Original Article

Physico-chemical assessment of indoor air quality of a tertiary hospital in South–South Nigeria

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Abstract

Background: Good ventilation is one of the structural designs used to reduce the risk of transmission of airborne infections in hospitals. This is, however, rarely observed in Nigeria as hospital designs used to shut out the inclement weather in temperate countries are copied without much modification. This study assessed the physico-chemical air quality at different areas of the University of Port Harcourt Teaching Hospital, Port Harcourt, to ascertain the level of pollutants in the ambient air.

Methods: The study was carried out in July, 2015, in randomly selected inpatient wards, outpatient clinics and clinical laboratories of the hospital, using the appropriate measuring equipment. The study tested for the presence of particulate matter 2.5 ($PM_{2.5}$), volatile organic compounds (VOCs) and nitrogen dioxide (NO_2) in the ambient air; as well as the prevailing micrometeorological indices of relative humidity, temperature, wind direction and speed of the study sites.

Results: A total of 36 air quality measurements were carried out in nine study sites in the hospital. The assessed pollutants were present in the ambient air of most of the study sites but were within the regulatory limits. The concentration of NO_2 in the study sites ranged from 133 $\mu g/m^3$ in the immunisation clinic to 151 $\mu g/m^3$ in the gynaecology ward, with a mean concentration of 141 $\mu g/m^3$; while $PM_{2.5}$ was not detected in the gynaecology and urology wards and present in very low levels in the other study sites. There was, however, greater variability in the levels of VOCs, ranging from 236.57 mg/m^3 in the HIV clinic to 530.77 mg/m^3 in the male surgical ward.

Conclusion: The levels of the assessed pollutants were within regulatory levels, even as there were evidence of poor ventilation in several of the study sites.

Keywords: Hospital, indoor air quality, Nigeria, nitrogen dioxide, particulate matter 2.5, pollutants, Port Harcourt, volatile organic compound

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INTRODUCTION

Communicable diseases are still the most prevalent diseases in Nigeria, despite the increasing prevalence of non-communicable diseases.[1] These patients with communicable diseases prefer to seek treatment in orthodox hospitals, thus aggregating the various causative agents of their diseases in one place, placing other patients, visitors to the hospital and healthcare workers at risk. The risk of infection in a hospital is further increased by the

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increasing number of patients with immune depression, as a result of HIV/AIDS, and other immune-suppressing diseases such as cancer and diabetes.[2]

Good ventilation is one of the structural designs used to reduce the risk of transmission of airborne infections in hospitals.[3] Studies have shown that ventilation rates lower than two air changes per hour (ACH) are associated with higher tuberculin skin test conversion rates among health workers;[4] because a higher ventilation rate can provide a higher dilution capability and consequently reduce the risk of airborne infections.[5] Lower ventilation rates have also been associated with outbreaks of sick hospital syndrome, causing headaches, fatigue, eye and skin irritations and other symptoms.[6] These explain why the WHO recommends the use of natural ventilation to achieve a minimum of 80 l/s/patient (hourly average ventilation rate) for airborne precaution rooms such as theatres and a minimum of 60 l/s/patient for general wards and outpatient departments, to reduce the risk of airborne infections in the hospital, especially for hospitals in developing countries.[5]

This is, however, not the case in many hospitals in Nigeria as hospital designs used to shut out the inclement weather in temperate countries are copied without much modification and without adequate provisions to constantly power the mechanical ventilation mechanisms required to achieve the required number of ACH.[7] We, therefore, suspect that several hospitals in Nigeria, especially the newly constructed tertiary hospitals, have poorly ventilated wards, clinics and laboratories and are therefore putting the health of patients, hospital visitors and health workers at risk. To test this hypothesis, we assessed the physico-chemical air quality of the laboratories, wards and clinics of a tertiary hospital in Port Harcourt, before and after the peak working period. It is hoped that the results of this study would help highlight the risk of poor ventilation in hospitals, enough to elicit corrective actions.

METHODS

Study site

The study was carried out in the University of Port Harcourt Teaching Hospital, one of the two multi-speciality tertiary healthcare institutions in Port Harcourt, the capital of Rivers State, South–South Nigeria. Although located in Port Harcourt, the catchment area of the hospital extends beyond Rivers State, to include much of the Niger Delta region; a catchment population that can be conservatively put at 10 million people. The hospital is an 800-bed multi-specialist teaching hospital located in a large expanse of land, but housed in interconnected multi-storey buildings that occupy a small percentage of the total land space, and ventilated by both natural and mechanical ventilation. The hospital offers not only tertiary healthcare services but also secondary and primary health care, due to the near collapse of the other facilities in the State and region. It is heavily patronised with average bed occupancy of more than 78% and a daily average outpatient attendance of 624. It carries out an average of 8.42 surgical operations every day and handles an average of 9.24 deliveries each day.

A descriptive cross-sectional study design was used. The physico-chemical air quality of randomly selected inpatient wards, outpatient clinics and clinical laboratories of the hospital was assessed using the appropriate measuring equipment. The hospital has 23 inpatient wards, 17 outpatient clinics and 4 clinical laboratories; of these, only those who attend to a minimum of 30 patients in each service day were considered for the study. Subsequently, four outpatient clinics (immunisation clinic, HIV clinic, surgery outpatient clinic and antenatal clinic), three wards (gynaecological ward, male surgical ward and urology ward) and two laboratories (medical microbiology and anatomical pathology) were randomly selected for the study.

The study was carried out in July, 2015, the peak of the rainy season in the study area. The assessment of the physico-chemical air quality of the study sites was carried out *in situ*, through the measurement of particulate matter 2.5 ($PM_{2.5}$), volatile organic compounds (VOCs) and nitrogen dioxide (NO_2) in the ambient air, as well as the assessment of the prevailing micro meteorological indices of relative humidity, temperature, wind direction and speed in the study sites. An Aeroqual environmental gas monitor equipped with the infrared sensor was used to measure VOCs and NO_2; an Aerocet 531 particle mass monitor was used to measure $PM_{2.5}$; while an Extech portable weather station was used to collect the meteorological data. Measurements with the various instruments were carried out by first warming up the instrument, for about 3 min, to burn off any contaminant on the sensor of the instrument; and then holding the sensor at the height of 1.5 m, in the prevailing wind direction, to take the required measurement.

The assessments were carried out *in situ*, twice a day, between 9 and 11 am, at the peak of clinical activities, and later in the day, between 4 and 6 pm, at the end of the peak working period. A total of three weekly assessments were carried out in each of the study sites.

The data collected during the study were recorded on a field notebook, inputted into a database, after checking for consistency and completeness; and then analysed.

Summary measures were calculated for each outcome of interest, while the test of significance was conducted using the relevant statistical test, at 95% confidence interval, with $P \leq 0.05$ considered statistically significant. The mean ambient levels of the assessed air pollutants were compared with the relevant WHO guideline values,[8] to ascertain if they met the regulatory standard; while the health implications of the mean ambient levels were assessed by comparing with the relevant toxicological studies.[8] The guideline value of $PM_{2.5}$ was taken as 25 μg/m^3/day, while that for NO_2 was taken as 200 μg/m^3 for 1 h mean.

Ethical consideration

The approval to conduct the study was sought and obtained from the Ethical Review Committee of the University of Port Harcourt, Port Harcourt; while informed consent was sought and obtained from the management of the University of Port Harcourt Teaching Hospital and the heads of all the study sites.

RESULTS

A total of 36 air quality measurements were carried out in nine study sites in the hospital. There was a detectable level of the assessed pollutants in the ambient air of most of the study sites although the levels were all within the regulatory limits. The mean concentrations of the air pollutants are presented in Table 1. The concentration of NO_2 in the study sites ranged from 133 μg/m^3 in the immunisation clinic to 151 μg/m^3 in the gynaecology ward, with a mean concentration of 141 μg/m^3. $PM_{2.5}$ was not detected in the gynaecology and urology wards and was detected in very low levels of between 0.01 and 0.03 μg/m^3 in the other study sites.

There is no statistically significant difference in the concentration of the pollutants in the different study sites. The mean concentration of NO_2 in the clinics was 137.50 μg/m^3, which is comparable to 145.10 μg/m^3 recorded in the laboratories and 143.33 μg/m^3 recorded in the wards (P = 0.95). There is wide variability in the concentration of VOCs in the study sites, even as there is no statistically significant difference in the mean concentration of VOCs in the clinic (423.71 mg/m^3) when compared to 487.70 mg/m^3 recorded in the laboratories and 497.22 mg/m^3 recorded in the wards (P = 0.70).

The mean concentrations of the pollutants during and after the peak working time are presented in Table 2. There were no significant differences in the concentrations of the pollutants during and after the peak working time. The mean concentration of NO_2 in the clinics during the peak working time was 133.33 μg/m^3, which is not significantly different from 140.10 μg/m^3 recorded after the clinic hours. The mean concentration of $PM_{2.5}$ in the laboratories during the peak working time was 12.32 μg/m^3, which is not significantly different from 19.53 μg/m^3 recorded after the peak working period.

The meteorological data of the study sites are presented in Table 3. There were significant differences in the temperature, relative humidity and wind speeds of the study sites. The mean temperature of the study sites was 27.8°C, ranging from 27.03°C in the HIV clinic to 28.15°C in the antenatal care (ANC) clinic; however, the mean temperature of the laboratories (28.11°C) is higher than 27.69°C in the clinics and 27.85°C in the wards (P = 0.00). The mean relative humidity in the laboratories (84.03%) is also higher. The wind speed in the anatomical pathology laboratory and in the ANC is the lowest at 0.07 m/s, compared to the mean value of 0.13 m/s, and the highest of 0.27 m/s recorded in the urology clinic. Wind speed was generally higher in the inpatient wards (0.16 m/s).

DISCUSSION

The study showed comparable levels of NO_2 and $PM_{2.5}$ in all the study sites, wide variability in the levels of VOCs and significantly differences in the meteorological data of the study sites, which are all comparable to the findings of

Table 1: The mean concentrations of the air pollutants in the study sites

Pollutant	Clinics	Laboratories	Wards	*P*
NO_2 (μg/m^3)	137.50	145.10	143.33	0.95
$PM_{2.5}$ (μg/m^3)	6.67	2.51	3.33	0.75
VOC (mg/m^3)	423.71	487.70	497.22	0.70

VOC: Volatile organic compound, PM: Particulate matter, NO_2: Nitrogen dioxide

Table 2: The mean concentrations of the pollutants during and after the peak working time

Pollutant	Clinics	Laboratories	Wards
NO_2 (μg/m^3)			
Morning	133	147	144.67
Evening	140	148.50	134.33
$PM_{2.5}$ (μg/m^3)			
Morning	10.5	12.08	5.33
Evening	9.25	19.53	5.01
VOC (mg/m^3)			
Morning	445.18	466.55	451.14
Evening	402.25	508.82	543.33

VOC: Volatile organic compound, PM: Particulate matter, NO_2: Nitrogen dioxide

Table 3: The meteorological data of the study sites

Pollutant	Clinics	Labs	Wards	Mean	*P*
Temperature (°C)	27.69	28.11	27.85	27.83	0.00
Relative humidity (%)	83.99	84.03	82.57	83.52	0.02
Wind speed (m/s)	0.13	0.10	0.16	0.13	0.08

other studies.[9] The levels of NO_2 and $PM_{2.5}$ recorded in our study are comparable to those recorded in other hospitals.[9] The pollutants are often not produced by clinical activities, as shown by the comparable levels we recorded in all the study sites, during and after the peak working time. The pollutants are principally generated from the burning of hydrocarbons, mainly from sources outside the hospital. The levels of the pollutants in hospitals are, however, related to the outdoor air quality. Outdoor air quality at city centres is often worse than in the suburbs.[9,10] The study hospital is located more than 10 km from the city centre and some distance from the highway, which can explain the low levels of the pollutants recorded in the hospital.

The mean concentration of the pollutants in the study hospital is lower than the WHO regulatory levels,[8] which means they pose little hazard to health. However, some studies suggest that NO_2 can cause respiratory symptoms in children, at levels significantly lower than the WHO guideline value, especially in the presence of other pollutants such as $PM_{2.5}$.[8] This means that the levels of NO_2 recorded in the study hospital could affect the lung function of children and trigger off bronchitic symptoms in asthmatic children.[8]

The presence of $PM_{2.5}$ in the ambient air of the hospital is also not without any adverse health effect, especially as studies have established a link between the level of PM in the ambient air and the mortality and morbidity from pre-existing diabetes, respiratory and cardiac diseases.[11,12] The risks of these pollutants to children, even at the levels recorded in our study, indicate the need to install properly maintained filters in paediatric wards and clinics of the hospital, especially where mechanical ventilation is used.[13]

Wide variations in the level of VOCs were, however, recorded in the study sites, which indicate a possible endogenic source, unlike NO_2 and $PM_{2.5}$.[14] VOCs are a wide range of organic compounds with low boiling points such that they exist in gaseous form at room temperature. They often accumulate in the indoor environment and are commonly generated in the hospital in the course of cleaning, disinfection, clinical and laboratory activities. More than 40 different types of VOCs were found in a teaching hospital in France, with the majority of them alcohol, ketones and ethers that were released in the course of carrying out different activities in the hospital.[15] These explain the higher levels of VOCs recorded in our study in the inpatient wards and the laboratories, where therapeutic, cleaning and disinfection agents are used in greater quantity, and where there are more procedures likely to aerosolise the VOCs. These are consistent with the findings of a similar study carried out in Taiwan.[14] The presence of significant levels of VOCs calls for action as VOCs have been associated with many adverse health effects including subjective symptoms, eye and nose irritation, allergy, liver and kidney dysfunction, neurological impairment and cancer.[16,17] Toxicological studies suggest that some of the VOCs such as benzene, xylenes, chloroform and formaldehyde can be carcinogenic.[15,17]

There are significant differences in the meteorological data recorded in the different study sites. This indicates possible differences in the level of ventilation of the study sites and confirms our study hypothesis of poorly ventilated clinics, inpatient wards and laboratories that put the health of patients and health workers at risk. The antenatal clinic had the lowest wind speed but also had the highest mean ambient temperature. This means that the clinic did not have enough ventilation to provide thermal comfort to the hundreds of pregnant women who attended the clinic, resulting in increased ambient temperature. It also confirms the inadequacy of the mechanical air conditioning used in the clinic, a situation that is very common in hospitals in resource poor countries[18] that prompted the WHO to recommend the use of natural ventilation.[5]

The wind speed was also very low in the anatomical pathology laboratory, which also explains the high mean ambient temperature of 28.11°C recorded in the laboratory. These also indicate that the laboratory was poorly ventilated. While the poor ventilation in the antenatal clinic pre-disposes the patients and health workers in the clinic mainly to airborne infections, the situation in the anatomical pathology laboratory, in addition, puts the health workers in the laboratory to dangerous levels of chemicals such as latex allergens and formaldehyde that are routinely used in the laboratory. Several of the chemicals have been shown to cause the sick hospital syndrome;[6] while latex allergens dispersed by latex gloves have been shown to trigger asthmatic attack in sensitive health workers.[19]

The health hazard was posed by poor ventilation calls for the proper maintenance of the mechanical ventilation system of the study hospital, to ensure that it continues to effectively serve its purpose. This would involve the establishment of an Indoor Air Quality Management Programme to not only ensure the proper maintenance of the mechanical ventilation system but also coordinate all activities required to achieve the recommended level of air quality in all areas of the hospital.[13] This programme should be headed by an engineer in the works department of the hospital, with useful inputs from the environmental health department.

CONCLUSION

The levels of the assessed pollutants are within regulatory levels, even as there are evidence of poor ventilation in several of the study sites. An Indoor Air Quality Management Programme is recommended to coordinate all activities required to achieve the recommended level of air quality in all parts of the hospital.

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Conflicts of interest

There are no conflicts of interest.

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