EXAMINING THE EFFECTS OF SPACE ON INDOOR AIR POLLUTION EXPOSURE

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ABSTRACT

Humans' interaction with the built environments generally actuates a rather severely exposure process. One of the important aspects under this category: indoor air and its pollution cause premature death of nearly four million people every year. The vital necessity to sustain existing built environment through proper improvement requires adaptability by using a consciously structured assessment process which focuses on the relationship of space and humans in a systematic perspective. Accordingly, as an alternative to common tendencies in indoor air pollution studies, the subject can be structured on three pillars: pollutants, humans and indirect participant of their relationship: exposure environments. Due to the complex interactivity created between hierarchical environmental systems of building, main aspects of closed spaces play an essential role as creating complicated impact-result mechanisms on progress of exposure. The existence, location, duration and concentration levels of indoor air pollutants are affected by the volume of closed spaces, air movements in and between indoor and outdoor environment, possible interactivity among surfaces and pollutants and related factors such as temperature, humidity, dampness that transforms these interrelations. Furthermore, the architectural arrangement of the spaces affects the exposure by determining location and duration of building users. It is believed that constituting systematization for fundamental properties of closed spaces as exposure environments can be useful to reveal interrelations between three participants of exposure in a broader and more holistic comprehension consistent with whole systems thinking in preference to common popularized approaches which mainly concentrate on quantitative properties in a single building scale towards better structured assessment activities with a higher potential for accurate results.

Key words: Indoor air pollution, Exposure environment, Exposure assessment, Exposure factors, Indoor spaces

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1. INTRODUCTION

Humans' interaction with the key entities of built environments under the influence of numerous inconsistent factors generally actuates an exposure process which has the tendency to occur rather severely in closed spaces of buildings regarding the frequently encountered level of negative consequences. World Health Organization (WHO, 2018) states that 3,8 million people a year die prematurely from illnesses such as pneumonia, stroke, ischemic heart disease, chronic obstructive pulmonary disease and lung cancer which are attributed to one of the major aspects that falls under this category: indoor air pollution. The vital necessity to sustain built environments while enhancing their properties invokes a requisite of adaptability via accurate improvement and transformation. In order to achieve this, not only the production but also the assessment processes, focusing on the relationship of space and human, must be revitalized in a critical and reformatory form to supply a more supportive influence and prevent destructive effects of built environment on personal, economic and even social wellbeing. Despite the large number of indoor air pollution studies, prevalent restricted perspectives, which tend to regard the subject by narrowing the boundaries of focus on pollutants to a great extent, creates an essentiality to re-consider the fundamental structure of approaches towards embracing all ignored but essential constituents. As an alternative to this pollutant centered research tendency, the subject can be concerned on a three pillar structure: pollutants, humans and environment (Darçın, 2014) based on the fact that problems occur in the event of indoor air pollution meets with building users for a definite period of time (National Research Council [NRC], 1991) in closed spaces. Different from direct participants of the phenomenon: pollutants and users, closed spaces have generally indirect yet more complex impacts on the formation and development of exposure (Darçın & Balanlı, 2015) through the interactivity between their multi-scale nested environments. Accordingly, it is possible to remark that an important scarcity appears about the main aspects of spaces in the context of stated potency of creating complicated impact-result mechanisms.

The aim of this research is to examine the fundamental properties of building spaces in order to constitute a systematization by using related knowledge from scientific literature and to reveal interrelations of three phenomena of the exposure by pursuing a broader and more holistic comprehension consistent with whole systems thinking in preference to common popularized approaches which concentrate solely on quantitative properties in a single building scale. The scope of the study is limited with the stated aim and it is anticipated that this kind of a consideration can create a different standpoint for future studies and

categorical system as the result finding of the research can serve as a strategic input particularly for determination activities regarding the labor-cost-time expenses or the quality of quantitative values towards a better engagement by reflection and reaction in shaping and sustaining healthier environments.

2. EXPOSURE TO INDOOR AIR POLLUTION

Air pollution in closed spaces of built environments is quite often a mixture of many different pollutants (Ferro & Hildemann, 2007) that may emerge from a vast number of sources and mostly prone to undergo hard to predict transformations (Milner, Vardoulakis, Chalabi, & Wilkinson, 2011). Existence of pollutants in or around the living environments may cause this problem to create a certain level of risk through exposure that can develop as the pollutants touch and / or enter to building users' body (Environmental Protection Agency [EPA], 2012). In exposure science, opposite to the past source-oriented approaches, the focus has been moved on to the target where the pollutants at the contact boundary of the receptor are being examined (Ott, 2007). Accordingly, it can be stated that possible consequences are correlated not only with the characteristics of exposed individuals but also with several aspects of pollutants such as types, physical / chemical / biological properties and concentration levels (NRC, 1991) in their breathing zone or metabolism and particularly all the mechanisms of elemental patterns and relations that have an effect on them.

A building, basically created by separating a part of the nature with an envelope to be re-organized as a living area for their users (İzgi, 1999), comprises many interwoven sub-systems with numerous different participants. On account of this, a certain closed space or a definite part of it, which gathers users and pollutants together, can be defined as an exposure environment. The nested systems with ever-changing boundaries, fundamentally specified by the physical existence of the permeable building envelope which constantly transfers not only matter but also energy as well, have a major potential to affect indoor air, building users and their co-presence separately and simultaneously. Therefore, it can be asserted that the impact-response mechanisms as the result of complex interrelations through up and down these hierarchical systems: indoor environment embracing the exposure environment which are encircled with building envelope and all together enclosed by outdoor environment (Figure 1) can be counted among the important factors that define the exposure process. It is required that basic properties of the exposure environment should be determined congruous with the focus of this context.

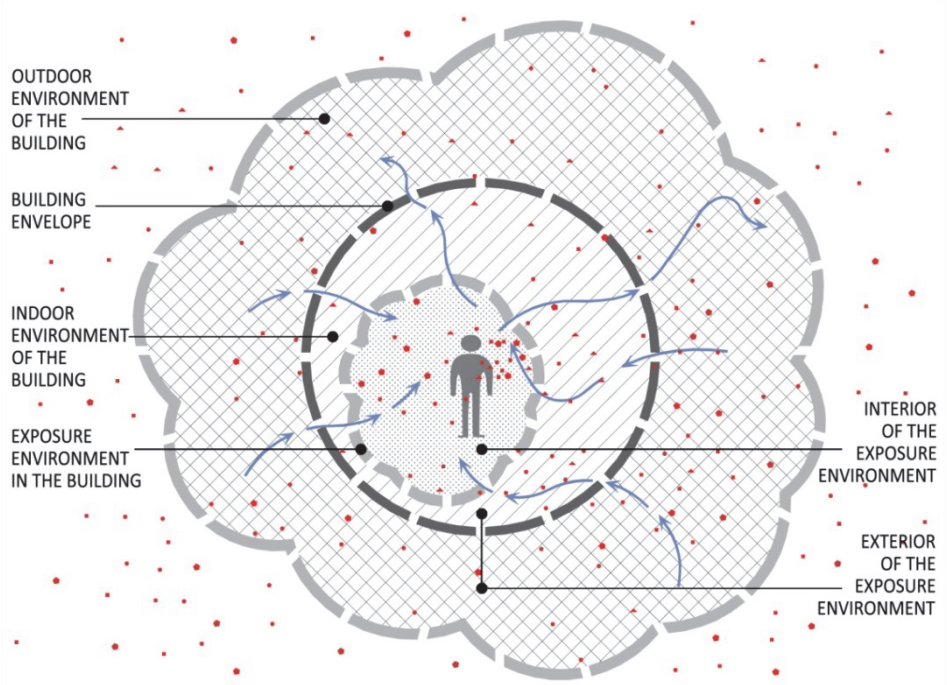

Figure 1. Building and Its Environments

3. EFFECTS OF EXPOSURE ENVIRONMENT ON EXPOSURE PROCESS

Qualitative and quantitative properties of indoor air pollutants such as existence, types, positions, duration and concentration levels tend to constantly change in different parts of the indoor environment and accordingly create various exposure environments as they meet with building users mainly because of varying volumes of closed spaces (Mølhave, 1998), air movements (Spengler, Chen & Dilwali, 2001) in and between exposure environments and their surroundings, interactivity between different surfaces of the spaces and pollutants (European Commissions Scientific Committee on Health and Environmental Risks [EC SCHER], 2007) and certain factors that transform these interrelations (Chen & Glicksman, 2001). Furthermore, the architectural organization of the spaces affects the exposure due to determining specific properties related to users.

3.1. Volume of the Exposure Environment

As the air pollutants emerge into the building, they disperse in the indoor air filling the volume of the closed space depending on their physical properties and air conditions to develop a certain level of concentration. Under proper circumstances, molecules of the pollutants in the gas / vapor state can homogeneously

mix into indoor air (Kephalopoulos, Koistinen & Kotzias, 2006) and reveal a constant concentration level throughout the space (Repace, 2007). Subsequently, the volume of the space is inversely proportional to concentration level of gas / vapor pollutants (Figure 2). On the other hand, particulate matter pollutants may present a heterogeneous dispersion according to their size, weight, form, surface properties, etc. as they become airborne for a certain period of time and almost always sink.

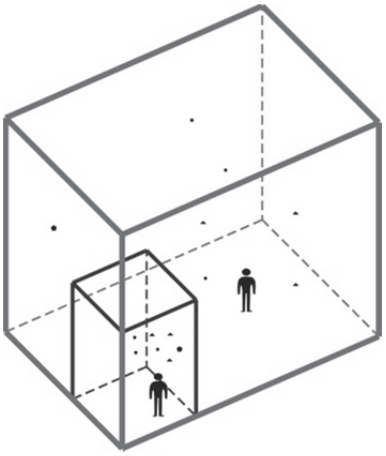

Figure 2. Relationship between Volume of the Space and Concentration Level

3.2. Air Movements in and around the Exposure Environment

The fundamental physical phenomenon affecting the properties of indoor air pollution is the movement of air molecules. The basic cause to trigger a movement is the driving effect created by the differentiation among air pressures which can occur naturally or by force between different parts of a closed space or between its interior and exterior (outdoor environment of the building or indoor environment that encloses the related closed space) environments (Kephalopoulos, Koistinen & Kotzias, 2006) by natural ventilation / air infiltration through the permeable borders of the space or via a mechanical ventilation system. Geometric properties of the space (Chen & Glicksman, 2001) and its interior organization (such as the positions of furniture or separators) (Spengler, Chen & Dilwali, 2001) are the other constituents that determine the speed, direction, behaviour and form of the airflow (Darçın & Balanlı, 2012). Replacement of indoor air of a closed space with outdoor air is defined as air exchange and the ratio between the incoming air flow (m^3/h) and the volume of the space (m^3) determines the air exchange rate (h^{-1}) (Salthammer & Bahadir, 2009).

Along with the moving molecules of air in and between interior and exterior environments of the space all other airborne substances are replaced and transported (Demokritou, 2001) therefore the position, duration and concentration levels of pollutants can be affected (Figure 3).

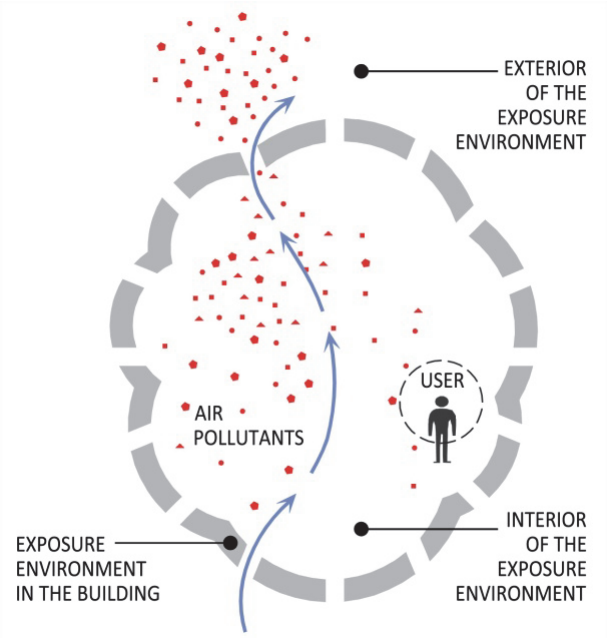

Figure 3. Effects of Air Movements

3.3. Relations between Indoor Air Pollutants and Surfaces of the Exposure Environment

Physical or chemical interactions between pollutants and substances that compose the building products / furniture in the exposure environment have a significant potential to affect the properties of indoor air pollution and accordingly exposure.

The main phenomenon in the context of interactions, described as indoor sinks (Koontz, Evans & Wilkes, 1998), subsumes possible situations that may occur when pollutants of gas / vapour or particulate form encounter an indoor surface during their movement in indoor air in which the pollutant may rebound / bounce off from this surface back to the indoor air, may get attached to the surface or may be absorbed by the surface (NRC, 1991). In the event of attachment or absorption, same pollutant may be reemitted back to indoor air (deposition) or may react with the substance and form a new type of pollutant (Kephalopoulos, Koistinen & Kotzias, 2006).

It has been stated that, mostly particulate matter can attach (Milner, et al., 2011), however, gas molecules can also adhere to the surfaces to form a very thin film (Kephalopoulos, Koistinen & Kotzias, 2006). Properties such as size, weight and smoothness with features of the surface constitute essential factors (Wallace & Smith, 2007). Furthermore, mold spores easily proliferate in proper circumstances on the materials which provide nutrition (Brennan & Burge, 2005). Mostly, large and porous surfaces absorb gas / vapour pollutants (Logue, McKone, Sherman & Singer, 2011) substantially cause a decrease on the concentration levels and become secondary sources. Even if the primary resource is removed from indoor space, these secondary sources can reemit the absorbed pollutants for a long period of time (Colombo, et al., 1993).

Relations between indoor surfaces and air pollutants can be affected by air temperatures, humidity and the dampness of the surfaces or inner layers (EC SCHER, 2007).

3.4. Architectural Organization of the Exposure Environment

Humans use buildings in accordance with their biological, psychological and sociological properties and requirements originated from these aspects (Balanlı, 2014). In the frame of exposure to indoor air pollution, duration, frequency and location of co-presence of humans and pollutants are related to properties of usage, in other words, how long, how often and where the users be in the building which are mainly determined by architectural organization and function of indoor spaces. The positions of furniture, location of windows and doors, indoor physical environment features such as lighting, auditory properties, indoor temperatures, etc. can be listed as basic factors under this category.

4. CONCLUSION AND RECOMMENDATIONS

An indoor space, designed and constructed primarily to offer a healthy living area, can turn into an exposure environment due to bringing air pollution and users together. Because there is a very high potential that various aspects of indoor air pollution, building users and their co-presence are determined and affected by this environment, its properties that create an impact-result mechanism on exposure should be examined and systematized.

The existence, location, duration and variable concentration levels of pollutants – especially types which are emitted in outdoor environment and transported – can be affected by the volume of the closed spaces, air movements in and between indoor and outdoor environments, possible interactivity between surfaces and pollutants such as deposition, absorption or chemical reactions,

temperature and humidity / dampness of the air or surfaces. The location of the primal user: humans in exposure environment and their duration of presence are highly correlated with the architectural arrangement in accordance with the function of the space.

Resolving and preventing indoor air pollution require an efficient assessment process in which an accurate decision must be made about the exposure in terms of health. Realistic and effective determination of the encountered situation within the scope of direct participants of exposure: indoor air pollution and building users in appropriate time-money-labour conditions constitutes one of the critical steps and depends on the examination method. The quality of the determination activities is believed to be related to the structure of the process where the complex impacts of the exposure environment can be utilized for a more realistic interpretation of the pollutant – user relationship through a holistic consideration towards all nested hierarchical systems created by the building envelope. In accordance with this aim, examining

- transportation of air between exposure environment and its surroundings,
- air movements and air exchange rate,
- properties of the surfaces,
- air and surface temperatures, relative humidity, current and previous dampness on the surface materials or inner layers,
- volume of the air,
- arrangement of the furniture in the indoors of exposure environment are highly essential in order to correctly specify
- entrance of outdoor originated air pollutants, accordingly the possible increase in their concentrations,
- departure of indoor originated pollutants, accordingly the possible decrease in their concentrations,
- location and duration of the pollutants in exposure environment,
- possible sinks and interactivity between pollutants and surface materials,
- emission properties of secondary sources and proliferation possibilities of biological pollutants,
- concentration levels
- location and duration of building users in exposure environment respectively.

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