Assessment of Particulate Matter (PM$_{2.5}$) in Residential Staff Quarters of Covenant University, Nigeria

Itebimien Oghenovo, Nsikak Benson*, Adebusayo Adedapo, Omowunmi Fred-Ahmadu
Department of Chemistry, Covenant University, Km 10 Idiroko Road, Ota, Ogun State, Nigeria
*Corresponding authors email: nsikak.benson@cu.edu.ng

Abstract. Over the years, the quality of outdoor air has received more attention than indoor air quality because people generally assume that only ambient air is polluted. Studies have shown that humans spend 70-80% of their time indoors, ranging from workplaces to homes. Based on the findings of these studies, outdoor exposure measurement is insufficient to estimate the total exposure of humans to particulate matter, PM$_{2.5}$ pollution. The increasing interest of researchers and international bodies in indoor air quality evidenced in the study of different indoor pollutants, placing PM at the forefront. The air quality in the residential staff quarters of Covenant University was examined by taking continuous measurements from the indoor environment for three (3) days using standard sampling and analytical methods Air Ae Steward, an air quality monitoring device. The concentrations of PM$_{2.5}$ in eleven (11) residential apartments were determined. The results indicate substantial indoor levels of PM$_{2.5}$ with the highest and least mean values of 91.0±5.0 and 34.0±4.0 µg/m$^3$, respectively. PM$_{2.5}$ indoor concentration was found to be higher than the World Health Organisation guideline value of 25 µg/m$^3$. Considering that inhabitants of these facilities spend more time indoors, appropriate ventilation systems would reduce health related risks associated with PM$_{2.5}$.

Keywords: Particulate matter (PM$_{2.5}$); Indoor air quality; Residential building; Indoor air pollution; Toxicity potential

1. Introduction

Indoor air pollution has become a major universal problem and has been largely associated with different human health issues. However, the degree of risks linked with indoor air pollutants such as fine particulates is a function of the pollutant indoor burden, chemical composition and particle size, which sums the overall air quality of an indoor facility. Indoor air quality (IAQ) describes the quality of air within a building or structure as it relates to the occupants' health and comfort [1]. Particulate matter (PM) refers to complex mixtures composed of liquid and solid particles suspended in the air [2]. It is a significant component in the indoor air. It has been observed universally, that exposure to PM emissions pose a variety of health concerns to the public, especially in developing countries. Many gaseous pollutants and particulates are known to originate from indoor sources that are possibly hazardous to health and their concentrations are often much higher than outdoors [3]. According to World Health Organization (WHO), particulates are classified according to their aerodynamic diameter and ranged from the ultrafine (< 2.5 µm) to coarse (> 2.5 µm - 10 µm) particles. PM$_{2.5}$ known as fine PM with diameter less than 2.5 µm are capable of penetrating the alveolar region of the
respiratory system [1,5]. It is formed from the burning of fuels in vehicles, wood, stoves and power plants [4]. The reported levels of PM$_{2.5}$ in some countries were higher than the standards recommended by the WHO for indoor PM$_{2.5}$ (25µg/m$^3$ 24-hour and 10µg/m$^3$ annual mean) [5]. Indoor air pollution has caused an alarming increase in the mortality rates and incidences of respiratory diseases. The leading human health risk factor has been shown to be PM in the indoor air. Both natural and anthropogenic activities emit pollutants that react to form PM in the atmosphere thereby contributing to the emission of PM directly or indirectly [6]. Fine particles (PM$_{2.5}$) are considered to be an essential indicator of PM related health risk [7].

Residential buildings are ranked as the most used indoor place and can lead to adverse health effects of residents if IAQ is poor [8]. Indoor exposure to PM$_{2.5}$ may be higher than those from ambient air exposure because of lesser dilution degree and longer duration of dispersion of pollutants. However, activities of humans are important indoor factors. Various studies have quantified and reported the contributions of humans to concentrations of pollutants in the indoor environment [9, 10]. The inadequate IAQ in the indoor environment can easily counteract the well-being of an individual [11, 12]. Unlike other indoor air pollutants, PM vary considerably with regards to their physical state (liquid or solid), toxicity, how they behave and transform in the air, chemical composition, mass and size. In highly populated areas, health risks are more likely where a combination of PM$_{2.5}$ pollution and other hazardous factors such as odours, vibrations and noise can result to great disturbance and damage to health of occupants [13, 14]. The size of the particle determines where the particle will be deposited in the human body. Fine particles ≤ 2.5 µm can penetrate as far deep as the alveoli [15]. Different sources generate the PM in the indoor environment and it also diffuses from outside. However, the PM$_{2.5}$ generated is influenced by other factors which include socio economic factors (types of stoves, type of cooking fuel, kitchen facilities and cooking methods), cleaning, smoking, use of air fresheners, use of mechanical or natural ventilation systems, burning of candles [16,17,18]. Building structure and design also determine the rate of infiltration.

In 2012, WHO reported that over 3.3 million deaths worldwide were attributed directly to particulate matter pollution [19]. The associated health effects are classified into short term and long term health effect. Short term health effects may be evident immediately after just a single exposure; these effects include irritation of the nose, throat and eyes, dizziness, fatigue and headaches. Short term exposure to PM$_{2.5}$ has also been associated with an increase in the rate of mortality [20, 21], hospital admissions [22], and risks of hospital emergency visits for cardiovascular diseases (CVD) [23]. For people with diseases like asthma, exposure may begin to show immediate symptoms and their condition may be aggravated. The treatment most times, is to ensure that persons are not exposed to the sources of pollution. Several factors can contribute to the immediate effect on air pollution. These include previously existing medical conditions, individual sensitivity and age which varies to a large exists from person to person [24]. Other effects on health become obvious after several years of exposure or after prolonged and repeated exposure. These effects include respiratory diseases, cancer and heart diseases which are very serious and fatal [25]. The aim of this study therefore, was to investigate the air quality in residential staff quarters of Covenant University where faculty, staff and their families practically spend a higher percentage of their time and to generate credible scientific data on the pollution levels of residences in order to prevent undesirable health effects.

2. Materials and method
2.1 study Area
The concentrations of PM$_{2.5}$ were monitored at eleven (11) residential staff quarters of Covenant University using Air Ae Steward: Air quality monitor for three (3) consecutive days. Morning and evening sampling was conducted in the living room and dining area during the on-set of wet season.
Sampling started at about 06:00 am and ended by 18:00 pm daily. Meteorological parameters (temperature and relative humidity) were also measured using same equipment. The temperature range was between 26°C - 32°C while relative humidity was between 65.5% - 79.0%.

2.2 Description and procedure for the operation of Air Ae Steward: Air quality monitor

The 6 in 1 multifunctional air quality monitor is a reliable and simple instrument for measuring PM$_{2.5}$, PM$_{10}$, formaldehyde (CHOH), total volatile organic compounds (TVOC), relative humidity (RH) and temperature. It combines both performance and ease of use, powered by dry cell AA batteries. It has high quality sensing elements to provide reliable and precise readouts with two display options, TVOC/CHOH and PM$_{2.5}$/PM$_{10}$.

Table 1: Description of Air Ae Steward: Air quality monitor

| Specification                          | Product function parameters |
|----------------------------------------|----------------------------|
| Display: LCD screen + LED display light| PM$_{2.5}$: 0-50 µg/m$^3$, precision 1 µg/m$^3$ |
| Power supply Voltage: DC 5V/1mA        | PM$_{10}$: 0-999 µg/m$^3$, precision 1 µg/m$^3$ |
| Operating temperature range: -15 to +50°C | CHOH: 0-99.99 µg/m$^3$, precision 0.001 mg/m$^3$ |
| Relative humidity range: 15-90% RH     | TVOC: 0-99.99 µg/m$^3$, precision 0.001 mg/m$^3$ |

2.3 Procedure for the operation of Air Ae Steward: Air quality monitor

The monitor was hand-held at breathing level (1.5m above ground level). Boot nob was longed pressed for about 3 seconds to turn on the Air Ae Steward: Air quality monitor. PM$_{2.5}$/PM$_{10}$ µg/m$^3$ and TVOC/CHOH mg/m$^3$ character twinkled recognition, all parameters read 0000 on the LED display. The monitor read the first parameters PM$_{2.5}$/PM$_{10}$, relative humidity and temperature readout on the LED display. The alarm light beeps green for optima, green for nice, yellow for pollution and then red for serious air pollution levels.

3. Results and discussion

3.1 Concentrations of PM$_{2.5}$

Generally, from the results obtained for PM$_{2.5}$, it was observed that the mean values from both morning and evening for all residences ranged from 43.0±1.0 to 91.0±5.0 µg/m$^3$ for day 1, 34.0±4.0 to 57.5±2.5 µg/m$^3$ for day 2 morning, 41.5±1.5 to 61.0±0.0 µg/m$^3$ for day 2 evening, 42.0±2.0 to 62.0±1.0 µg/m$^3$ for day 3 morning, 42.0±2.0 to 53.0±3.0 µg/m$^3$ for day 3 evening. All the residential quarters present values that are above the standard (25µg/m$^3$) set by WHO, EPA and FEPA [5, 1, 26]. According to [4] the air indoors can sometimes be more polluted than even the highly polluted outdoor urban air. This may pose a potential health risk for people living in these residences [27-28]. The indoor PM$_{2.5}$ concentration from the eleven (11) residential buildings for the three (3) days sampling is as shown in Figure 1. The concentrations of PM$_{2.5}$ were observed to be higher in the evening than in the morning. This may be attributed to higher human activities such as cooking, cleaning, playing and raising dust, after work and school by parents and children, respectively.
3.2 Toxicity assessment

The toxicity capacity of the measured concentration levels was assessed by using a calculated index (Toxicity potential, TP), that reflects the potential harm of a unit of pollutant present in the indoor environment. It is calculated using equation (1).

\[
\text{Toxicity potential (TP)} = \frac{C_p}{S_p} \quad (1)
\]

Where \( C_p \) is the measured pollutant concentration and \( S_p \) is the air pollutant standard [29]. Ideally, the TP value should be \( \leq 1 \).

The estimated toxicity potential based on the concentrations of PM\(_{2.5}\) is presented in Figure 2. In correlation with the concentration levels, the TP values were found to be higher in the evening than in the morning. The TP values for all residences ranged from 1.72 to 3.64 for day 1, 1.36 to 2.3 for day 2 morning, 1.66 to 2.44 for day 2 evening, 1.84 to 2.48 for day 3 morning, and 1.6 to 2.2 for day 3 evening. This suggests that occupants are at higher risk of exposure and toxicity to PM\(_{2.5}\) in the evenings than in the mornings. The quality of the indoor air is controlled by a mixture of different pollutants from different sources, and is influenced by building maintenance, construction materials used, ventilation channels, the sort of action performed by different occupants [30]. Since most of the human activities occurs in the evening. The factors mentioned might contribute to this claim. In general, the values of TP for all investigated locations were greater than 1, which indicates high levels of PM\(_{2.5}\) toxicity.

Figure 1: Comparison of PM\(_{2.5}\) concentrations (mean±s.d) at indoor locations against the recommended standard.
Figure 2: Toxicity potential assessment for indoor locations at Covenant University, Ota.

4. Conclusion
The air quality in the indoor environment of selected Covenant University staff residences was measured. Our results show an increased concentration of PM$_{2.5}$ at all sampled locations, which is an indication of likely potential risk to the occupants of the residences. Women and children are also likely to be the most affected by indoor PM$_{2.5}$. The hotspot for elevated IAP was identified to be kitchens and this is as a result of biomass combustion during heating. The deterioration of IAQ and the elevation of IAP associated with PM$_{2.5}$ have previously been found to cause non-respiratory and respiratory diseases due to exposure to particulate-laden indoor air. Indicatively, the indoor air quality at these investigated locations could in the long run exacerbate cardiovascular and respiratory diseases. From the results, the PM$_{2.5}$ are substantially high and could pose a high risk to occupants’ health and well-being. To this end, the following are recommend: a) the implementation and development of strategies for indoor PM$_{2.5}$ intervention and should cover aspects such as good housekeeping, proper ventilation, and improved cooking gas and stoves fuel efficiency; b) the installation of air quality monitors in homes to alert occupants when the PM$_{2.5}$ level is elevated, and c) regular air quality monitoring programs should be conducted to safeguard the lives of faculty and staffers against enhanced levels of pollution.

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References

[1] United States Environmental Protection Agency (US EPA), (2009). Integrated Science Assessment for Particulate Matter (Final Report). United States Environmental Protection Agency (US EPA), Washington, DC.

[2] Long, C., & Valberg, P., (2017). Indoor Airborne Particulate Matter: Unregulated, but a Major Contributor to Our Everyday Exposure. *Natural Resources and Environment Chicago*. 32(1), 8-12.

[3] Rudel, R., & Perovich, L., (2009). Endocrine disrupting compounds in indoor and outdoor air. *Atmosphere Environment*. 43, 170-181.

[4] Philip J., Charlse S., & Emily D., (1992). Indoor Air Quality. 7th Edition ISBN 0-8493-5015-8 (4), 6-20.

[5] World Health Organization (WHO), (2006). Air Quality Guidelines. The Regional Office for Europe of the World Health Organization, Copenhagen, Denmark Available online at http://www.euro.who.int/__data/assets/pdf_file/0005/78638/E90038.pdf.

[6] Liu, L., Ruddy, T., Dalipaj, M., Poon, R., Szyszkowicz, M., You, H., Dales, R., & Wheeler, A., (2009). Effects of indoor, outdoor, and personal exposure to particulate air pollution on cardiovascular physiology and systemic mediators in seniors. *Journal of Occupational and Environmental Medicine*. 51(9), 1088-1098.

[7] World Health Organization (WHO), (2016). Ambient (Outdoor) Air Pollution Database, by Country and City Available online at www.who.int/phe/…/outdoorair/databases/WHO_AAP_database_May2016_v3web.xlsx.

[8] Fairchok, M., Martin, E., Chambers, S., Kuyers, J., Behrens, M., & Braun, J., (2010). England Epidemiology of viral respiratory tract infections in a prospective cohort of infants and toddlers attending daycare. *J. Clin. Virol.* 49

[9] Buonanno G., Fuoco, F., Mariní, S., & Stabile, L., (2012). Particle resuspension in school gyms during physical activities. *Aerosol Air Qual. Res.* 12 (5), 803–813.

[10] Braniš M., & Šafránek, J., (2011). Characterization of coarse particulate matter in school gyms. *Environ. Res.* 111 (4) 485–491.

[11] Andrade A., Dominski, F., & Coimbra, D., (2017). Scientific production on indoor air quality of environments used for physical exercise and sports practice: bibliometric analysis. *J. Environ. Manage*. 196 188–200.

[12] Ramos C., Reis, J., Almeida, T., Alves, F., Wolterbeek, H., & Almeida, S., (2015). Estimating the inhaled dose of pollutants during indoor physical activity. *Sci. Total Environ.* 527–528.

[13] Bo, M., Clerico, M., & Pognant, F. (2016), Annoyance and disturbance hazard factors related to work and life environments: A review. *Geam-Geoing.Ambient.EMineria-Geam-Geoengin. Environ. Min.* 149, 27–34.

[14] Kephalopoulos, S., Koistinen, K., Paviotti, M., Schwela, D., Kotzias, D., Proceedings of the International Workshop on “Combined Environmental Exposure: Noise, Air Pollutants and Chemicals”. Available online: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/proceedings-international-workshop-combined-environmental-exposure-noise-air-pollutants-

[15] Utell, M., & Frampton M., (2000). Acute health effects of ambient air pollution: The ultrafine particle hypothesis. *J. Aerosol. Med.* 13, 355-359. doi:10.1089/10.2000.13.355.

[16] Wallace, L., (1996). Indoor Particles: A Review. *J. Air Waste Manag. Assoc.* 46, 98–126.

[17] Jones, N., Thornton, C., Mark, D., & Harrison, R., (2000). Indoor/outdoor relationships of particulate matter in domestic homes with roadside, urban and rural locations. *Atmos. Environ.* 34, 2603–2612.

[18] Lai, H., Kendall, M., Ferrier, H., Lindup, I., Alm, S., Hänninen, O., Jantunen, M., Mathys, P., Colville, R., & Ashmore, M., (2004). Personal exposures and microenvironment concentrations of PM2.5, VOC, NO2 and CO in Oxford, UK. *Atmos. Environ.* 38, 6399–6410.

[19] World Health Organization (WHO), (2012). Burden of disease from household air pollution for 2012. World Health Organization. Available at: http://www.who.int/phe/health_topics/outdoorair/databases/AAP_BoD_results_pdf.
[20] Fajersztajn, L., Saldiva, P., Pereira, L., Leite, V., & Buehler, A., (2017). Short-term effects of fine particulate matter pollution on daily health events in Latin America: a systematic review and meta-analysis. *Int. J. Public Health*. 62, 1–10. https://doi.org/10.1007/s00038-017-0960-y.

[21] Laden, F., Schwartz, J., Speizer, F., & Dockery, D., (2006). Reduction in fine particulate air pollution and mortality: extended follow-up of the Harvard Six Cities Study. *Am. J. Respir. Crit. Care Med.* 173, 667–672. https://doi.org/10.1164/rccm.200503-443OC.

[22] Dominici, F., Peng, R., Bell, M., Pham, L., McDermott, A., Zeger, S., & Samet, J., (2006). Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. *JAMA*. 1127–1134 https://doi.org/10.1001/jama.295.10.1127.

[23] Metzger, K., Tolbert, P., Klein, M., Peel, J., Flanders, W., Todd, K., Mulholland, J., Ryan, P., & Frumkin, H., (2004). Ambient air pollution and cardiovascular emergency department visits. *Epidemiology*. 15, 46–56. https://doi.org/10.1097/01.EDE.0000101748.28283.97.

[24] Pan L., Dong W., Li H., Miller M., Chen Y., Loh M., Wu S., Xu J., Yang X., Shima M., Deng F., & Guo X., (2018). Association patterns for size-fractioned indoor particulate matter and black carbon and autonomic function differ between patients with chronic obstructive pulmonary disease and their healthy spouses. *Environ Pollut.* 26(236), 40-48. doi: https://doi.org/10.1016/j.envpol.2018.01.064.

[25] Gharaibeh, A., El-Rjoob, A., & Harb, M., (2010). Determination of selected heavy metals in air samples from the northern part of Jordan. *Environ. Monit. Assess.* 160, 425-429.

[26] Federal Environmental Protection Agency (FEPA) (1991). National Interim Guidelines and Standards for Industrial Effluents, Gaseous Emissions and Hazardous Waste. *Environmental Pollution Control Handbook*. Lagos. 62-67.

[27] Goyal, R., Khare M., & Kumar P., (2012). Indoor air quality: current status, missing links and future road map for India. *J Civil Environ Eng*. 2:4. http://dx.doi.org/10.4172/2165-784X.1000118.

[28] Baek, S., Kim, Y., & Perry, R., (1997). Indoor air quality in homes, offices, and restaurants in Korean urban areas indoor/outdoor relationships. *Atmos Environ*. 31, 529–44.

[29] Ayodele C., Fakinle B., Jimoda L., & Sonibare J., (2016). Investigation on the ambient air quality in hospital environment. *Cogent Environ. Sci.* 2.

[30] Ramos, C., Wolterbeek, H., & Almeida, S., (2014). Exposure to indoor air pollutants during physical activities in fitness centers. *Building and Environment*. 82, 349-360