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Quality of indoor environment for aging people: A review based study

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Abstract
Indoor Environment Quality (IEQ) presents a very significant challenge in vulnerable population. In order to maintain an indoor environment that is adequate for occupants, it is necessary to comply with a set of requirements regarding concentrations of airborne pollutants and hydrothermal comfort conditions. There are factors which influence indoor environmental qualities like airborne contaminants or pollutants (construction, furnishing activities), indoor air qualities, ventilation, humidity, thermal environment, light and lighting comfort, acoustic comfort. It has vital effect on the health of human being. Indoor environment quality can be improved by various ways like by using fragrance free and volatile organic compounds cleansing products, vacuuming regularly, cleaning the equipment and maintain it. Ventilation and optimizing of light is another effective method for improving indoor air quality. The indoor environment can be influenced or altered by building services: lighting systems can increase indoor light levels; and heating, ventilation and air-conditioning (HVAC) systems are used to control temperature and humidity. With biological ageing, a number of sensory changes occur as a result of the intrinsic ageing process in sensory organs and their association with the nervous system. These changes can in turn change the way we perceive the environment around us. It is important to understand these changes when designing for older occupants, for instance, care homes, hospitals and private homes, as well as office spaces given the developments in the domain of staying active at work until older age. In this paper we will discuss about indoor environment quality, factors and aging challenges.

Keywords: Indoor environment quality, factors, air quality, aging challenges

Introduction
With people generally spending more time indoors, and buildings being more tightly constructed and isolated from the external environment, a greater importance is being placed on the indoor environment.

Indoor environmental quality (IEQ) is a general indicator of the quality of conditions inside a building. A better indoor environmental quality can enhance the wellbeing of building occupants and help decrease the occurrence of sick building syndrome and building related illness. It can also lead to a decrease in worker complaints and absenteeism which in turn can improve productivity. The indoor environment is of key importance for human health and well-being, not only due to the time spent indoors during our lifespan (approximately 90%), but also due to the combination of health and safety threats encountered on a daily basis.

Indoor environmental quality (IEQ) refers to the quality of a building's environment in relation to the health and wellbeing of those who occupy space within it. IEQ is determined by many factors, including lighting, air quality, and damp conditions. It is most simply described as the conditions inside the building. It includes air quality, access to daylight and views, pleasant acoustic conditions, and occupant control over lighting and thermal comfort. Workers are often concerned that they have symptoms or health conditions from exposures to contaminants in the buildings where they work. One reason for this concern is that their symptoms often get better when they are not in the building. Aging people faced difficulty breathing in high humidity environments may possibly be related to respiratory conditions such as asthma, anxiety. Sufferers will often hyperventilate in reaction, causing sensations of numbness, faintness, and loss of concentration, among others. While research has shown that some respiratory symptoms and illnesses can be associated with damp buildings, it is still unclear what measurements of indoor contaminants show that workers are at risk for disease. In most instances where a worker and his or her physician suspect that the building environment is causing a specific health condition, the information available from medical tests and tests of the environment is not sufficient to establish which contaminants are responsible.

Objectives of the Study

1. To discuss the major factors influencing indoor environment quality.
2. To discuss ageing-related changes in the perception of indoor air quality.
3. To give suggestion for appropriate indoor environment for elderly people.

Review of literature

Carter *et al*. (2000) [2] illustrated that the kitchen is the place where most non-fall injuries (31%), including burns, knocks, cuts, and bumps, take place, whereas fall-related injuries happen most frequently (20%) in the bedroom.

Veitch *et al*., (2002) [13] analyzed that the acoustic problems in offices could be divided into two major categories: annoyance from various noises and lack of communication privacy. The level, the spectrum, and the variation with time of the noise may influence the level of disturbance. Noise from other people talking, telephones ringing, and other irregular sounds may create more annoyance and disturbance compared to the more continuous regular sounds.

Ceylan (2011) [3] reported that human body exchanges heat through heat conduction mechanisms for establishing thermal balance. The metabolic heat produced by the body is removed through, 30% convection, 40 % radiation, 20 % evaporation and 10 % respiration.

Kort (2012) [11] analyzed that build with more care for health offers the possibility to reduce the chance of disease and (the feeling of) insecurity, to stimulate the physical and mental activity and to provide support in daily work and life operations. It increases the possibility of self-care and informal care and increases the quality of professional care.

Alhorr, *et al*., (2016) [1] mentioned that few symptoms or discomfort from poor acoustic of indoor environment can lead to short and long-term effects on the health of residents and acoustics comfort is to create a good acoustic environment and protect the residents from noise and create a privacy space. He also mentioned that airborne sound, outdoor noise, noise from adjacent spaces, noise from equipment, the sound of nearby facilities, people talking, telephones ringing and any irregular sounds may cause annoyance and disturbance to the residents.

Falkenberg *et al*. (2019) [5] reported that in the intervention group , lighting levels significantly improved self-assessed lighting levels, abilities to perform ADLs, and read and write in the living room (all $p<0.03$). In the Control Group the only change was a deterioration in performing ADLs ($p<0.05$) and the difference in change was significant between the IG and CG (all $p<0.02$). "Normal" lighting was the preferred level and improved comfort and well-being. The IG also resumed visually challenging tasks, and recognized that avoiding these tasks were mainly due to poor lighting.

Shelley Little (2020) [12] reported that indoor lighting for the elderly is something new for architects and lighting designers to consider, especially since poor lighting can lead to accidents and falls. As people age they experience a plethora of vision problems from macular degeneration, neuro-degeneration and reduced retinal luminance (essentially, smaller pupils and a thicker eye lens causes everything to appear less vivid and bright).

Research Methodology

This paper is a descriptive study in nature. This paper is based on a review and analysis of the published scientific literature addressing the linkages of IEQ with health and aging-relating changes. The secondary data and information have been analyzed for preparing the paper extensively and have been collected from different scholars and researchers, published books, articles published in different journals, periodicals, conference paper and websites. Duplicate articles and other works that did not have information's related to the study's addition criteria were disregarded.

Factors influencing indoor environmental qualities

The indoor building environment is complex and there are a variety of factors that can influence its environmental quality.

- Airborne contaminants (gases and particles) from; office equipment, cleaning products, construction activities, furnishings and carpets, water-damaged building materials, microbial growth (fungal, bacterial and mould), outdoor pollutants, and so on.
- Indoor air quality.
- Ventilation.
- Humidity.
- Thermal comfort.
- Daylight, lighting and views.
- Electromagnetic frequency levels.
- Acoustic conditions.

Understanding the sources of indoor environmental contaminants and controlling them can often help prevent or resolve building-related worker symptoms.

There are a number of ways that the indoor environmental quality of existing buildings can be improved, including

- Using fragrance-free and low VOC (volatile organic compounds) cleaning products.
- Undertaking audits of cleaning products and devising a cleaning plan to replace products with safer alternatives.
- Vacuuming regularly and using vacuums with HEPA (High-efficiency particulate arrestance) filters.
- Ensuring that HVAC equipment is well maintained and working optimally.
- Creating a door and window opening protocol to maintain sufficient air flow.
- Avoiding dust blowing equipment such as leaf blowers and diesel-powered engine equipment.
- When using pesticides, fertilizers and lime applications, ensuring there is little or no wind.
- Maintaining buildings and furnishings to a high standard reducing the need for renovation and remodeling.
- Ensuring filters in HVAC systems are properly maintained.
- Optimizing lighting.

As people age as their increase tendency to live in the same place (Andersson & Abramsson 2012; Sandstedt & Abramsson 2012). This phenomenon is called 'ageing in place' (Davey, Nana, de Joux, & Arcus, 2004). This is no surprise given that people's physical fragility increases with age; they are less mobile than those of young cohorts, spending most of time indoors (Iwarsson *et al*., 2007).

Today, average life expectancy is over 80, and by 2020 around 25% of the population will be over 65. The increasing group of older people poses great challenges in terms of creating suitable living environments and appropriate housing

facilities. The physical indoor environment plays an important role in creating fitting, comfortable and healthy domestic spaces. Our senses are the primary interface with the built environment. With biological ageing, a number of sensory changes occur as a result of the intrinsic ageing process in sensory organs and their association with the nervous system. These changes can in turn change the way we perceive the environment around us. It is important to understand these changes when designing for older occupants, for instance, care homes, hospitals and private homes, as well as office spaces given the developments in the domain of staying active at work until older age.

Within the domain of building sciences, the indoor environment is the realm of building physicists, environmental engineers and building services engineers. It is the engineers who can help achieve fitting indoor environments for the ageing population. Many standards and models relating to indoor environmental quality focus on office situations, which are mainly populated by people roughly aged between 20 and 65 years old. It is, therefore, of the utmost importance to have a closer look at the effects of biological ageing on the perception of the indoor environment. The effects of biological ageing on the perception of the indoor environment, in particular is (1) the thermal environment, (2) indoor air quality, (3) light and lighting, and (4) the acoustical environment.

Thermal Environment

A heat balance should be established between a person and his surroundings for the said individual to continue to live a comfortable life. Thermal comfort is about senses and feelings. Therefore, heat balance and comfort conditions are different notions. ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) defines it as „the condition of mind which expresses satisfaction with the surrounding environment the occupants". In general, parameters that are affective in thermal comfort could be categorized as personal and environmental parameters. While, ambient temperature, ambient relative humidity, ambient air speed and average radiant temperature are named as environmental parameters; personal parameters consists of the person's metabolic activity level and clothing.

The thermal environment is affected by the air temperature and surrounding surface temperatures, humidity and flow rate. Good indoor air is characterized by the right room temperature, proper humidity, cleanliness and freshness. Thermal comfort refers to a condition where a person is satisfied with the ambient temperature. The effect of temperature on comfort and morbidity and thus on the productivity of work is undeniable. According to thermal comfort recommendations, a temperature range of 21–25 °C is considered comfortable.

Recommend Thermal Comfort

- Thermal comfort can be measured as the predicted mean vote (PMV), which is a scale from – 3 (cold) to + 3 (hot) (Table 1). The value is derived from a complex equation that factors in a range of criteria, including clothing insulation, metabolic rate, air velocity, vapour pressure, and the mean radiant temperature (MRT). Generally, thermal comfort guidelines recommend that interior spaces be regulated such that the PMV is between – 0.5 and + 0.5.

Table 1: The predicted mean vote (PMV) scale for measuring thermal comfort. From ASHRAE standard 55.

Value	Sensation
+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

The PMV can be used to calculate the predicted percentage dissatisfied (PPD). The PPD is a function of the PMV, and describes the expected percentage of people dissatisfied with their thermal environment given the PMV. As the PMV moves away from 0, the PPD increases. 100 % PPD would indicate that 100 % of people would be expected to be dissatisfied with the thermal environment. Therefore, guidelines suggest that interior spaces should aim for a PPD below 10 %.

Ageing-related changes in thermal perception

Until recently, scholars supported the hypothesis that in relation to thermal comfort, older adults did not perceive thermal comfort differently from younger college-age adults. The effects of gender and age were accounted for by PMV-model parameters, such as activity and clothing level. The ability to regulate body temperature tends to decrease with age, and these changes vary widely among individuals and are related more to general health than age. Moreover, basal metabolism declines with advancing age leading to lower body temperatures. In recent studies by Schellen *et al*. (2010) and Schellen (2012) on moderate temperature drifts, it was found that the thermal sensation of older adults is in general 0.5 scale units on the 7-point ASHRAE scale of thermal sensation lower in comparison to younger adults under the same thermal conditions. According to Schellen (2012), older adults, thus, prefer higher ambient temperatures. In her words, mild thermal challenges can cause significant physiological responses. For instance, cold temperature exposures can results in increased systolic blood pressure levels. Older adults, should, therefore, be protected from even mild thermal disturbances.

Indoor Air Quality

Indoor air is considered to be healthy when air does not contain contaminates in harmful concentrations and is acceptable when the majority of people feel satisfied. A human being breathes about 12000 litres of air everyday and is vital for our health. Exposures to hazardous airborne agents present in indoor causes adverse effects such as respiratory and cardiovascular diseases, allergy and irritation respiratory track and possibly leads to cancer.

Main source of indoor air pollutant are from outdoor air, household cooking (specially biomass or frying) , tobacco, smoking, polluted ambient air, cleaning agents, resuspension of dust during the cleaning activities, construction materials and paints, copy machines and printers as well as other human activities. Respectively, ambient air pollutants are vehicle emissions, thermal power plants, biomass burning, construction work, unattended debris, open sewerage pipes; fossil fuels based power generators and various industrial processes.

Some guidelines for parameters are:

Parameter	WHO guideline value*	ASHRAE**	OSHA***
PM10	50µg/m3 (24-hr mean)	----	15mg/m3 (total)
PM2.5	25µg/m3 (24-hr mean)	----	5mg/m3(resp.)
SO2 (sulphur dioxide)	20µg/m3 (24-hr mean)	----	5ppm (8-hr)
NO2	200µg/m3 (1-hr) 40µg/m3(annual mean)	----	5ppm (8-hr)
CO (carbon monoxide)	10ppm (8-hr)	9ppm (8-hr)	50ppm (8-hr)
CO2	----	1000ppm (8-hr)	5000ppm
Humidity	----	30% - 65%	----
Temperature	----	68°F – 74.5°F (20-23.6oC)(winter) 73°F – 79F° 22.8-26.1oC)(summer)	----

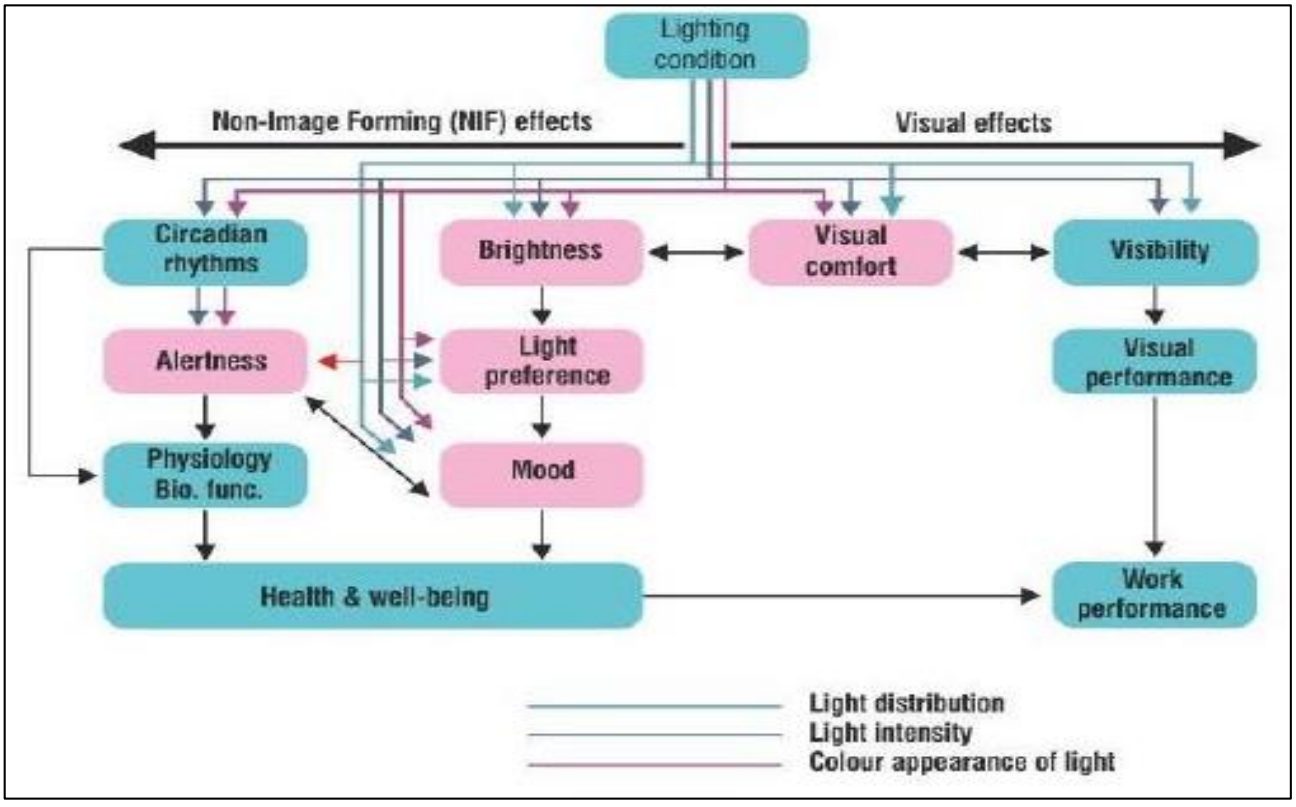
*WHO air quality guidelines global update 2005 and WHO guideline value for the ―classicall air pollutants (WHO 1999a
** ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers Inc.) Standard 55
*** Occupational Safety and Health Administration Permissible Exposure Limit — this level is a time-weighted average and is an enforceable standard that must not be exceeded during any eight-hour work shift of a 40-hour work week
**** The National Ambient Air Quality Standards (NAAQS) were developed by the U.S.

Ageing-related changes in the perception of indoor air quality

There is strong evidence that smell perception declines markedly with age. Age-related losses of smell normally begin after the age of sixty. Age-related sensory changes to smell include a decrease in the number of olfactory cells. These changes may lead to decreased appetite and poor nutrition, as well as a decreased protection from noxious odours. The loss of cells in the olfactory bulb in the human forebrain can lead to changes in smell. In addition, a history of upper respiratory infections, exposure to tobacco smoke and other toxic agents, and changing levels of hormones negatively influence olfactory function (van Hoof *et al*., 2010a).

Light and Lighting Comfort

Light has significant impact on many bodily functions, including the nervous system, circadian system, pituitary system. Endocrine system, pineal gland and alertness as there affected by different wavelength of light variation over time in lighting condition, in terms of intensity. Illumination level, distribution, ambient lighting and colour temperature, can stimulate alertness and well-being of people as shown in figure.



Effect of Lighting Condition

Ageing-related changes in vision and effects of light

Ageing negatively affects vision. In general, the performance of the human eye deteriorates at early age. Many people aged 45 and over wear glasses to compensate for impaired vision due to presbyopia, the significant loss of focusing power. Older people are known to have vision impairments stemming from the normal ageing process, which include an impaired ability to adapt to changes in light levels, extreme sensitivity to glare, reduced visual acuity, restricted field of vision and depth perception, reduced contrast sensitivity, and restricted colour recognition. Changes in vision do not happen overnight, and depend on the progress of age. After the age of

50, glare and low levels of light become increasingly problematic. People require more contrast for proper vision and have difficulty perceiving patterns. After the age of 70, fine details become harder to see, and colour and depth perception may be affected. Apart from the influence of ageing, there are pathological changes leading to low vision and eventual blindness, such as cataract, macular degeneration, glaucoma, and diabetic retinopathy (van Hoof *et al*., 2010a, Sinoo *et al*., 2012).

Apart from being indispensable for proper vision, light exposure is the most important stimulus for synchronising our day and night rhythm. Research by Aarts and Westerlaken (2005) in The Netherlands has shown that light levels that older adults are exposed to (due to their mainly indoor lives in general), even during daytime, are too low to allow for proper vision and biological effects. Nowadays, older people are being exposed to so-called ambient bright light from ceiling-mounted luminaries. This encompasses an increase of the general illuminance in rooms. There are several short-term and long-term effects such as lessened nocturnal unrest, a more stable sleep-wake cycle, possible improvement to restless and agitated behaviour as well as sleep, increased amplitude of the circadian body temperature cycle, and a lessening of cognitive decline (van Hoof *et al*., 2012).

Table 2: Threshold values of parameters for lighting comfort

Parameters	Units	Type of space	Classification		
			Class A	Class B	Class C
Illuminance	Illuminance should be as per the value/range defined in NLC2010 at the task				
Circadian Lighting Design (For Workspaces)	Equivalent Melanopic Lux (EML)		At least 240 EML in regularly occupied spaces, through electric light only	At least 150 EML in regularly occupied spaces, through electric light only	
Uniformity of illuminance at task areas			0.7	0.7	0.7
Uniformity of illuminance at immediate surrounding areas			0.5	0.5	0.5
illuminance of the immediate surrounding areas			As per the above table given in NLC 2010		
Percentage of the workstations meeting the required illuminance of task plane	%		100	90	90
Occupant satisfaction	%		90	80	
Controllability of lighting environment			Yes	Yes	No

Acoustic Comfort

Building acoustics deals with controlling the quality of sound inside a building. It has two parts, namely, room acoustics and building acoustics, which deal with the sound propagation within a room and between rooms (through walls, doors, and floors), respectively. While the room acoustics focuses mainly on the sound quality (e.g., easy communication and high level of intelligibility in office spaces), the building acoustics is concerned with the "unsolicited" sound (e.g., the noise in a room should not be a nuisance to other rooms). The acoustic comfort in a building has a crucial impact on the health, well-being, communication, and productivity of the occupants. The acoustic comfort can be affected by factors such as the geometry and volume of a space, generation of sound within or outside the space, airborne noise transmission, impact noise, and the acoustic characteristics (absorption, transmission, and reflection of sound) of the interior surfaces. The measuring unit of sound intensity is decibels (dB), and of sound pitch is hertz (Hz). The comfortable range of sound for human is typically 20-20,000 Hz.

The common parameters used for evaluating the acoustic performance of a building are reverberation time (RT), sound pressure level (SPL), early decay time (EDT), clarity (C_{50} for speech and C_{80} for music), sound definition or speech intelligibility (D or D50), and speech transmission index (STI). RT is defined as the time for the sound level to decay by 60 dB after a sound source has been switched off. EDT is similar to RT, but it is the initial rate of sound decay in a room, measured as the slope of line 0–10 dB decay below the maximum sound level. D50 is defined as the ratio of the early received sound energy (0–50 ms after direct sound arrival) to the total received energy. Clarity is defined as the ratio of the energy in the early sound (received in the first 80 ms) to that in the reverberant sound. STI is a measure of speech transmission quality, which indicates the degree to which a transmission channel degrades speech intelligibility. STI ranges from 0 to 1; a speech transferred through a channel with STI of 1 is perfectly intelligible, but the intelligibility reduces as the STI approaches zero. International standards and guidelines (e.g., ISO 18233) are available for the measurement of these character tics.

Ageing-related changes in Noise and room acoustics

In addition to sight, one of the first senses to be affected by age is hearing, and this begins to occur by the age of 40. High-frequency pitches are the first to become less audible, with a lesser sensitivity to lower frequency pitches. The ability to understand normal conversation is usually not disturbed at first, but when combined with the presence of background noise comprehension may be affected. A laboratory study by Sato (2005) involving 20 younger and 20 older subjects using various speech tests showed that speech recognition (intelligibility) scores of the older listeners were 25% lower than those of young adults for any kind of speech test. The effect of this difference is equal to the 5 dB increase of ambient noise.

Suggestions

1. To reduce illumination intensity at the exits in living areas to ensure the safety of particularly vulnerable residents.
2. To should establish a comfortable and healthy indoor lighting, through optimum integration of artificial and natural lightings, and use of energy-efficient, user-friendly, and eco-friendly artificial lighting.
3. To emphasize doors to washrooms, recreation areas or public spaces with effective lighting.
4. To should avoid low-shadow lighting prevents missteps and falls.
5. To enhance the esthetics and indoor environment by

proper integration of natural and man-made facilities.
6. The interaction between color temperatures and the color scheme of the rooms should be considered.
7. There should be warm-white light is preferred in the living area.
8. To provide good color rendering in a dining area enhances the appearance of food, good energy efficiency, two-component lighting.
9. There should be direct/indirect lighting is supplemented using a care and examination light or reading light, which can be switched on and off independently.
10. Aging people require illumination intensity which is up to four times higher than younger people.
11. There should give good glare reduction, room appears bright and uniform lighting.

Conclusions

In conclusion point there are many researchers who already study that relate to the indoor environment quality. This review study contributes how appropriate indoor environment quality for aging people. These different studies define the current indoor housing standards meet the needs of the older adults. Aging people are very sensitive to glare, which can cause them to miss obstacles in their path, so to design the indoor home according to the accessible of them. The indoor environment can be included services i.e. lighting, noise, humidity and temperature. To enhance the wellbeing for aging people, the design criteria for the indoor environment should be changed because they suffer difficulty inappropriate environment. Aging and younger people, even in the same environment, respond in a different way to the indoor environment. Aging people have a lower tolerance for uncomfortable situations than young people. There should be support encourage physical and mental activity in the daily work and life operations. More research is required to understand problems in indoor environment can affect health of aging people.

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