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# Indoor Air Quality and Sick Building Syndrome Among Nigerian Laboratory University Workers

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**ABSTRACT:** *Indoor air quality refers to the air quality in and around laboratory buildings and facilities, which directly affects the health and comfort of workers. Poor air quality poses numerous health challenges to the laboratory workers and environment, and causes sick building syndrome (SBS) among workers. The objective of this study is to determine associations of SBS related to indoor air concentration in a dose-dependent manner among Nigerian laboratory university workers. This was a cross-sectional study on a population-based sample of Nigerian university laboratories and the workers. Data were collected using an indoor air quality control meter, dosimeter tubes gases of interest, and a set of questionnaires (MM-40). The results showed that the mean indoor air concentrations in a dose-dependent manner for chemical parameters range from 473.0 ppm to753.0 ppm, 17.9 ppm to 27.3 ppm, 5.7 ppm to 8.5 ppm, and 6.3 ppm to 9.1 ppm for $CO_2$, CO, $NO_2$, $H_2S$ and $SO_2$, respectively. The prevalence of SBS, i.e., skin-related syndrome (SRS) is 38.5%, general-related symptom (GRS) is 28.3%, mucosal-related symptom (MRS) is 19.2% and at least one score was a respiratory-related symptom (RRS), which is 13.9%. The significant associated factors of SBS revealed by multinomial logistic regression in this study were $NO_2$ [SRS ($P = 0.022$), GRS ($P = 0.023$), MRS ($P = 0.032$)], $H_2S$ [SRS ($P = 0.031$), GRS ($P < 0.001$), MRS ($P = 0.021$)], and $SO_2$ [SRS ($P = 0.001$), GRS ($P < 0.001$), MRS ($P = 0.022$)]. On the other hand, office laboratory temperature and relative humidity were shown to be negatively statistically associated with prevalence symptoms relative to RRS. In this study, SBS was found to be high. Indoor air concentration* *in a dose-dependent manner and environmental parameters could increase the prevalence and incidence of SBS-related symptoms. Therefore, it is important to educate the workers on occupational and environmental health at a workplace to minimise SBS in the future.*

**Keywords:** Sick building syndrome, dosimeter tubes, air quality control meter, indoor air quality, workplace health

## 1. INTRODUCTION

Indoor air pollution poses numerous health challenges to the laboratory workers and the environment. This implies to the air quality inside and around the laboratory buildings and facilities as it concerns the health and comfort of the workers.[11] Indoor air quality, which is related to health problems such as exasperation of asthma, headaches, nausea, allergic reactions, irritation to the skin, eyes, nose and throat are global health challenges limited not only to developing countries like Nigeria.[3] In Nigeria, indoor air pollution and sick building syndrome (SBS)-related illnesses are currently a subject of interest, because till date, there is no documentation on mean indoor air concentration in a dose-dependent manner related to SBS. SBS is a group of non-specific symptoms of general complaints such as skin related symptom (SRS), general-ill related symptom (GRS) and mucosal related symptom (MRS) reported by the laboratory workers.[21] Individuals exhibiting environmentally and occupationally-associated symptoms have been exposed to the elements of airborne materials coming not from outdoors but within a building. Studies, observations and complaints indicated that workers spend much of their working time in laboratories.[8]

Etiology may not be easy to establish a link to SBS related-symptoms because numerous signs and symptoms are often nonspecific, creating a degree of differential diagnosis for a distinct challenge in an occupational job.[2,14] Obviously, multiple chemical exposures and poor indoor air quality may be the cause of such challenges and also the unfavourable environmental conditions in workplace.[23] The likelihood of an etiological association increases if the workers can credibly relate the vanishing or attenuation of the placed symptoms to being absent from the workplace. Many effects may also be connected independently or in group combination with stress, work pressure, anxiety and periodic discomforts.

A lot of institutional chemical laboratories in the developing countries are faced with challenges such as wet and dilapidated laboratories offices, deprived meteorological factors, poor laboratory fittings and facilities such as ventilation system and fume cupboards.[10] The health effects from indoor air pollutants may be experienced shortly after exposure from multiple chemical activities in the laboratories or, most likely, years afterward.[11] A longitudinal study conducted in reported that 80% of the occupational chemical related job workers spent their working time in offices and laboratories and suffer from negative health credentials due to poor indoor air quality.[9] Size and nature of laboratory and office buildings can increase the risk of SBS symptom-related and down-and-out of the indoor air quality in the laboratories.[19] A study revealed that poor environmental temperature, relative humidity, poor laboratory structure (> 90 $m^2$) and student overpopulation in a laboratory during work session does not comply with the international recommendation of facilitator-to-student ratio of 1:25.[19]

Moreover, in maintaining healthy environment and safety culture in workplace, there is a need to determine and assess the indoor air quality of working environment to reduce the challenge of the negative credential health of the workers. Apart from the psychological depression of the workers, the costs of medical and social remedy are substantial. A cross sectional study conducted in Nepal found a decrease in workers' productivity and enthusiasm due to SBS related-symptoms circumstances.[18] These symptoms range from itchy eyes, skin rashes, nasal allergy symptoms, fatigue, aches and pains and sensitivity to odours.[16,25] Meteorological and clinical parameters such as temperature, humidity, bacteria, fungi, carbon dioxide and formaldehyde have also been unfolded by Wolkoff and Nielsen, who reported that air quality and SBS symptoms are related.[24] Other factors identified in a cross sectional laboratory-based sample in Japan by Takigawa et al. also related SBS symptoms in laboratories with indoor air quality which included odours, particulate matter (PM), bioaerosol and volatile organic compounds (VOCs) contamination, and thus, resulting to negative impact on the working environment.[22] Mourshed and Zhao observed the physical condition and effects of poor indoor air quality in hospitals which affected the health of hospital workers as a result of SBS-related symptoms identified.[12] Hence, the objective of this study is to determine the associations between SBS-related symptoms and indoor air concentration in a dose-dependent manner among Nigerian laboratory university workers.

### 1.1 The Rationale of the Study

The present study's contribution to the elimination of gap in the existing pool of literature is one of the essential requirements for this study. For example, while hundreds of studies have been previously conducted on various aspects of SBS in relation to indoor air quality this present topic as far from being exhausted as a research area. Specifically, report from the National Institute of Science Laboratory Technology of Nigeria (NISLT) and the Ministry of Health Nigeria indicated that 80% of the occupational chemical related job workers spent their working time in offices and laboratories and suffer from negative health credentials due to poor indoor air quality. The documented data of this study may aid public health workers, National Universities Commission (NUC), educational sector and NISLT in creating policies affecting the laboratory system and also help review the laboratory practices and procedures. It would also help to integrate the legal system in Nigeria into the Occupational Safety and Health Administration (OSHA) and International Organization for Standardization (ISO). This act would present the legislative framework to promote, stimulate and encourage a high standard of hazards and safety for the purpose of protecting the employees from hazards related to SBS in their workplace and from promising growing of poor indoor air quality.

## 2. EXPERIMENTAL

### 2.1 Materials and Methods

Indoor air quality control meter (IAQCM) was calibrated, configured and equipped with a sensor to measure different levels of carbon dioxide ($CO_2$), carbon monoxide (CO) and some meteorological factors such as temperature ($^oC$) and relative humidity (Rh%), as shown in Figure 1(a). Similarly, sulphur dioxide ($SO_2$), hydrogen sulphide ($H_2S$) and nitrogen dioxide ($NO_2$) were measured using calibrated dosimeter tubes of gases of interest in (PPM) at time weighted average (TWA), as seen in Figure 1(b). The tubes were equipped with a length-of-stain indication proportional to the amount of gaseous air of interest present in the laboratory. All gas dosimeter tubes use a simple colour change to estimate total concentration of toxic gases or vapour exposure dose in a workplace as shown in Section 2.2. To record the assessed gaseous air, the dosimeter tube tip is broken off to insert the recorded measurement starting time on the peel off numbered label in the box of the tube; thus, the label was placed on the tube for appropriate sampling. The maximum sampling was reached when the scale reading corresponds to the end of the stain length. Hence, the concentration of the target gas obtained and time on the label of the tube was recorded. The length-of-stain gas dosimeters tube work by diffusional sampling. The results are immediately available by visual observation of colours, i.e., CO: pale yellow analysing agent → brown stain produced; $NO_2$: green soluble substance produced; $SO_2$: white analysing agent → brown stain produced; $H_2S$: pale yellow analysing agent → brown stain produced. Thus, no auxiliary sampling, test, nor analysis equipment was needed for the estimation (Section 2.2).

The gaseous air concentration was determined and compared with threshold limit value.[23] The average concentrations of the gases were obtained by dividing the reading to the total length of time that the tube was exposed in the sampling area according to Equation 1. The coexistence of uninterested gases during the sampling was factored out in the concentration range on stain label in the tube, hence equivalent to the gas concentration assessed in the laboratories.

$$\text{Average concentration} = \frac{\text{Dosimeter tube reading (PPM.hour)}}{\text{Sampling times (hours)}} \tag{1}$$

## 2.2 Reaction Principle

1. CO dosimeter tube reading: $CO + Na_2Pb(SO_3) \rightarrow CO_2 + Pb + SO_2 + Na_2SO_3$

   Pale yellow analysing agent → Brown stain produced

2. $CO_2$ indoor air quality control meter

3. $NO_2$ dosimeter tube reading: ABTS + $NO_2$ → Green soluble substance produced

4. $SO_2$ dosimeter tube reading: $SO_2 + BaCl_2 \rightarrow HCl + Ba_2SO_4$

   White analysing agent → Brown stain produced

5. $H_2S$ dosimeter tube reading: $H_2S + Pb(CH_3COO)_2 \rightarrow Pb_2S + 2(CH_3COOH)$

   Pale yellow analysing agent → Brown stain produced

## 2.3 Sample Size Determination

### 2.3.1 Prevalence of SBS relation to indoor air quality

The sample size was calculated for this study by using the following:

$$n = \left(\frac{Z}{\Delta}\right)^2 \times P(1 - P)$$

where n = sample size, $Z$ = coefficient of standard deviation (usually expressed as 1.96 for 95% confidence interval), $P$ = anticipated sampling population proportion for this as 19.2% (i.e., prevalence of SBS relation indoor air quality), and $\Delta$ = absolute precision (considered for this study to be 5%).

The sampling error has been recommended to be taken as 5% when a prevalence of 10% to 90% is expected in any study.

Hence,

$$n = \frac{1.96 \times 1.96 \times 0.192 \times 0.808}{0.05 \times 0.05}$$

$$= 238.39$$

The sample size was 286 per group after adding 20% as dropout rate from the study, i.e., 238.39 + (238.39 × 0.2) = 238.39 + 47.68 = 286. Therefore, a minimum of 286 participants were needed to participate.

## 2.4 Operational definition/Inclusion-exclusion Criteria

Members of NISLT Nigeria and analytical chemists developed the operational definition for this study based on a review of existing literature and international standards. The criteria required by OSHA and Association Advancing Occupational and Environmental Health (ACGIH) on indoor air quality assessment were strictly followed. It required that the gases under study should not exceed the threshold limit values within the sampling area: CO ≤ 50 ppm, $CO_2$ ≤ 5000 ppm, NO ≤ 5 ppm, $H_2S$ ≤ 10 ppm, $SO_2$ ≤ 5 ppm, temp ≤ 26.5°C, Rh40%–70%, and LVS ≤ 65 cfm$^{-1}$.[1,4,20] Also, SBS: ≥ 4SLS/TSBS, ≥ 4GLS/TSBS, ≥ 4MRS/TSBS, and ≥ 4RRS/TSBS (skin, mucosal, general, and respiratory related symptoms imply total sick building syndrome).[21]

This was a cross sectional study conducted from November 2016 to May 2017 among 286 Nigerian laboratory university workers. All the respondents returned the questionnaires and 90% of the responses were valid for inclusion in this study. The study area and the respondents were randomly selected from 30 available accredited Nigerian university laboratories. The indoor air quality control meter and gas dosimeter of gasses of interest were used to measure the indoor air concentration in a dose-dependent manner and environmental conditions. Those aged 18 years old and above, and have been working at the same place for at least two years and are active members of NISLT Nigeria were included in this study. Workers who have other chemical occupational job-related and who were also diagnosed of having chronic health disorders such as asthma, chronic obstructive pulmonary disease and bronchitis were not included in this study. The respondents were required to answer a set of questionnaires (MM-40) on demographic data and symptoms experienced at workplace. The data were analysed using IBM SPSS Version 22.0. The final sample was drawn from a potential study population of 286 persons.

Moreover, this study was conducted in accordance with the regulation and standard of Universiti Sains Malaysia (USM), Malaysia. Ethics approval of the current study was granted by Human Research Ethics Committee of USM (Ref. USM/JEPeM/16090130), National Health Research Ethics Committee (NHREC) of Nigeria (Ref. NHREC/01/01/2007-28/12/2016) as well as West African Bioethics and Collaborative Institutional Training Initiative (CITI) (Ref. ID 5949144). All the protocols of the study were carried out in agreement with good research practice principle as enshrined in the Helsinki Declaration.[6]

### 2.5 Assessments

A brief structured demographic form was served to record the participants' socio-demographic characteristics such as age, gender, working experience, monthly income and SBS-related symptoms. For each laboratory worker, the occurrence of any SRS, GRS, MRS and RRS symptoms was determined by multiple response analysis (MRA) and the medical history of the respondents was followed. At the beginning, new SRS is defined as mutually exclusive and score at least 4SLS/TSBS which applied to the four categories of SBS-related-symptoms. IAQCM and dosimeter tubes were used to measure indoor air concentration in a dose-dependent manner and environmental factors.

## 3. RESULTS AND DISCUSSION

### 3.1 Results

#### 3.1.1 Respondents, environmental and indoor air concentrations characteristics

The respondents' sociodemographic characteristics, environmental and chemical parameters are summarised in Tables 1, 2 and 3. The study included 286 respondents consisting of 121 females and 165 males. The average age of analysed participants was 40.2 (range 18–58) years. The mean age was 38 (5.1) years for females, and 43 (8.1) years for the males. The mean working experience and monthly income of the laboratory workers were 13.6 (6.2) years and 246.6 (120.8) USD. The mean indoor air concentrations in a dose-dependent manner of the selected 30 chemical laboratories are shown in Table 2. They were found higher than the international permissible exposure limits and Nigerian air quality guidelines, except for CO and $CO_2$, which were below the recommended limits. Table 2 shows environmental parameters of the same chemical laboratories which include temperature, laboratory ventilation system (LVS), relative humidity and size of the laboratory. The results revealed that the parameters were below the recommended international standard, i.e., ISO and CLEAPSS standards, though LVS was moderate as at the period of sampling.

Table 1: Sociodemographic profiles of respondents.

| Personal parameters (n = 286) | Gender | | Age (years) | | Monthly income ($) | Working experience (Years) |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | | |
| n (%) | 165 (57.7) | 121 (42.7) | | | | |
| Mean (SD) | | | 43.1 (8.1) | 38.4 (5.1) | 246 (120.8) | 13.6 (6.2) |

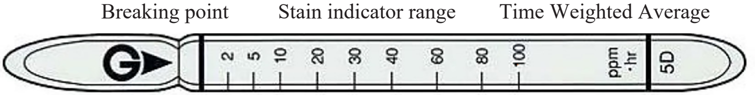
Table 2: Chemical parameters.

| Chemical parameters (n=30) | CO (ppm) | $CO_2$ (ppm) | $NO_2$ (ppm) | $H_2S$ (ppm) | $SO_2$ (ppm) |
|---|---|---|---|---|---|
| Mean (S.D) | 17.9 (2.3) | 473.0 (52.4) | 5.5 (0.5) | 5.7 (0.5) | 6.3 (0.7) |

Table 3: Environmental parameters.

| Environmental parameters (n = 30) | Temp (°C) | LVS ($cfm^{-1}$) | RH (%) | LD ($m^2$) |
|---|---|---|---|---|
| Mean (S.D) | 28.8 (1.5) | 25.8 (12.6) | 24.4 (1.9) | 44.7 (21.3) |


(a) Indoor air Quality Control meter




(b) Dosimeter tube of gases of interest

Figure 1: Illustrations of (a) indoor air quality control, and (b) gas dosimeter tube meter (courtesy of Walden oil tech services limited Port Harcourt, Rivers, Nigeria).

### 3.1.2 Occurrence of SBS -related Symptoms

The workers who often complained of SRS, GRS, MRS and RRS were mutually exclusively scored and are summarised in Table 4. From the table, the SBS-related symptoms were categorised, and no observation fell into more than one category provided in the questionnaires. Figure 2 shows the prevalence and trends of SBS in the laboratory where almost all the laboratory workers suffered from at least one SBS-related symptom. Among the most frequently reported symptoms during work session was SRS 38.5%, followed by GRS, MRS and RRS, with frequency rates of 28.3%, 19.2 and 13.9%, respectively (Table 4). As many as 8% of workers reported weekly complaints of skin rashes; 7% reported headache tiredness, nausea, facial itching, eye irritation, dryness in throat; 6% reported vesicles, and about 2% reported cold and nasal obstruction as least. These SBS-related symptoms declined when workers are away from their occupational job which might suggest the associated factors with the working condition and environment as well.

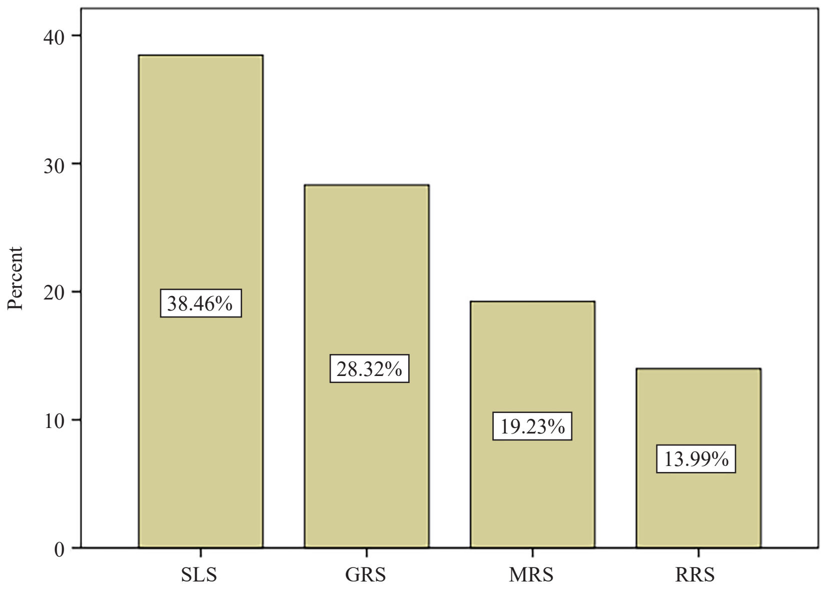



Figure 2: Prevalence and trends of SBS in the laboratory.

Table 4: Prevalence of SBS-related symptoms in the laboratory (n = 286).

| SBS symptom related | Frequency | Prevalence SBS % | SBS symptom | Frequency n (% ) |
|---|---|---|---|---|
| SRS (≥ 4SRS/TSBS) | 110 | 38.5 | Skin rashes | 159 (7.7) |
| | | | Swollen eyelids | 110 (5.3) |
| | | | Eye irritation | 139 (6.7) |
| | | | Mold allergy | 98 (4.8) |
| | | | Vesicles | 140 (6.8) |
| GRS (≥ 4GRS/TSBS) | 81 | 28.3 | Facial itching | 145 (7.0) |
| | | | Facial rash | 146 (7.1) |
| | | | Itching on the hands | 143 (6.9) |
| | | | Rashes on the hands | 143 (6.9) |
| MRS (≥ 4MRS/TSBS) | 55 | 19.2 | Headache | 153 (7.4) |
| | | | Tiredness | 145 (7.0) |
| | | | Nausea | 138 (6.7) |
| | | | Sensation of getting a cold | 33 (1.6) |
| RRS (≥ 4RRS/TSBS) | 40 | 13.9 | Wheezing | 30 (1.5) |
| | | | Nasal catarrh | 38 (1.8) |
| | | | Nasal obstruction | 30 (1.5) |
| | | | Dryness in throat | 141 (6.8) |
| | | | Sore throat | 36 (1.7) |
| | | | Acute cough | 93 (4.5) |

### 3.1.3 Associations between SBS-related symptoms, environmental factors and indoor air concentrations

Relationships among the symptom mutually exclusively scored, environmental factors and measured indoor air concentrations in a dose-dependent manner in the sampling areas were analysed using multinomial logistic regression and the results are presented in Table 5. The selected measured chemical parameters were categorised as low, high and moderate after being compared with the international permissible exposure limits and Nigerian air quality guidelines. In the multinomial logistic regression analysis, the symptoms (SRS, GRS, MRS and RRS) scores were significantly related to mean positive of the measured air parameters which included CO, $CO_2$, $NO_2$, $SO_2$, LVS, relative humidity and temperature.

Table 5: Multinomial analysis between the measured indoor air quality, environmental factors and SBS-related symptoms (n = 286).

| Type of exposures | SRS<br>b, (LR/Wald) OR (95%CI)<br>P-value | GRS<br>b, (LR/Wald), OR (95%CI)<br>P-value | MRS<br>b, (LR/Wald), OR (95%CI)<br>P-value |
|---|---|---|---|
| CO (ppm) | | | |
| Low | 0, 1 | 0, 1 | 0, 1 |
| High | 0.28, (0.87), 1.32 (0.57, 3.08) | 0.43, (0.78), 1.54 (0.62, 3.82) | 0.22, (0.98), 1.26 (0.48, 3.26) |
| | 0.520 | 0.439 | 0.640 |
| $CO_2$ (ppm) | | | |
| Low | 0, 1 | 0, 1 | 0, 1 |
| High | 0.30, (0.64), 1.36(0.63, 2.92) | 0.59, (0.12), 1.81 (0.78, 4.11) | 0.59, (0.11), 1.82 (0.75, 4.39) |
| | 0.439 | 0.155 | 0.186 |
| $NO_2$ (ppm) | | | |
| Low | 0, 1 | 0, 1 | 0, 1 |
| High | 0.79, (6.83), 2.21(1.22, 4.17) | 0.20, (6.17), 1.22 (0.13, 2.86) | 0.79, (5.21), 2.22 (1.21, 4.46) |
| | 0.022 | 0.023 | 0.032 |
| $H_2S$ (ppm) | | | |
| Low | 0, 1 | 0, 1 | 0, 1 |
| High | 0.09, (9.13), 1.10 (0.97, 2.76) | 0.81, (10.25), 1.08 (0.42, 2.83) | 0.74, (9.87), 2.11 (1.18, 4.96) |
| | 0.031 | $P < 0.001$ | 0.021 |
| $SO_2$ (ppm) | | | |
| Low | 0, 1 | 0, 1 | 0, 1 |
| High | 1.23, (10.10), 3.42 (2.31, 5.86) | 0.28, (11.23), 1.32(0.53, 3.31) | 0.54, (9.81), 1.72 (1.09, 3.46) |
| | 0.001 | $P < 0.001$ | 0.022 |
| LVS | | | |
| ($cfm^{-1}$) | 0, 1 | 0, 1 | 0, 1 |
| Poor | -1.17, (12.80), 0.31 (0.01, 0.96)[a] | –1.51, (11.21), 0.22 (0.11, 0.86)[a] | –1.46, (0.13), 0.33 (0.01, 1.86)[a] |
| Moderate | –4.38, 0.01(0.001, 0.006)[b] | –2.20, (0.87), 0.11 (0.001, 0.008)[b] | –1.34, 0.26 (0.01, 0.98)[b] |
| Good | $P < 0.001$[a], $p < 0.001$[b] | $P < 0.001$[a], $p < 0.001$[b] | 0.621[a], 0.541[b] |
| Temp. ($^{o}C$) | | | |
| Poor | 0, 1 | 0, 1 | 0, 1 |
| Moderate | –0.26, (7.17), 0.77 (0.26, 2.32) | –0.09, (8.88), 0.91 (0.36, 2.33) | -0.86, (7.66), 0.42 (0.01, 4.69) |
| | 0.021 | 0.033 | 0.023 |
| RH (%) | | | |
| Poor | 0, 1 | 0, 1 | 0, 1 |
| Moderate | 0.10, (10.12), 0.90 (0.37, 2.19) | –0.41, (2.54), 0.66 (0.48, 4.43) | –0.09, (0.47), 0.91 (0.33, 2.47) |
| | 0.012 | 0.040 | 0.054 |

*Notes: The reference category: Respiratory-related symptoms (RRS); odds ratio (OR) with 95% confidence interval (CI) calculated by multinomial logistic regression; LVS = laboratory ventilation system; Rh= relative humidity*

## 3.2 Discussion

The overwhelming benefits of investigating the relationship of indoor air concentrations and the environmental factors of Nigerian university laboratories and SBS-related symptoms among the workers are being taken notice. SBS is a global health challenge and not for only developing nations confirmed in a study by Takaoka et al.[21] A longitudinal study conducted in China by Chang et al. documented that 80% of the occupational chemical-related-job workers spent their working time in office and laboratories and suffer from SBS-related symptoms corresponding to indoor air quality.[2] Thus, results of indoor air quality showed that, in general, there were higher concentrations of some selected gasses in the laboratory environments than the international permissible exposure limits and Nigerian air quality guidelines. However, in the case of CO and $CO_2$, Laurent et al. found out that they were below the recommended limit.[7] Dilapidated laboratory buildings, poor waste disposal and use of expired chemicals could be among the causes of the outcome of this study which has led to great health challenge for the workers and the environment.

Comparatively, a similar cross-sectional study was conducted in Saudi Arabia by Salama et al. revealing that the mean indoor air quality of $NO_2$, $SO_2$, CO, VOCs, PM10, PM4, PM2.5 and PM1.0 $\mu g\ m^{-3}$ were also higher than the international permissible exposure limits and the Saudi air quality guidelines.[17] Another documented study in the Republic of Benin by Fanou et al. showed the mean level of indoor chemical contaminants above the international recommended limit.[5] Their study revealed the mean indoor air quality for $SO_2$, CO, $NO_2$, $CO_2$, VOCs, PM5.3, PM3.2, PM2.5, PM8.9 PM3.9 and PM1.3 $\mu g\ m^{-3}$ were higher than the internationally permissible exposure limits of Benin air quality guidelines. Furthermore, the dilapidated laboratory buildings, poor waste disposal and use of expired chemicals could be accounted for the outcome of this study, which in turn has led to great health challenge for the workers and environment. Standardisation of laboratory operation and management systems in work places are of great challenge. Environmental factors are not left out and these could contribute to the increase in the levels of poor indoor air and SBS-related symptoms in the laboratories. The incidences of SRS, GRS, MRS and RRS increase during the work sessions. The symptoms appear to improve when workers stay away from their occupational job. Among individual symptoms, SRS is most prevalent, followed by GRS and MRS. The results also showed that RRS was the least scored by the workers. This indicates that RRS is the least suggested cause of SBS-related symptoms among Nigerian laboratory university workers. However, as no concrete explanation to this observation is available, a further research in this respect is suggested.

Associations between the prevalence of SBS symptoms and measured environmental factors at baseline were studied by multinomial logistic regression, by adjusting the chemical parameters and the environmental factors, while keeping each exposure factor separately in the models relative to the reference category. Multivariable analyses revealed statistically significant factors associated with the increased SBS-related symptoms among the workers and hence were retained in the model as the main factors predicting SBS-related symptoms of the laboratory university workers. Typically, most of these chemical parameters considered in this study were found positively significant as reported in the literature.[2,25] After adjusting other associated factors in the model, the scores of skin rashes, eye irritation vesicles and mold allergy and overall SBS-related factors considered as SRS significantly increased with high concentration in a dose-dependent manner of $NO_2$, $H_2S$, $SO_2$, LVS, relative and temperature.

A study conducted in the Netherlands revealed a significant negative association between high concentration CO, $CO_2$ and symptoms related to SBS.[15] Similarly, this study also found an insignificant association between office laboratory CO and $CO_2$ at high concentration and SRS, GRS and MRS relative to RRS but not statistically significant. This implies that none of the laboratory indoor environments contained concentrations of CO and $CO_2$ that exceeded 50 ppm and 5000 ppm respectively. Thus, the laboratory office ventilation system appeared to be adequate. Office laboratory with high $NO_2$ dose however was positively associated higher with MRS, followed by SRS, GRS relative to RRS, and was statistically significant. High levels of $NO_2$ had 2.22 times significantly higher odds of increasing MRS compared to low concentration in a dose-dependent manner relative to RRS. This result is similar to several previous studies conducted on the important relationship of SBS-related symptoms on public building, offices and laboratories. A report by Zhang et al. revealed that MRS, GRS, SLS and RRS-SBS are 21.7%, 18.6%, 4.1% and 37.7%, respectively and significantly associated with the indoor air quality in a chemical related jobs.[25] Similar study by Takaoka et al. showed that MLS, GLS and SLS-SBS with respective values of 45.4%, 22.5% and 38.9% were significantly associated with the indoor air quality in a chemical-related job, but did not report for RRS.[21]

Office laboratory $H_2S$ concentration dose was also found to be positively associated with higher MRS, SRS whilst GRS had the least odds ratio. High concentration $H_2S$ had 2.11 times significantly higher odds of increasing MRS compared to the low concentration in a dose-dependent manner relative to RRS. Additionally, a concentration of $SO_2$ in laboratory office was positively associated with higher SRS followed by MRS whereas GRS score the least relative to RRS. In our instance, high-level concentration of $SO_2$ had 3.42 times significantly higher odds of influencing SRS compared to the low concentration in a dose-dependent manner relative to RRS. Further, there were negative relationships with moderate LVS, temperature and relative humidity. Moderate temperature and LVS had likely significantly less odds of influencing SRS, GRS and MRS relative to RRS, conversely, the association with MRS not statistically significant.

Present evidence related to these findings suggests unsuitable environmental conditions, such as the following: relative humidity, temperature and LVS; decrepit laboratory buildings with poor office and laboratory facilities, poor waste disposal, with forceful use of expired chemicals; and deplorable lighting system, with offensive noise levels and poor working condition. Poorly designed work responsibilities and unprincipled laboratory procedures and practice, as well as job-related psychosocial stress and pressure, are also suggested. Additionally, excessive moisture seems to promote mold growth and is associated with an increased prevalence of SBS-related symptoms due to irritations, allergies and infection.[9]

Several studies have indicated that high levels of indoor $NO_2$, $SO_2$, $H_2S$ and $CO_2$ are recorded in buildings with poor indoor air and relative humidity. Higher indoor $CO_2$ levels influences SBS in workplaces, although temperature score is not significantly correlated.[13,15] However, there was a close correlation between indoor $NO_2$ and $SO_2$, but no significant correlations between other air pollutants documented by the researchers which are contrary to our present study. The result of the present study was found inclined probably due to the difference in the susceptive study environment. Place of origin and difference in study design could also account for the disparity in the results. Most of the responses from the workers were mutually exclusive and self-evaluated, hence results could be biased. On the other hand, concerning the association between chemical concentrations and SBS-related symptoms, the bias was not predicted since workers could not know their chemical exposure level even if they had symptoms. Most of the limitations of this study would most likely lead to non-differential misclassification. We do recommend relationship between SBS-related, outdoor air in a confined and open work environment as future study.

## 4. CONCLUSION

The results of this study showed that the level of indoor air quality and the environmental condition were poor and higher than the international permissible exposure limits and the Nigerian air quality guidelines. However, exceptions were recorded for CO and $CO_2$ which did not exceed 50 ppm and 5000 ppm, respectively. High dose laboratory of $NO_2$, $SO_2$, $H_2S$ and high temperature were positively associated with SBS (MRS, SRS and GRS relative to RRS). The environment and poor indoor air quality remain the main factors contributing to SBS, and the study also revealed that $NO_2$, $H_2S$, and $SO_2$ are significant factors associated with SBS. Health education and adaptation programs should be conducted to minimise the symptoms of the SBS among the workers.

## 5. RECOMMENDATIONS, REMEDIAL ACTION AND PREVENTIVE MEASURES

The study recommends a review in laboratory practice and procedures for a healthy indoor environment such as sufficient and high rate of fresh outdoor air supply using green method approach. Electromagnetic heating system and proper use of fume hood in the laboratory should be adopted to provide suitable environmental conditions for workers and environment. Integration of legal system regarding OSHA and ISO for enforcement and monitor the compliance of standard laboratory procedure, practice and workplace design that encourages and promote the physical and psychological well-being of the occupational workers, thus, should be accepted as a system in laboratories.

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