove use to heat a bedroom. [34]. It is also supported that combustion products from smoky coal were found to be more carcinogenic and mutagenic than the combustion products from smokeless coal and wood products[35]. According to Mu L. et al (2013) among non-smoking women, lung cancer was strongly associated with multiple sources of indoor air pollution 10 years ago, including heavy exposure to environmental tobacco smoke at work, high frequency of cooking, and solid fuel usage for cooking and heating [36]. Housing characteristics related to poor ventilation are associated with lung cancer. It is suggested that adequate ventilation in the household and the installation of chimney in homes would reduce the exposure to indoor air pollutants, leading to a reduction of the lung cancer incidence and mortality [35], [37].

## IV. EFFECTS OF INDOOR AIR QUALITY ON CARDIOVASCULAR SYSTEM

The risk of cardiovascular diseases is associated with personal exposure to particles, which are coming from a variety of indoor sources (frying, candles burning, heating devices, environmental tobacco smoke, office equipment, chemical reactions, biological sources and human activity), possibly through endothelial dysfunction [38],[39].

The chronic exposure to biomass smoke has been related to adverse health effects, as it causes activation of leukocytes and the formation of leukocyte-platelet aggregates, which is a risk factor for possible thrombotic disease such as unstable angina, myocardial infarction and stroke [40], [41]. The burning of solid fuels at home release several pollutants, which have been linked to Cardiovascular Diseases (CVDs). Indoor air pollution is associated with inflammation, oxidative stress, blood coagulation and autonomic dysfunction.[42].

It is well documented in the literature that reductions in indoor air pollution and subsequent improvements in cardiovascular health can be achieved by filtration of recirculated indoor air, closing windows and turning on air conditioners at home [38],[42].

## V. CONCLUSIONS

People spend most of their time indoors, so the indoor air quality is a significant factor in maintaining good health. The result of the indoor pollution contributes to a wide range of respiratory and cardiovascular health effects, from simple symptoms until the development of severe illnesses. Several pollutants may interact in a given environment, increasing the risk of upcoming diseases. Understanding of the harmful effects induced by indoor air pollution will help us to take all the appropriate preventive measures to reduce the possible health risks.

## REFERENCES

[1] American Lung Association of the Mid-Atlantic (2015) [Online] Available: http://www.lung.org/associations/charters/mid-atlantic/air-quality/indoor-air-quality.html?referrer=https://www.google.gr/

[2] M. Hulin et al. "Respiratory health and indoor air pollutants based on quantitative exposure assessments." *European Respiratory Journal*, 2012, vol.40 (4): pp.1033-1045.

[3] S. C. Lee, W.-M. Li , C.-H. Ao."Investigation of indoor air quality at residential homes in Hong Kong—case study", *Atmospheric environment*, vol.36 (2), 2002, pp. 225-237.

[4] World Health Organization (WHO). Public Health & Environment Department (PHE) (2011) "Health in the green economy." [Online] Available: http://www.who.int/hia/hgebrief_henergy.pdf

[5] S.S. Lim, T. Vos , A.D. Flaxman, G. Danaei, K.Shibuya, H. Adair-Rohani , et al. "A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010". *Lancet*, vol.380 (9859), 2012, pp. 2224–60.

[6] Chuck W. F. Yu, Jeong Tai Kim. "Building Pathology, Investigation of Sick Buildings — VOC Emissions. *Indoor and Built Environment*," vol.19 (1), 2010, pp. 30-39

[7] N. Bruce, R. Perez-Padilla , R. Albalak. "Indoor air pollution in developing countries: a major environmental and public health challenge." *Bull World Health Organ* [Online], vol. 78(9): Jan 2000, pp. 1078-1092. Available: http://www.scielosp.org/scielo.php?script=sci_arttext&pid=S0042-96862000000900004&lng=en. http://dx.doi.org/10.1590/S0042-96862000000900004.

[8] R.J. Heinsohn, J.M. Cimbala. "Indoor Air Quality Engineering: Environmental Health and Control of Indoor Pollutants." CRC Press, 2003, New York.

[9]. WHO Media Centre , Fact Sheet No 292, Updated March 2014. Available: http://www.who.int/mediacentre/factsheets/fs292/en/

[10] E.Gareth (2011) "Green Buildings` can lead to problems with Indoor Air Quality (IAQ). Pure Earth Environmental Laboratory, Inc." Available: http://www.environmental-expert.com/articles/sick-building-syndrome-and-building-related-illness-51823.

[11] P. S. Burge. "Sick building syndrome. *Occupational and Environmental Medicine"*, 61(2), 2004, pp.185-190.

[12] A.F. Marmot, J. Eley, M. Stafford , et al (2006) "Building health: an epidemiological study of "sick building syndrome" in the Whitehall II study." *Occup Environ Med*, vol.63 (4), 2006, pp.283-9.

[13] D. Norback , K. Nordstrom. "Sick building syndrome in relation to air exchange rate, CO(2), room temperature and relative air humidity in university computer classrooms: an experimental study." *Int Arch Occup Environ Health;* vol.82 (1), 2008, pp.21-30. Epub 2008 Feb 2.

[14] T. Takigawa, B.L.Wang, N. Sakano, D.H.Wang, K. Ogino, & R. Kishi. "A longitudinal study of environmental risk factors for subjective symptoms associated with sick building syndrome in new dwellings." *Science of the total environment*, vol. 407(19), 2008, pp.5223-5228.

[15] E.J. Bardana, A. Montanaro, & , M.T. O'Hoilaren. "Building-related illness." *Clinical reviews in allergy*, vol.6 (1), 1988, pp.61-89.

[16] K. Kreiss. "Building-related illness. Preventing occupational diseases and *injury" in Preventing occupational diseases* and *injury, 2005. 2nd ed, B. Levy, G. Wagner, K. Rest, and J. Weeks, eds.*, 2005, pp.34

[17] M. Orozco-Levi, J. Garcia-Aymerich , J. Villar , A. Ramirez-Sarmiento, J.M. Anto, J. Gea. "Wood smoke exposure and risk of chronic obstructive pulmonary disease." *Eur Respir J.* vol.27, 2006, pp. 542–546.

[18] M.D. Eisner, C. Iribarren ,E.H. Yelin, S. Sidney, P.P. Katz, G. Sanchez, P.D. Blanc. "The impact of SHS exposure on health status and exacerbations among patients with COPD." *Int J Chron Obstruct Pulmon Dis*, vol.4, 2009, pp. 169-76.

[19] Om P. Kurmi, Sean Semple s Padam Simkhada, W. Cairns, S. Smith, Jon G Ayres. 'COPD and chronic bronchitis risk of indoor air pollution from solid fuel: a systematic review and meta-analysis." *Thorax*, vol.65, 2010, 221-228.

[20] M.D. Eisner. "Indoor Air, Passive Smoking, and COPD", *American Journal of Respiratory and Critical Care Medicine*, vol. 176 (5), 2007, pp. 426-427.

[21] M. Liesl, J. Osman, G. Douglas, C. Garden, K. Reglitz, J. Lyon, S. Gordon, and Jon G. Ayres. "Indoor Air Quality in Homes of Patients with Chronic Obstructive Pulmonary Disease", *American Journal of Respiratory and Critical Care Medicine*, vol. 176 (5), 2007, pp. 465-472.

[22] P. Goodman, M. Agnew, M. McCaffrey, G. Paul, and L. Clancy "Effects of the Irish Smoking Ban on Respiratory Health of Bar Workers and Air Quality in Dublin Pubs", *American Journal of Respiratory and Critical Care Medicine*, vol. 175 (8), 2007, pp. 840-845.

[23] G.B. Diette, M.C. McCormack, N.N. Hansel, P.N. Breysse, E.C. Matsui. "Environmental issues in managing asthma." *Respir Care*; 53, 2008, pp. 602–615, discussion 616–617.

[24] P.N. Breysse et al. "Indoor Air Pollution and Asthma in Children." *Proceedings of the American Thoracic Society* 7.2, 2010, pp.102–106. *PMC*. Web. 3 Aug. 2015.

[25] K. Rumchev, J. Spickett, M. Bulsara, M. Phillips & S. Stick. "Association of domestic exposure to volatile organic compounds with asthma in young children." *Thorax*, vol. 59(9), 2004, pp. 746-751.

[26] M.D. Eisner, E.H. Yelin, P.P. Katz, G. Earnest, P.D. Blanc PD. "Exposure to indoor combustion and adult asthma outcomes: environmental tobacco smoke, gas stoves, and woodsmoke." *Thorax*, vol. 57(11), 2002, pp.973-978.

[27] V. Mishra. "Effect of indoor air pollution from biomass combustion on prevalence of asthma in the elderly." *Environmental Health Perspectives*, vol.111 (1), 2003, pp.71.

[28] M. Ezzati, & D.M. Kammen. "Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study." *The Lancet*, vol. 358(9282), 2001, p.p. 619-624.

[29] J.M. Tielsch, J. Katz, S.L. Zeger, S.K. Khatry, L. Shrestha, P. Breysse, P., ... & S.C. LeClerq, S. C. " Designs of two randomized, community-based trials to assess the impact of alternative cookstove installation on respiratory illness among young children and reproductive outcomes in rural Nepal." *BMC public health*, vol.14 (1),2014, pp. 1271.

[30] S.Y. Azad, K.M. Bahauddin, M.H. Uddin, M. H., & S. Parveen, S. "Indoor air pollution and prevalence of acute respiratory infection among children in rural area of Bangladesh." *Journal of Biology, Agriculture and Healthcare*, vol. 4(2), 2014, pp.60-71.

[31] Y. Ramesh Bhat, N Manjunath, D. Sanjay & Y. Dhanya. "Association of indoor air pollution with acute lower respiratory tract infections in children under 5 years of age." *Paediatrics and international child health*, vol.32(3), 2012, pp. 132-135.

[32] R.J. Laumbach & H.M. Kipen. Respiratory health effects of air pollution: update on biomass smoke and traffic pollution. *Journal of allergy and clinical immunology*, vol.129 (1), 2012, pp.3-11.

[33] WHO. "Burden of disease from Household Air Pollution for 2012." Available at:http://www.who.int/phe/health_topics/outdoorair/databases/FINAL_HAP_AAP_BoD_24March2014.pdf?ua=1.

[34] B.C. Reid, A.A. Ghazarian, D.M. DeMarini, A. Sapkota, D. Jack, Q. Lan,, ... & L.S. Birnbaum. "Research opportunities for cancer associated with indoor air pollution from solid-fuel combustion". *Environmental health perspectives*, vol.120 (11), 2012, pp.1495.

[35] W. J. Seow, W. Hu, R. Vermeulen, H.D. Hosgood III, G.S. Downward, R.S. Chapman… & Q. Lan. "Household air pollution and lung cancer in China: a review of studies in Xuanwei". *Chinese journal of cancer*, vol.33 (10),201, pp. 471.

[36] L.Mu, L. Liu, R. Niu, B. Zhao, J. Shi, Y. Li, ... & Z.F. Zhang. "Indoor air pollution and risk of lung cancer among Chinese female non-smokers." *Cancer Causes & Control*, vol.24 (3), 2013, pp.439-450.

[37] Z.Y. Jin, M. Wu, R.Q. Han, X.F. Zhang, X. S. Wang, A.M. Liu,, ... & J.K. Zhao. "Household ventilation may reduce effects of indoor air pollutants for prevention of lung cancer: a case-control study in a Chinese population." 2014:e102685

[38] E. V. Brauner, L. Forchhammer, P., Møller, L., Barregard, L., Gunnarsen, A., Afshari, ... & S. Loft. "Indoor particles affect vascular function in the aged: an air filtration–based intervention study." *American journal of respiratory and critical care medicine*, vol.177 (4), 2008, pp.419-425.

[39] D.G. Karottki, M. Spilak, M. Frederiksen, L. Gunnarsen, E. Vaclavik Brauner, B Kolarik, ZJ Andersen, T Sigsgaard, L. Barregard, B. Strandberg, G. Sallsten, P. Møller, and S. Loft "An indoor air filtration study in homes of elderly: cardiovascular and respiratory effects of exposure to particulate matter." *Environ Health*, vol.12, 2013, pp. 116.

[40] M.R. Ray, S. Mukherjee, S. Roychoudhury, P. Bhattacharya, M. Banerjee, S. Siddique, et al. "Platelet activation, upregulation of CD11b/CD18 expression on leukocytes and increase in circulating leukocyte-platelet aggregates in Indian women chronically exposed to biomass smoke." *Hum Exp Toxicol.*, vol. 25, 2006, pp.627–35.

[41] J.C. Uzoigwe, T. Prum, E., Bresnahan, and M. Garelnabi "Air pollution exposure is a major problem worldwide and has been linked to *cardiovascular diseases* (CVDs)". *N Am J Med Sci*, vol.5 (8), 2013, pp.445-53.

[42] L. Y. Lin, H. C. Chuang, I. J. Liu, H. W. Chen, & K. J. Chuang. "Reducing indoor air pollution by air conditioning is associated with improvements in cardiovascular health among the general population." *Science of The Total Environment*, vol.463, 2013, pp.176-181.