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Indoor air quality of new office building of National Institute of Health Sciences in Kawasaki INnovation Gateway at SKYFRONT (KING SKYFRONT) (Part II)

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ABSTRACT— This work presents an original method to identify priority indoor air pollutants in office buildings. It uses both a chronic risk assessment approach by calculating a hazard quotient, and a hazard classification method based on carcinogenic, mutagenic, reprotoxic, and endocrine disruptive effects. A graphical representation of the results provides a comprehensive and concise visualization of all of the information, including the number of buildings where each substance was measured, an indicator of exposure data robustness. Seventy-one out of 342 substances (20%) for which indoor air concentrations have already been measured in office buildings were identified as priority pollutants. The results were compared to previous prioritization studies in various types of indoor environments to assess the reliability of the method and highlight its advantages. Sensitivity analyses were performed to reduce the geographical scope (OECD countries only), time scope (after 2010 only), and measurement duration (working hours only) and showed little influence on the results. Finally, 123 additional substances that could be present in office indoor air but could not be assessed due to the lack of measurement data are proposed for future monitoring surveys to update the prioritization of indoor air pollutants in offices.

KEYWORDS: indoor air quality; air monitor; particulate matter 2.5; COVID-19; employee health; remote work

1. INTRODUCTION

Indoor air pollution has been classified as one of the top five environmental health hazards. In the United States (US), the average person spends nearly 90% of their time indoors, where air quality is estimated two to five times worse than outdoors [1]. Indoor air quality (IAQ) is affected by outdoor factors (i.e., motor vehicle and industry), indoor activities (i.e., cooking and smoking) and building-related factors (i.e., ventilation and air conditioning systems) [2]. Outdoor chemicals, including fine particulate matter ($PM_{2.5}$), volatile organic compounds (VOCs), ozone (O3), carbon monoxide (CO), and radon could affect IAQ. However, there are a variety of additional sources for indoor air pollution in offices and homes. In offices, most indoor pollutants are related to building materials and human activities such as carpet and other office furniture, cleaning agents, air fresheners, paints, adhesives, printers, pesticides, and biological contaminants from poor ventilation systems or water-damaged walls [3- 6]. A study conducted by prioritized the indoor air pollutants in office buildings and found formaldehyde, acetaldehyde, benzene, $PM_{2.5}$, and PM_{10} as priority pollutants [7]. In households, activities performed by individuals including cooking, laundry, smoking, and the use of chemicals for cleaning and hobbies increase indoor air pollution [8]. The primary indoor air pollutants include particulate matter, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), ozone, asbestos, tobacco smoke, nonpolar volatile organic compounds, allergens, and mold [9], [10]. Modern buildings are designed to be airtight, eliminating natural ventilation as they are controlled by heating, ventilation, and air conditioning (HVAC) systems that recirculate a high percentage of the air with minimal fresh air replacement, maintaining constant IAQ across seasons [10- 12]. HVAC

systems have a critical role in keeping people inside buildings comfortable and healthy, and they are intended to provide an air supply to the room and have an exhaust system to remove dirty air from indoor spaces [13]. Non-residential buildings like offices usually have an mechanical ventilation for outdoor air change, with less natural ventilation or infiltration contribution, maintaining constant IAQ over seasons [14]. It is recommended to install filters (F7 grade or above) to filter fresh air to the unit to protect HVAC units and limit the ingress of outdoor particles. However, inadequate system installation and poorly maintained air ducts and filters diminish the air quality [15]. Biological particles such as bacteria, fungi, and viruses correlated with respiratory health conditions can float in the air and linger longer in poorly ventilated indoor spaces [16- 18].

2. Materials and Methods

2.1 Participants and Study Design

This pilot study was conducted in McAllen, South Texas, during May–July 2019 in employees' offices before the COVID-19 pandemic and during June–September 2020 at their households while employees worked from home during the pandemic. A total of eight staff members working in the same building in an academic organization participated in the study. The study protocol was reviewed and approved by Texas A&M University's Institutional Review Boards. The methodology presented here was adapted to comply with the COVID-19 regulation from a previous study from our research group [51].

2.2 Air Quality Assessment

This study used a low-cost consumer monitor called Foobot® Air Monitor (Model# FBT0002100, AirBoxLab, San Francisco, CA, USA) to assess the IAQ in the offices and households. The performance and accuracy of the Foobot monitor were assessed and determined to be a reliable tool for measuring indoor pollution levels. The Foobots (low-cost air monitors) were used in the offices and homes (bedroom, kitchen, and living room), where occupants stay for a longer time [54]. As suggested in previous studies, calibration equations, data quality, and data corroboration were followed by comparison. The IAQ was measured according to the ASTM D7297-14. The Foobot monitors (air temperature (−40–125 °C), relative humidity (0–100%), $PM_{2.5}$ (0–1300 µg/m^3), and tVOC (100–1000 ppb) were installed in each office on top of a bookshelf (5–6 feet). The Foobot air monitors collected data at 5-minute intervals for two months in each office. The same procedure was done in households to avoid any accidents with children living at the house. We used hotspots in both locations to have a stable WiFi connection throughout the study periods. The data was stored automatically every five minutes in a protected online storage and were safely saved in an encrypted computer. The outdoor temperature and $PM_{2.5}$ levels in the study area during the same periods of IAQ measurements were retrieved from the Texas Air Monitoring Information System (TAMIS), a database maintained by the Texas Commission on Environmental Quality (TCEQ). The outdoor tVOC levels were not collected because data were not available.

3. Results

In our study, eight female academic staff members aged 23 to 67 years old (average 36.1, standard deviation 13.1) participated. All participants lived in single-family detached houses with central air conditioning systems and electric heaters. All households had electric dryers vented outside and kitchen fans, and none of their family members smoked or worked with hazardous materials on the job. Table 1 summarizes other characteristics of the residential environment and behaviors in the participants' home. The average numbers of rooms and people living in the house were 3.3 and 3.4. Six homes had furry pets and non-carpeted floors at their homes. Seven families used electronic stoves and bathroom fans, and three households had air purifiers. Most households rarely opened windows for ventilation and only three

households cleaned their floors regularly using a vacuum cleaner. Five houses used chemicals for lawn care. The averages of indoor temperature and relative humidity measured at homes during the study period were 24.6 °C (range: 23.6–26.9) and 52.8% (range: 46.3–57.5), which are within the recommended ranges of indoor temperature (23–27 °C) and relative humidity (30–60%).

4. Discussion

The advent of COVID-19 caused the shift of working pattern to work from home remotely for many employees. However, homes may not be a good working environment, compared to conventional office settings with better air conditioning and ventilation systems [4]. In addition, activities performed by individuals at homes may increase indoor air pollution, contributing to more negative health issues [8]. Therefore, in this pilot study, IAQ in the offices before the COVID-19 pandemic and at homes during the pandemic and employees' health status in both periods were compared to assess the impact of working from home on employees' health during the pandemic. Our study found that the IAQ in households during the pandemic was worse than that in the office before the pandemic in all participants, and participants experienced higher frequency of SBS symptoms while working from home. Specifically, home IAQ was worse than the outdoor air quality, and the $PM_{2.5}$ levels in all households while working from home were greater than the health-based standard 12 μg/m^3. The interest in studying the impact of COVID-19 in different settings has led to higher scrutiny of the IAQ at homes during the lockdown. A recent study conducted in Northern Italy estimated the average indoor $PM_{2.5}$ levels ranged from 8.6 to 18.7 μg/m3, which were higher than the outdoor PM2.5 levels (7.4–15.4 μg/m3) for a two-week study period in summer during the lockdown [4]. In a study conducted in Norway, the IAQ in home offices were evaluated for up to two weeks, and levels of CO_2 and other pollutants higher than health-based standards were detected [50]. Our findings were consistent with previous studies to investigate the IAQ at homes during the COVID-19 pandemic. However, previous studies only focused on home IAQ during the pandemic without comparing with IAQ in the office before the pandemic and the IAQ was measured for shorter time periods (2 weeks) than our study (2 months), and the health impact was not evaluated directly from the participants.

5. Conclusions

This pilot study assessed workplace IAQ and SBS symptoms before and during the COVID-19 pandemic in academic administrative staff members whose workplace changed from office to home due to the pandemic. Low-cost sensors were found suitable for in situ and continuous IAQ monitoring due to their simplicity, speed, and data accessibility. This study found that working from home may cause greater health issues for employees due to poor home IAQ, emphasizing the importance of the interventions to improve the home IAQ. One of the recommendations to enhance IAQ at homes can be achieved through behavioral changes such as opening windows and doors unless the outdoor air quality is harmful. Another approach is to provide remote workers with portable air purifiers with HEPA filters, particularly in locations where appropriate ventilation is difficult to attain. Lastly, integrating these strategies with smart building technologies would maximize the health and wellness of building occupants.

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