

Effects of combustion generated pollutants on the indoor air quality of university laboratories

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Abstract:

Health threats in a learning environment can jeopardize the entire effort of teaching and learning. One of such health threats is the presence of hazardous gaseous elements within the building interior due to learning processes such as combustion activities, especially in laboratories or from the external environment. This paper assessed the perception of laboratory users on the effect of combustion generated pollutants on the indoor air quality of a typical university laboratory using some selected laboratories in Ahmadu Bello University Zaria as a case study. A well-structured questionnaire was designed and administered to a hundred and twenty-seven laboratory users randomly selected. Data collected were analyzed using a computer-based software SPSS version 16.0. The results revealed among others that combustion processes in laboratories is a major contributor to poor indoor air quality compared with other learning processes; fatigue (RII: 0.81) was identified as the most prominent symptom of poor indoor air quality during combustion among other symptoms like; coughing and sneezing; dryness and irritation of eyes and throat; sinus congestion; shortness of breath and headache, arranged in the order of intensity. The absence of functional fume hoods, congestion in laboratories and inadequate ventilation system intensify the discomforting effect of combustion generated pollutants in laboratories. Hence, provision, where there are none and adequate maintenance of fume hoods for functionality, is recommended. Consequently, the construction of new laboratories to accommodate the students enrolled to avoid congestion in the laboratories is highly recommended.

Keywords: combustion generated pollutant, indoor air quality, sustainability

1 Introduction

Interest in the role of air quality in health and disease dates back to antiquity. In his treatise on "Airs, water and places" Hippocrates drew attention to the impact of polluted air, among other transmission media, on disease burden. For centuries, the emphasis on pollution associated air problems was mainly placed on outdoor air; concerns about indoor air quality are fairly recent in comparison (David, 2010)

The National Health and Medical Research Council (NHMRC) (2009), defines indoor air as air within a building occupied for at least one hour by people of varying states of health. This can include the office, classroom, transport facility, shopping centre, hospital and/or home. Indoor air quality (IAQ) can be defined as the totality of attributes of indoor air that affect a person's health and wellbeing. Similarly, the Environmental Protection Agency (EPA) defines

IAQ as the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants (USEPA, 2020)

In developing countries like Nigeria, the main source of indoor air pollution is biomass which contains suspended particulate matter like nitrogen oxide (NO₂), sulphur dioxide (SO₂), carbon monoxide (CO) formaldehyde and polycyclic aromatic hydrocarbons (PAHs). However, in industrialized countries and NO₂, CO and formaldehyde, radon, asbestos, mercury, human-made mineral fibers, volatile organic compounds, allergens, tobacco smoke, bacteria and viruses are the main contributors to indoor air pollution (David, 2010).

In the last several years, a growing body of scientific evidence has indicated that the air within homes and other buildings can be more polluted than the outdoor air in even the largest and most industrialized cities. In addition to daily human activities that lead to the generation of indoor air pollutants, combustion sources and actions especially in laboratories contribute to carbon dioxide (CO₂), sulfur dioxide (SO₂), CO, nitrogen dioxide (NO₂), and particulate matter (PM) emissions into indoor air environments (Awbi, 2003).

The intrinsic nature of the health effects from indoor air pollutants is that it may be experienced soon after exposure or, possibly, years later. Immediate effects may show up after a single exposure or repeated exposures (Vinh Van Tran, Duckshin Park, and Young-Chul Lee, 2020). These include irritation of the eyes, nose, and throat, headaches, dizziness, and fatigue. Such immediate effects are usually short-term and treatable. Sometimes the treatment is simply eliminating the person's exposure to the source of the pollution, if it can be identified.

The World Health Organization, as at 2002, estimated that indoor air pollution is responsible for roughly 1.6 million deaths each year; however, the recent update as at 2020, shows that indoor air pollution (IAP) is responsible for the deaths of 3.8 million people annually (WHO, 2020) with its symptoms ranging from acute lower respiratory infections, chronic obstructive pulmonary disease, lung cancer, and other diseases. Indoor air pollution from biomass contributes to about 2.6 percent of the global burden of disease. Hromadka, Korposh, Partridge, James, Davis, Crump, and Tatam (2017), indicated that decreased IAQ can negatively affect human health by causing building-associated illness.

This paper examines the perception of the laboratory users on the impact of combustion generated pollutants on the indoor air quality of the laboratories considering the users' lengthy exposure during research activities.

2 Literature review

The concept of indoor air pollution has been a contemporary one, which has stirred up much research with the general aim of emphasizing the health impact of poor indoor air and the identification of the major pollutants of the indoor air. Some of the research is discussed in this section. Saravanan (2004), on a general study of indoor air established that the major factors that determine the indoor air quality are:

- i) The nature of outdoor air quality around the building
- ii) The ventilation rate of the building
- iii) The materials used in the construction of the building (presence of chemicals)
- iv) The activities that go on inside the interior (cleaning, cooking, heating etc.)
- v) The use of household chemicals

Saravanan (2004), identified some of the pollutants sources as; radio activity (the emissions from uranium in the soil or rocks on which the houses are built, Volatile Organic Compounds (VOC) usually from aliphatic and aromatic compounds, chlorinated compounds with formaldehyde being in many locations). The emphasis of the sources of indoor air pollutants was on the indoor combustion activities. Combustion of fuels such as oil, gas, kerosene, etc inside a building contributes to the concentration of VOCs and it is also a source of stable inorganic gases. The common indoor pollutants due to combustion of fuels are particulate matter, oxides of nitrogen, oxides of sulphur, carbon monoxide, hydrocarbons and other odour causing chemicals. Saravanan (2004), concluded by opining that indoor air pollution is one of the major problems that have to be solved since a large part of human life is spent indoors. All necessary precautions to eliminate or minimize the harmful effects of indoor air pollution need to be taken.

Smith and Zhang (2005) studied the indoor air pollution from household fuel combustion, and estimated that air pollution from solid waste in China is responsible for 420,000 premature deaths annually with more than 300,000 attributed to the pollution of the urban outdoor environment. To help elucidate more fully the extent of hazard caused by combustion of pollutants in China, Smith and Zhang (2005) reviewed nearly 200 publications in China reporting health effects, emission characteristics and/or indoor air pollutants concentrations associated with solid fuels. Smith and Zhang (2005), also took measurements in 122 individual studies, from which they concluded that indoor air pollutant concentrations exceeded health standards in many of the households.

In like manner, Stanley (2010) assessed the environmental suitability of electric power generators for power supply to buildings with a view to devising appropriate control measures for a cleaner environment. The assessment was for buildings within Kaduna metropolis and the approach adopted was the use of both a well-structured questionnaire and an IMR 1400C combustion gas analyzer. The research results showed that the level of awareness of health hazards caused by generators was high and that the mean concentration of SO₂ and NO_x indoor was higher than the FEPA limits (0.01ppm and 0.04-0.06ppm), respectively. The research also revealed that none of the ambient pollutants met the WHO and FEPA limits at the point source.

The above research itemizes the contribution of various researchers in evaluating the impact of combustion activities on the indoor air quality and the indoor environmental condition. And at this point, it can be seen that combustion is a major source of pollutants generation in the environment. Thus, this research work seeks to evaluate the impact of combustion activities in the laboratories on the indoor air quality of the laboratories.

2.1 HVAC requirements for a laboratory

Several write-ups have been done regarding the heating, ventilation and air conditioning (HVAC) requirements for a laboratory; with the emphasis being on the energy usage common to laboratories and the comfort requirements. According to Lindsay (2010), an HVAC engineer's prime concern when planning or constructing any laboratory building is the safety of the building's occupants. The system must operate to specification and meet appropriate regulations. To this end, many older laboratories were designed with little regard to energy efficiency. That's no longer true, and designers must account for operating costs as well as functionality (Lindsay, 2010).

A typical laboratory building consumes five to ten times more energy than a typical office building or school. HVAC systems consume almost 70% of a laboratory's energy, according to Labs21 (2010), a voluntary partnership program dedicated to improving the environmental performance of U.S. laboratories. The majority of this HVAC energy consumption originates from cooling (22%) and ventilation (44%) loads that help the laboratory function safely (Lindsay, 2010)

The high energy use can be attributed to high air-change requirements, large internal heat gains from laboratory equipment, and, in many cases, continuous hours of operation (Gordon, 2010). With a push toward a more energy-efficient laboratory environment, vendors are developing new technologies or adapting older ones to help reduce HVAC energy consumption. Lindsay (2010)'s emphasis was more in line with HVAC requirement for laboratories as an energy-saving measure and not on the adequacy of indoor air quality for laboratories.

3 Methodology

A survey of laboratory users (Staff and students) perception on the impact of combustion generated pollutants on the indoor air quality of the environment was conducted. A well-structured questionnaire was designed and administered to both staff and students (laboratory users) of Ahmadu Bello University, Zaria. A total of one hundred and forty (140) questionnaires were distributed, out of which one hundred and twenty-seven (127) representing 90.7% were properly completed and returned. The major issues addressed in the survey include: the presence of the necessary Heating Ventilation and Air Conditioning System; the presence and functional state of the fume boxes and other related factors like the frequency of maintenance of the HVAC system that can influence the effects of combustion pollutants on the indoor air quality.

3.1 Data analysis procedure

Most of the questions in the questionnaire involved assessing some indices of utilization on a five (5) point Likert's scale. The data analysis, therefore, employed the following steps.

a. Computation of the mean using the weighted average formula

$$\text{Relative importance index (RII)} = \frac{\sum fx}{\sum f} \times \frac{1}{k}$$

Where,

$\sum fx$ = is the total weight given to each attribute by the respondents.

$\sum f$ = is the total number or respondents in the sample.

K = is the highest weight on the Likert scale.

Results are classified into three categories as follows (Othman *et al.*, 2005) when;

$RII < 0.60$ -it indicates low frequency in use

$0.60 \leq RII < 0.80$ -it indicates high frequency in use.

$RII \geq 0.80$ – it indicates very high frequency in use.

4 Data presentation, analysis and discussion

Data from the expert opinion survey are presented in Table 1.

Table 1. Laboratory combustion activities

S/N	Variable	Option	Frequency	Percentage (%)
1	Combustion in laboratories:	a) Yes	94	74.0
		b) No	33	26.0

		Total	127	100
2	Heat generating device frequently used :	a) Stove	16	12.3
		b) Gas burner	89	70.1
		c) Hot plates	22	17.3
		d) Candle	0	0
		Total	127	100
3	Presence of functional fume hood:	a) Yes	40	31.5
		b) No	27	21.3
		c) Not Aware	60	47.2
		Total	127	100

Source: Field survey, (2020)

From Table 1, it is observed that the majority of the respondents opined that their work entails combustion (74.0%). Also, the major heat-generating device frequently used in the laboratories as opined by the respondents is the gas burner (70.1%). Concerning the presence of a functional fume hood installed in the laboratory, most respondents (with frequency of 47.2%) were not aware of its presence and its functional status; this corresponds to 47.2% of the respondents.

4.1 Combustion and ventilation in laboratories

The perceptions of the respondents with regards to the impact of combustion activities in the laboratory as well as the evaluation of the adequacy of the ventilation system were also assessed. Table 2 below, presents the results of the assessment.

Table 2. Combustion and ventilation in laboratories

S/N	Variable	Option	Frequency	Percentage (%)
1	Combustion as a source of discomfort:	a) Yes	117	92.1
		b) No	10	7.9
		Total	127	100
2	Process that poses more discomfort:	a) Combustion	69	54.3
		b) Filtration	0	0
		c) Lab cleaning	58	45.7
		d) Distillation	0	0
		Total	127	100
3	Presence of ventilation system:	e) Yes	40	31.5
		f) No	87	68.5
		Total	127	100
4	Adequacy of ventilation system during combustion:	a) Yes	26	20.5
		b) No	101	79.5
		Total	127	100

Source: Field survey, (2020)

It can be observed from Table 2, that combustion is a source of discomfort, as observed by 92.1%. Also, it can be observed that of all the processes identified combustion was more discomforting (54.3%). With regards to the ventilation system, it is obvious that the ventilation is not adequate as 79.5% of the respondent attested to it.

4.2 Health symptoms of poor indoor air quality

Several health symptoms of poor indoor air quality were assessed and the respondents ranked these symptoms. Table 3, presents the ranking of the various health symptoms that serve as indicators to poor indoor air quality. From Table 3, it is observed that the respondents ranked fatigue (with RII= 0.81) as the most reoccurring health symptom. Also, it is observed that only symptoms like fainting and nausea had a relative importance index less than 0.6, indicating that they are not a commonly observed symptom. Also from the mean values, it can be deduced that the values were closer to the Likert weighting of four (4) an indication that the respondents' general opinion was that the symptoms were truly an indication to poor indoor air.

Table 3: Ranking of the health symptoms of poor indoor air quality

	WEIGHTNG/RESPONSE FREQUENCY									
SYMPTOM	1	2	3	4	5	($\sum f$)	$\sum fx$	MEAN	RII	RANK
Fatigue	-	3	15	80	29	127	516	4.07	0.81	1 ST
Coughing and sneezing	03	17	-	82	25	127	490	3.85	0.77	2 ND
Dryness and irritation	-	16	8	86	17	127	485	3.82	0.76	3 RD
Sinus congestion	10	08	02	90	17	127	477	3.76	0.75	4 TH
Sneezing and chest tightness	02	26	07	68	24	127	467	3.68	0.74	5 TH
Shortness of breath	-	23	26	50	28	127	464	3.65	0.73	6 TH
Blurred vision	16	02	22	57	30	127	464	3.65	0.73	6 TH
Headache	11	10	20	66	20	127	455	3.58	0.72	8 TH
Dizziness	15	10	12	74	16	127	447	3.52	0.70	9 TH
Hypersensitivity and allergies	14	07	28	78	3	127	439	3.46	0.69	10 TH
Pains and discomfort	06	17	22	78	04	127	438	3.45	0.69	10 TH
Heart burn	10	29	04	67	17	127	433	3.41	0.68	12 TH
Nausea	8	17	34	63	05	127	421	3.31	0.66	13 TH
Fainting	29	60	22	07	09	127	288	2.27	0.45	14 TH

Source: Field Survey, (2020)

Where: 1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree

4.3 HVAC and combustion related factors that alter laboratories' indoor air quality

The questionnaire also sought the respondents' opinion regarding how the heating ventilation and air conditioning (HVAC) system and combustion contribute to the poor indoor air quality of laboratories. The respondents' opinions and ranking thereof are presented in Table 4.

Table 4: HVAC and Combustion Related Activities that Affect Indoor Air Quality in Lab.

CAUSES	WEIGHTNG/RESPONSE FREQUENCY						Σf	Σfx	MEAN	RII	RANK
	1	2	3	4	5						

Overcrowding in labs	-	-	07	40	80	127	581	4.57	0.91	1 ST
Combustion activities	-	-	02	73	52	127	558	4.39	0.89	2 ND
Inadequate ventilation	-	10	06	67	44	127	526	4.14	0.83	3 RD
Prolonged and reoccurring combustion	05	20	12	58	30	127	463	3.65	0.73	4 TH
Nonfunctional fume hoods	12	13	12	68	22	127	456	3.59	0.72	5 TH
Too humid air	03	26	70	28	-	127	377	2.97	0.59	6 TH
Faulty burners	04	40	62	21	-	127	354	2.79	0.56	7 TH
Poor air Movement	-	54	67	06	-	127	333	2.62	0.52	8 TH
Unvented combustion equipment	58	20	13	27	09	127	290	2.29	0.46	9 TH

Source: Field survey, (2020)

Where: 1= not a cause, 2 = not a major cause, 3 = barely a cause, 4 = a cause, 5 = always a cause

From Table 4, it can be observed that overcrowding in labs (RII=0.91) was ranked the first cause of poor indoor air quality. This is followed closely by combustion activities (RII=0.89). It can also be seen that other factors like, faulty burners, too humid air and unvented combustion though factors, did not have an intense effect owing to their relative importance indexes (RII), which are below 0.6. With regards to the mean, it can be observed that the values were closer to the weighting four (4), an indication that the respondents' opinion was that the identified factors are all causes of poor indoor air quality.

4.4 Remedial action to poor indoor air quality in laboratories

Table 5 gives the respondents ranking of the various remedial measures to poor indoor air quality identified. It also gives the percentage response per option as well as the mean.

Table 5: Remedies of poor indoor air quality

Remedy	Weighting/response frequency						Σfx	MEAN	RII	RANK
	1	2	3	4	5	(Σf)				
Provision of adequate HVAC system	07	-	10	32	78	127	555	4.37	0.87	1 st
Adequate air flow during combustion	-	13	14	28	72	127	540	4.25	0.85	2 nd
Use and maintenance of functional fume hoods	14	-	15	40	58	127	509	4.00	0.80	3 rd
Use of excellent combustion equipment	14	-	21	32	60	127	505	3.98	0.79	4 th
Orientation of both staff and student on the danger of poor indoor air quality	32	-	9	28	58	127	461	3.63	0.73	5 th

Source: Field Survey, (2020)

Where: 1 = not Effective, 2 = no effect, 3 = slightly effective, 4 = Effective, 5 = very effective

From the Table 5, it can be observed that the highest ranked remedy to the poor indoor air quality by the respondents is the provision of adequate heating ventilation and air conditioning system (RII= 0.87). Also from the mean values, it can be established that in general the respondents opined that the identified remedy were all feasible options as the value of the mean is closer to the Likert weighting of four (4).

5 Conclusion and Recommendation

Combustion activities are practically unavoidable in teaching and learning of practical science courses. The major source of heat for the combustion activities is the gas burner except in few cases of limited gas supply, when the water bath is used as an alternative heat generating source.

Fatigue is one of the most reoccurring health symptoms of poor indoor air quality due to combustion activities. However, other health symptoms are headache, dryness and irritation, sinus congestion, blurred vision, sneezing and chest pain.

As a matter of urgency, the school authority should try and construct new laboratories to address the overcrowding challenges in the laboratories that have intensified the effect of combustion activities, which in turn affect the indoor air quality. This would also help in accommodating the teaching and learning of the students enrolled.

Proper attention should be paid to maintaining the heating ventilation and air conditioning (HVAC) systems of the laboratories, particularly the fume hoods.

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