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Evaluation of the Indoor Air Quality in the Production Area of Pharmaceutical Factory Buildings in Southwest Nigeria

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Abstract
The factory building houses people, equipment, materials, and circulation spaces. These features contain various types of matter, and because the pharmaceutical factory building is active, these characteristics can have an impact on the workers' health and performance. This paper investigated the indoor air quality of the production area in order to compare it to the established data for the normal built environment. The air quality was measured using the Multifunctional Air Quality Detector, the KXL-801 LCD CO Gas Carbon Monoxide Detector, and the HABOTEST HT625A Digital Anemometer, and the results were compared to established data from published literature relating to indoor air quality on the ground from fourteen (14) sampled PFBs in the study area. In this study, regression analysis was used to analyse the data obtained, while tables and figures were used for presentation. It was discovered that 60% of the parameters exceeded the globally accepted limits, indicating the need for more IAQ consideration in the design and operation of PFBs. The study suggests that smart technology be used to control the excessive presence of IAQ.

Keywords
Indoor Air Quality, Design, Factory Building, Health, Production Area

INTRODUCTION

The production area is one of the major sections of the pharmaceutical factory buildings (PFBs). It is in fact the most important, secured, serene and the most controlled indoor environment in the PFB. This is largely because the production area is the space in the building where various chemicals and components are processed for the production of drugs for human consumption. It is here that Chemical Synthesis, Fermentation, Extraction, Formulation and Packaging occur in manufacture of pharmaceutical products (Kaplan and Laing, 2005). Mostly drugs were obtained through the extraction from medicinal plants and but pharmaceutical drugs may be used for a limited duration, or on a regular basis for the chronic disorders, (Patel et al., 2015; Tsompos, et al., 2015 and Swapnil, et al., 2015). It has been reported that factories are up against several constraints, including challenges posed by infrastructure decay, unfair government policies, poor marketing and administrative structure, low-capacity utilization, spiralling cost of business as a result of the high cost of inputs, lack of effective research and development, (pharmapproach, 2022).

It is known that indoor air has a large share of the influence on people in buildings compared to outdoor air. Indoor air can contain both biological and chemical pollutants indoor air (Abdulaali, et al., 2020). Smith and Pitt (2011) explained that chemical constituents of the pollutants comprise carbon dioxide (CO_2), radon, nitrogen oxide (NOx) asbestos, respirable suspended particulates (RSPs), construction chemicals, and ozone. While the biological pollutants could be pest, dust mites, houseplants, moulds, endotoxins, and pollen (Smith & Pitt, 2011). Joshi (2008) and Abdulaali, et al., (2020) proved that these pollutants can be hazardous to the human health and thereby cause asthma, sick building syndrome (SBS) as well as various respiratory allergies. Dubbs (1990), Wargocki et al., (2000), Lee et al., (2009), Smith and Pitt (2011), Abdulaali et al., (2020), and Bawa et al., (2022), agreed that indoor air quality (IAQ) is vital to the health of building users. The paper focuses on the chemical constituents of the indoor air pollutants and these are particulate matter ($PM_{1.0}$, $PM_{2.5}$, and PM_{10}), carbon dioxide (CO_2), formaldehyde (HCHO), total volatile organic compound (TVOC) and air velocity. Hence, the comparison of the indoor air quality of the production area in the PFBs in Southwestern Nigeria with the established data for the normal built environment.

PHARMACEUTICAL FACTORY BUILDING

The PFB houses processes that lead to the manufacturing of drugs, these processes could occur concurrently in any place, though sufficient pharmaceutical production is subcontracted to third parties (Kaplan and Laing, 2005). The API is a biologically dynamic compound(s) in a drug preparation that informs the anticipated therapeutic effect (Kaplan and Laing, 2005). In-between the processes in the PFBs is a material that is produced in the process of making a fragmentary with Active Pharmaceutical Ingredients (APIs) which has to experience more molecular modification before it progresses to an API (Kaplan and Laing, 2005).

Production in the PFBs happens in an enclosed environment for 7 - 9 hours for five or six days per week with only an hour for break daily for the workers (World Health Organization, 2007; Bawa et al., 2022). Adding to the above, the indoor air quality (IAQ) of the production area of the PFB has another influence, and it is that it always contains chemicals (Tait, 1998; Kubba, 2016; World Health Organization, 2007). Pharmaceutical factory buildings (PFBs) sustains active regulation and restriction of the influx of outside climatic elements (such as wind, water vapour, rain and moist air) from inside of the production area so the chemicals, processes and drugs produced are secured from pollution (World Health Organization, 2003). Most PFBs are designed without windows (Zhuang, 2020, Bawa et al., 2022); while those having them do so with constrictions so to permit only natural lighting into the inside environment (World Health Organization, 2007). Bornehag et al., (2001) and Bawa et al., (2022b) expressed that pollutants in built environments are often related with respiratory health challenges and could be traceable to the presence of moisture, water damage or microbiological pollutants. McCarthy (2001), Pilotto et al., (1997), Norback et al., (2000) Menzies et al., (1993), Milton et al., (2002), Pazdrack et al., (1993), Wilbur et al., (1999), Garratt & Nowak (1991) McCoach et al., (1999) and Zock et al., (2001) discussed that combustion products, nitrogen dioxide, low ventilation rates, formaldehyde and chemicals in cleaning products could serve as sources of respiratory problem in buildings.

INDOOR AIR QUALITY

Al horr et al., (2016) explained IAQ in the strategies which building design firstly emphasizes on the improvement of IAQ by increasing ventilation rate, which will in turn act to reduce air pollution and this position supports the assertion of Daisey et al., (2003) and secondly suggesting that reducing the basis of the air pollution from both inside and outside the building to reduce and possibly eliminate all air pollutants in the indoor space. Abdul-wahab et al., (2015), Jones and Molina (2017), Paleologos, et al., (2021) and Taştan and Gokozan (2020) agree that air pollution is the biggest environmental health problem in the world. It is known that air pollution could have adverse effects on human health, the climate and the ecosystems in any country or region. Air pollution can cause many serious health problems such as respiratory, cardiovascular and skin diseases in humans. Nowadays, where air pollution has become the largest environmental health risk, the interest in monitoring air quality is increasing. Air is contaminated by toxic gases released by different sources such as industries, vehicle emissions and the increased concentration of harmful gases and particulate matter in the atmosphere. Harrison (2002) and Bawa et al., (2022a) highlighting the need to understand the health implications of indoor air quality that contain gaseous deposits against the globally acceptable standard expressed that it affects the health, wellbeing and productivity of users of indoor environments.

METHODOLOGY

This study explored some literature concerning IAQ for data and measurements that expressed and explained the parameters for this study and their requirements for a healthy built environment. The parameters investigated in this study are; particulate matter ($PM_{1.0}$, $PM_{2.5}$, and PM_{10}), carbon dioxide (CO_2), formaldehyde (HCHO), total volatile organic compound (TVOC) and air velocity. The literatures sourced for this study are e-books, website articles, and journals. The air quality was measured with the aid of the Multifunctional Air Quality Detector (Plate III) and the KXL-801 LCD CO Gas Carbon monoxide Detector (Plate I) and the HABOTEST HT625A Digital Anemometer (Plate II). The Multifunctional Air Quality Detector was used to obtain data for particulate matter ($PM_{1.0}$, $PM_{2.5}$, and PM_{10}), formaldehyde (HCHO), and total volatile organic compound (TVOC). While the KXL-801 LCD CO Gas Carbon monoxide Detector was instrumental for the readings that concerned carbon dioxide (CO_2) and the HABOTEST HT625A Digital Anemometer was employed for the measurement of air velocity. The quantitative and qualitative research approach were used in this study to compare the established data for indoor air quality as obtained from reviewed literature to the data obtained on the ground from fourteen (14) sampled PFBs. Tables and figures were used for analysis and presentation in this study.

RESULTS AND DISCUSSION

The World Health Organization (WHO, 2010) noted that certain criteria were used in selecting compounds for which the development of WHO guidelines for indoor air were recommended, these criteria include the existence of indoor sources, availability of toxicological and epidemiological data indoor levels exceeding the levels of health concern. These led to the inclusion of Benzene, Carbon monoxide, Formaldehyde Naphthalene, Nitrogen dioxide, Particulate matter ($PM_{2.5}$ and PM_{10}), Polycyclic aromatic hydrocarbons, benzo-[a]-pyrene, Radon, Trichloroethylene and Tetrachloroethylene as worth checking.

Plate I KXL-801 LCD CO Gas Carbon monoxide Detector
Source: Jumia, 2021

Plate II HABOTEST HT625A Digital Anemometer
Source: Habotest, 2021

Plate III Multifunctional Air Quality Detector
Source: Tomtop, 2021

Niu, et al., (2015) research showed some places having Average CO_2 indoor levels being often higher than the outdoor levels as stipulated in CNIAQS, with results pointing that indoor air pollution caused by PM_{10} was most serious in the office although the PM_{10} concentration investigated exceeded the CNIAQS level of 150 lg/m3 in Table 1. Niu, et al., (2015) added that $PM_{2.5}$ contributed significantly to PM_{10} as the built space had PM which was highly influenced by indoor activities.

Chen, et al., (2016) had stations where the density of CO_2 and HCHO met the required standards stipulated in TIAQMA, it was also seen that the TVOCs, and PM_{10} and $PM_{2.5}$ measured at some stations had densities that exceeded the stipulated standards in Table 1. And the possible source of the added TVOCs levels in the stations were not identified (Chen, Sung, Chen, Mao & Lu, 2016). It was also suggested that air flow velocity could improve the micro-climate of a built environment when using a single transparent façade in Table 1.

It was observed from the data collected at the sampled PFBs in the study area that most of them had met the standards for total volatile organic compound (TVOC) and Carbon dioxide (CO_2) with an average of 0.31ppb and 773.60ppm respectively. Although, 3 PFBs met the standard for formaldehyde (HCHO) for the IAQ, most of the PFBs did not meet the international standards as outlined on Table 1.

Table 1 International Standards for Air velocity, CO_2, Particulate matter, and TVOC for healthy IAQ

Air parameter	Unit	Standard level	Notes	Source`
Carbon dioxide (CO2)	%	0.1	24-h average	CNIAQS
	ppm	1000	8-h Average	TIAQMA
Formaldehyde (HCHO)	mg/m3	0.1	1-h average	CNIAQS
	ppm	0.08	1-h Average	TIAQMA
suspended particles (PMl0)	mg/m3	0.15	24-h average	CNIAQS
Particulate Matter- 10 (PM10)		120	Annual 24-hours	MoSTE, 2010
particulate Matter of 2.5–10 µm (PM10)	µg/m3	75	24-h Average	TIAQMA
Particulate Matter (PM2.5)		40	24-hours	MoSTE, 2010
particulate Matter of ≤2.5 µm (PM2.5)	µg/m3	35	24-h Average	TIAQMA
Total volatile organic compounds	mg/m3	0.6	8-h average	CNIAQS
(TVOC)	Ppm	0.56	1-h Average	TIAQMA
Air velocity	m/s	0.25		WHO, EN ISO 7730:2005

Table 2 highlights the maximum standards for air velocity and Particulate matter (PM_{10} and $PM_{2.5}$) for a healthy IAQ were exceeded.

Table 2 Some International Standards for various CO_2, Particulate Matter, and TVOC

Air parameter	Unit	Standard level	average	Maximum(24hours)	minimum(24hours)
Air Velocity	m/s	0.25	0.98	1.98	0.39
PM_{10}	mg/m	0.15-0.075(mg/m3)	17.18	69.47	0.25
$PM_{2.5}$	mg/m	0.035(mg/m3)	33.92	110.27	0.40
TVOC	ppb	0.56 to 0.6	0.31	1.22	0.10
CO_2	ppm	1000	773.60	562.47	1639.73
HCHO	ppm	0.08 to 0.1	0.87	3.79	0.03

Note: *The conversion rates of 1µg/m3= 0.01mg/m3, 1mg/m3=1ppb, 1%=10,000ppm*

CONCLUSION AND RECOMMENDATION

In conclusion, the need to achieve a healthy indoor environment is important. As it was outlined from the study above, the attainment of this is very possible only when the Indoor Air Quality of the built environment is attained. As in the case of the results above, there is still plenty to do to make the indoor space of the production area of PFBs to be healthy and encourage higher productivity from the workers.

It is recommended that more research is done on the building materials used for the PFB, its construction, its occupation, the maintenance, as well as the hygiene of the outside environment work carried out on it, as it is suggested that they could also contribute to the IAQ of the PFB.

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