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RESEARCH PAPER

ASSESSMENT FRAMEWORK FOR IEQ OF CLASSROOMS IN BASIC SCHOOLS IN GHANA- REVIEW OF DATA COLLECTION METHODS

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ABSTRACT

An Indoor Environmental quality assessment framework goes through several processes including defining all features of the entity being studied, Reviewing of literature, Data Collection and Analyses and Validation of developed framework. The data collection aspect of the framework encompasses activities that need to be identified and established in the development of an assessment framework for basic schools in Ghana.

The Assessment of IEQ in classrooms of basic schools has been undertaken by many researchers. Standards provided by international bodies such as ASHRAE, WHO, European Union and USEPA have spelt out how specific IEQ parameters must be measured. This review identifies the various data collection methods used in assessing IEQ in buildings, (especially school buildings) with a focus on classrooms. It establishes a data collection methodology that can be used in an assessment framework for IEQ in classrooms in basic schools in Ghana.

Keywords: Indoor Environmental Quality, Assessment, Classrooms, Methods

INTRODUCTION

Indoor Environmental Quality (IEQ) performance in classrooms has been investigated vastly and continues to draw significant interest (Vijapur *et al.,* 2021). This is because it has been discovered that IEQ plays a significant role in ensuring the health and well-being of occupants. Physical design characteristics of buildings play a crucial role in classroom management and in mediating the teaching and learning process (Vijapur *et al.,* 2021). This makes it important for appropriate designing strategies and the choice of sustainable building materials to be considered when designing and constructing buildings (Munonye & Ji, 2021).

Studies on thermal comfort conducted in classrooms of basic schools have observed that uncomfortable temperatures can significantly impact the academic performance of children (Mishan and Bahadur, 2019). Children have a different sensitivity to temperatures as compared to adults, suggesting that the comfort levels of children must be investigated and given due consideration in the design of buildings (Teli *et al.,* 2017; Vijapur *et al.,* 2021; Kim & de Dear, 2018).

Studies by WHO, (2005) also revealed that children are more susceptible to air pollutants than adults because of immature lung growth. Poor air quality was found in randomly chosen classrooms of primary schools in metropolitan France (Annesi-Maesano *et al.,* 2012) and this was related to an increased prevalence of clinical manifestations of asthma and rhinitis among school children. Maintaining satisfactory ventilation and thermal comfort levels in classrooms could significantly improve the academic achievement of students. (Haverinen-Shaughnessy & Shaughnessy, 2015)

A study by the Heshong Mahone Group (1999) discovered that students with the most daylight in classrooms progress 20% faster in maths tests and 26% in reading tests in one year than those with the least daylight. Sheilds and Dockerell (2008) identified that noise could harm children's performance at school, with an associated reduction in memory, motivation, and reading abilities. The effect of IEQ on children has brought to the fore the need to evaluate indoor environmental conditions in classrooms in basic schools. The evaluation of IEQ in classrooms in basic schools requires an assessment framework as a guide for Ghana and other developing countries with similar conditions. This paper reviews methodology approaches employed in tdeveloping of IEQ assessment frameworks for schools. This will help gather information ondeveloping an IEQ assessment framework for basic schools in Ghana regarding components of IEQ assessed, processes involved in the development and gaps that will be identified.

METHODOLOGY

The methodology for this study is a review of existing literature on methods employed in assessing IEQ in classrooms of basic schools. Initially, a search was conducted with Science Direct, Google Scholar, and Research Gate search engines for articles with the keywords: Ghana. Articles that came up had studies relating to the assessment of IEQ in classrooms and other facilities with two relating to IEQ assessment in Ghana. Even for those that had thermal comfort and lighting as their focus. The search was conducted again with the keywords, Indoor Environmental Quality, IEQ, assessment, methods, classrooms, basic schools, primary schools and elementary schools. The search was limited to articles published from 2010 to 2022 in the English language. Science direct provided most articles related to the keywords. These articles were filtered by title and abstracts. Articles that had an assessment of IEQ, and methodology in basic, primary, or elementary schools was

used for the review. Nineteen peer reviewed papers were selected based on the following criteria: the article must contain IEQ or some of its components; it should be on the assessment of classrooms in basic, primary, or elementary schools, and include methodology. Other papers that did not directly fall under the keywords but had explanations for the methods like articles on measurement standards were also reviewed. A mapping review was conducted on the contents of the selected articles, considering the facility or facilities assessed the country in which the study was conducted, the methodology employed in the assessment,and the IEQ parameters assessed. Results from these were grouped under various headings, comparing the information to conclude on findings while identifying gaps therein.

Literature review

A review of existing works on assessing IEQ in classrooms revealed that different methods are used depending on the measured parameter

Since research methods involve the forms of data collection, analysis, and interpretation that researchers propose and use for their studies (Creswell, 2014), this paper seeks to review the types of data collection methods involved in assessing IEQ. The major methods discovered in the study are quantitative (objective) and qualitative (subjective) methods. These encompass surveys (questionnaires, interviews, and observation) and measurements of IEQ parameters. This aligns with Støre-Valen and Lohne's (2016) assertion that the conventional strategies employed for analysing building performance are based on physical measurements, in addition to separate studies of organisational or user behaviour. While some authors use only subjective or objective data collection methods, other authors combine both the subjective and objective methods in their research to curb the level of uncertainties involved with subjective assessments (Gyimah, 2019). Table 1 shows the articles reviewed on the methods employed in assessing IEQ in schools in different countries.

Table 1: IEQ parameters assessed in reviewed studies

Author	Facility	Country	Method	IEQ Parameters			
				IAQ	Visual Comfort	Thermal Comfort	Acoustic Comfort
Fadeyi *et al*. 2014	Elementary schools	United Arab Emirates	Measurement, observation	*	*	*	*
Sripongpun *et al*. 2015	Secondary and Primary Schools	Thailand	Measurement, observation		*	*	*
Turunen *et al*. 2014	Elementary schools	Finland	Measurement, questionnaire survey	*		*	
Toyinbo *et al*, 2019	Primary schools	Nigeria	Measurement, observation	*		*	

Rodriguez *et al* 2019	Primary schools	Colombia	Measurement, survey, observation	*		*	
Pajek *et al* 2017	Day care Centres	Slovenia	Measurement	*	*	*	*
Awang *et al* 2015	Secondary school	Malaysia	Measurement, Observation, Questionnaire survey	*	*	*	
Ismail *et al*. 2010	Primary schools	Malaysia	Measurement	*			
Canha *et al*. 2012	Primary Schools	Portugal	Measurement	*			
Hassan and Haryanti 2019	High school	Malaysia	Interviews		*	*	*
Hameen *et al*. (2020)	Schools	America	Survey, observation, measurement	*	*	*	*
Hassanain 2015	Schools	Saudi Arabia	Questionnaire survey, observation	*	*	*	*
Enitan *et al*. (2017)	Primary schools	Nigeria	Observation Measurement	*			
De Guili *et al* (2012)	Primary Schools	Italy	Measurement Questionnaire survey	*	*	*	
Barret *et al*, (2015)	Primary schools	United Kingdom	Measurements, Observation, questionnaire-based interviews	*	*	*	*
Toyinbo *et al*. (2016)	Primary schools	Finland	Questionnaire measurement	*		*	

Jarvi *et al*. 2018	Primary schools	Finland	Questionnaire Measurement	*			
Oldham and Kim (2019)	Elementary Schools	United States of America	Measurement Questionnaire	*	*	*	
Soccio (2016)	Schools	Australia	Observation, measurement questionnaire	*	*	*	*

DATA COLLECTION METHODS FOR ASSESSING IEQ IN BASIC SCHOOLS

From the literature reviewed, data collection methods used in assessing classrooms in basic schools take different forms. The methods employed in assessing IEQ in classrooms depend on the aim of the study being undertaken, the cost involved in the method to be used, the amount of details required, the frequency and level of exposure over time and the accuracy of the method available for assessment (Bluyssen, 2014). Bluyssen (2014) observed that methods used in assessing IEQ and occupants' well-being range from qualitative to quantitative methods These include exploration, secondary and primary data through low technological to high technological interventions. They are a combination of subjective and objective approaches, and these include surveys (Observation, questionnaires, interviews) and measurements. Bluyssen (2014) further reiterated that data collection covers human beings, the indoor and built environments and other possible factors that may influence IEQ. The methods for assessing IEQ in classrooms in basic schools have been discussed below. Table 1 shows the methods employed by authors in assessing IEQ in classrooms in basic schools.

Observational Survey

In the assessment of IEQ in classrooms, there is the need to identify the facilities to be assessed (Fadeyi *et al*., 2014). This is followed by detailed observational surveys of the facility and its surroundings. The survey includes observation of the building and its components e.g., the type of windows doors, etc; also, whether doors are opened or closed, wind direction and many more. There is a need to develop an observational checklist of conditions present in the study area according to the aim and objectives of the study. Enitan *et al*. (2017), in the microbial assessment of indoor air quality in selected primary schools in Nigeria, had a checklist that covered items like number of pupils in class, the condition of the classroom (including evidence of dampness and mould, level of classroom hygiene, etc.); elements that make up the classroom building (including window and door types, area of classroom, floor type and electrical fittings like fans and light), observed ceiling heights, layouts of rooms, furnishing and furniture and room organisation in basic schools in which they conducted studies to identify protocols for post occupancy evaluation of schools observed the following in evaluating indoor environmental quality

conditions in elementary schools in the United Arab Emirates: Building envelope including mechanical and electrical installation, interior of the classrooms and the structure of the classrooms. The outdoor conditions were also observed. Sripongpun *et al*. (2016) observed the reaction of occupants to the environmental conditions in classrooms, the weather, and activities that are likely to affect results of measurement of parameters. According to Rodriguez *et al*. (2019) these observations are important in the assessment of IEQ in rooms because they help to develop appropriate indoor conditions in classrooms which improve comfort. Even though the use of observation is important in the assessment of IEQ, not all assessments include observation. Turunen *et al* (2014), for instance, used questionnaires for principals of the schools under study on 'school buildings and the health and well-being of students', to identify the technical attributes of the school buildings and their conditions. Observational survey is usually undertaken with other objective or subjective methods of data collection. These include questionnaires, interviews, and measurements of IEQ parameters.

Occupants Survey

The use of questionnaires to the occupants of the classrooms- pupils and teachers, and interviews of facility managers or maintenance officers where necessary is a subjective approach to data collection which shows the stakeholder's perception of the facilities concerning the indoor environmental quality in classrooms. In the assessment of IEQ, authors used a survey to find out the views of stakeholders (occupants: teachers and students, and facility managers) (Hameen *et al*., 2020, Banani *et al*.,2016). Questionnaire surveys are regarded as the simplest and most cost-effective method for assessing IEQ in a building (Heinzerling *et al*., 2013; Hassanain 2015). A questionnaire survey tends to be relatively easy to distribute and to collect data from a large sample in a brief period than other types of surveys. (Hassanain, 2015). Sola (1998) posited that even though one would naturally think that good air quality depends on the necessary components and the absence of harmful gases in the air in suitable proportions, it is the user, who is the best judge of its quality through respiration. However, Heinzerling *et al*., (2013) observed that the subjective nature of surveys and the range of opinions for similar IEQ physical conditions make using surveys as the only tool for evaluating IEQ in buildings complicated. According to Dykes and Baird (2013), even though the response to questionnaires which allows insight into occupants' perception of indoor environmental conditions in a building are subjective, as everyone has different ideas on comfort, there are common trends in response which often allow problem areas to be identified. An overall rating of the building is to be determined.

In the assessment of IEQ, a questionnaire survey is often used to find information such as perception of comfort, indoor conditions, and satisfaction with indoor conditions. In the case of assessing IEQ in classrooms in basic schools, questionnaires in assessing IEQ are administered to adults and or children depending on the aim of the study. It is important that contents of questionnaires are normally framed to be understood by the respondents. The questions that are asked teachers cannot be the same as those answered by students. Questions asked students should be simple enough for them to understand, (Hameen et. al, 2020). De Guili *et al*. (2012) developed questionnaires for pupils to know their perception on thermal sensitivity and the indoor conditions in the classrooms. The researchers avoided the use of technical terms that were deemed difficult to be understood by the children, and the questions were developed to the understanding of the children. In like manner Rodriguez *et al*. (2019) administered questionnaires to

pupils and parents in the schools studied. There were paper questionnaires for the pupils, and online questionnaires for parents and staff. Questions in this study were formed according to occupants' age and development stage. The use of illustrations was employed in the children's questionnaire for easy understanding. Rodriguez *et al* (2021) observed that the meaning of expressions such as 'slightly, neutral, unacceptable or satisfied' were not well understood by the children and replaced them with terms like 'little, neither X nor Y, uncomfortable or happy'. Heinzerling *et al*., (2013) identified two types of surveys: the "Right-now" surveys which require information about conditions at the moment the survey is being conducted, and long-term surveys requires summarised information about their overall satisfaction for the past week, month, or year. Salamone *et al*. (2021) used the Right-now survey to assess the perception of students on IEQ in classrooms in Albania. The respondents to the above research expressed their perception of IEQ on hourly basis within three hours, whilst measurements were taken at the same time. In their study on 'IEQ Field Investigation in High-Performance, Urban Elementary Schools,' Oldham, and Kim (2019) distributed online questionnaires and hard copies of questionnaires addressing IEQ satisfaction and self-rated productivity to only elementary school teachers in selected schools via email and by hard copies. The hard copies were distributed and collected simultaneously as the IEQ monitoring devices. This infers that the current survey was used in the study.

IEQ surveys have been developed and validated for use during assessments. These surveys were developed in developed countries like the United States of America, the United Kingdom, Canada, and the Netherlands. Sadick (2018) mentions the following types of surveys in his study of assessments of school buildings in relation to IEQ: the Building Use Studies (BUS) Occupant Survey, the Building Assessment Survey and Evaluation (BASE), the Centre for the Built Environment (CBE) Survey, the Cost-effective Open-Plan Environments (COPE) and the Health Optimization Protocol for Energy Efficient Buildings (HOPE). Dykes and Baird (2013) identified twenty such surveys, all from developed and temperate countries. Out of the twenty (20), only four of these surveys: Centre for Built Environment (CBE), Design Quality Indicator (DQI), Higher Education Funding Council (HEFC) methodology, and Alex Marmot Associates (AMA) Workwear, could be used for educational facilities. In contrast, all the twenty could be used for offices and residential facilities. These surveys have been in operation for decades and as such, researchers need to use them as guides to formulate their own surveys by adjusting them according to the research objectives of the research. While some researchers used established surveys in their studies (Oldham and Kim, 2019; Turunen *et al*., 2014), others developed questionnaires for assessment of IEQ). (Rodriguez *et al*., 2019;Awang *et al*., 2015; Barret *et al*., 2015; Toyinbo *et al*., 2016; Jarvi *et al*., 2018). The answers received from questionnaire surveys can be affected by how they are phrased. This can lead to biased or otherwise inaccurate results which in turn makes comparisons between surveys complicated (Heinzerling *et al*., 2013).

Measurement

'Mindless measurement is pointless if it serves no useful purpose' Reay and Swift-Hook (1979 (pp619)).

Another dominant form of data collection used by authors for the development of IEQ assessment framework from reviewed articles is the measurement of IEQ parameters by developers of the frameworks (Ibrahim *et al.*, 2021; Hameen *et al.,* 2020; Rickenbacker, 2019). Measurements of IEQ parameters form the objective aspect of IEQ assessment (Gyimah *et al.,* 2019). From the literature reviewed, measurement of IEQ parameters was employed by most of the authors as the objective approach to data collection, in the assessment of IEQ in classrooms in basic schools (Table 1). Measurement of indoor environmental quality parameters and observation of existing conditions, help assessors to validate, and explain occupants' perceptions of IEQ conditions. The IEQ parameters have components that when measured provide the holistic condition of the parameter. The components are chosen based on the authors' aim and objectives for the frameworks.

Indoor Air Quality (IAQ)

According to the literature reviewed IAQ happens to be the parameter that appears most in the assessment of IEQ. Assessment of IAQ encompasses the testing of the indoor space for pollutants which are potentially harmful to occupants' health, including carbon monoxide, particulate matter 2.5 and particulate matter 10 and volatile organic compounds and air movement or ventilation rates. (Hameen *et al.,* 2020; Toyinbo et. al., 2019; Fadeyi *et al.,* 2014) Fadeyi *et al.,* 2014 measured Volatile Organic compounds (VOCs), CO, CO2, Ozone (O3), Formaldehyde, and particulate matter in evaluating IEQ conditions in schools in Saudi Arabia; Hameen *et al.,* (2020) also measured CO (ppm), CO2 (ppm), TVOCs (ppb), and Particulate matter in their study to establish protocols for POE in schools. From the literature it has been observed that together with temperature and relative humidity, carbon dioxide has been used in many studies to determine the rate of movement of air or ventilation rates through the indoor space and this is used to show whether occupants are comfortable or not so far as stagnation of air in the indoor space is concerned. (Hameen *et al.,* 2020; Vilcekova *et al.,* 2017; Oldham & Kim, 2020; Ragazzi *et al.,* 2017; Pajek *et al* 2017; Rodriguez *et al*, 2019; Toyinbo *et al*. 2016; Jarvi *et al.,* 2018; Haverinen Shaughnessy & Shaughnessy, 2015). It has also been observed from the review of the literature that the choice and the number of AIQ components measured depends on the aim and objectives of the study. Additionally, when the study is only on IAQ the number of components measured are more than when the study is on a combination of IEQ parameters.

Thermal Comfort

Other factors that can create an environment that negatively affects its occupants' health and well-being include the lack of the occupants' ability to control temperature and humidity. (Sassi, 2006). Thermal Comfort is a subjective component in determining good or poor IEQ, which cannot be directly quantified. It is however a particularly important determinant of good or poor IEQ. 'It has been established that the thermal comfort level is acceptable if at least 80% of the occupants feel comfortable with it' (Mujeebu, 2019). The building envelope plays a significant role in providing an acceptable thermal comfort level (Samad *et al.,* 2017). Thermal Comfort components assessed in reviewed IEQ assessment studies include air temperature, relative humidity, Radiant temperature, Air infiltration through walls and windows, draught, occupants' ability to adjust the thermal indoor environment, ambient Temperature, and air speed (Hameen *et al.,* 2020; Anderson *et al.,* 2021) Soccio

(2016) measured Radiant Temperature, Ambient Temperature, Relative Humidity, Air Speed to determine thermal comfort in the development of a tool to assess IEQ in educational environments; Hameen *et al.* (2020) measured Air temperature, relative humidity, Radiant temperature, spatial qualities Air infiltration through walls and windows to determine thermal quality in the establishment of protocols for the post occupancy evaluation of classrooms to improve IEQ. However, the most measured components in the assessment of Thermal comfort when assessing IEQ in classrooms in basic schools are temperature and relative humidity. All the authors listed in Table 1 measured air temperature and relative humidity in assessing thermal comfort as part of the assessment of IEQ in classrooms in basic schools.

Visual Comfort

From studies reviewed the light levels were the third measured parameter in the assessment of IEQ in classrooms of basic schools (Table 1). Adequate light in a classroom enables children to study without straining the eye and promotes effective interaction between teachers and students. Daylight penetrating the classrooms makes students efficient, improves overall health and increases energy efficiency (Qhatan, 2019). Visual comfort is facilitated by adequate lighting levels depending on the activities carried out within a space (Mujeebu, 2019). Lighting levels are measured in IEQ studies to ascertain the level of comfort occupants have visually. Fadeyi *et al.* (2014) measured daylight levels in assessing classrooms in Saudi Arabia; Pajek *et al.* (2017) measured illuminance of surfaces in nursery classrooms in Slovenia; Awang *et al*. (2015) measured artificial lighting levels in assessing IEQ and user perceptions in a school in Malaysia. Oldham and Kim (2019), Barret *et al*. (2015) and De Guilli (2012) also measured illuminance in various studies regarding IEQ conditions in classrooms. It has been observed that building orientation, windows and openings in walls, and shading devices are the main aspects of buildings to consider in the provision of lighting indoors, (Fadeyi *et al.,* 2014; Abanyie *et al.,* 2014)

Acoustic Comfort

Acoustic discomfort is one of the factors that make the most contribution to the dissatisfaction level of the occupants in schools, which could affect the teaching and learning performance (Awang *et al.,* 2015). The acoustic comfort in a building has a crucial impact on the health, well-being, communication, and productivity of the occupants. However, from the literature reviewed, acoustic comfort is the least assessed parameter in IEQ assessments in classrooms in elementary schools. From Table 1, seven out of the nineteen papers reviewed assessed acoustic comfort. Some of the components of acoustic comfort measured include acoustic attenuation Room Criteria, reduced background sound levels Noise Criteria Optimise speech communication and reduced intelligibility Balanced Noise Criteria to determine acoustic comfort (Hameen *et al*., 2020); Reverberation, Signal to noise ratio, Background noise, mechanical noise (Soccio, 2016). The main component measured by assessors of IEQ in classrooms in basic schools is sound level (outdoor and indoor). The location and orientation of buildings and their ability to prevent infiltration of noise into the indoor space (by choice of materials) are important for the provision of acoustic comfort. Since classrooms are used for teaching and learning, optimising the comprehension of speech is essential.

A review of IEQ parameters measured in IEQ assessment brings to the fore the fact that there are various components. Interestingly it has been observed that the parameters measured to assess IEQ remain the same no matter the country or objective. These are Thermal comfort, Indoor Air Quality,

Visual comfort, and Acoustic comfort. The components however differ according to the authors' aims and objectives of the study.

Tools for Assessment

Even though bulky and many sophisticated tools have been used to assess indoor parameters, Rodriquez, and Medina (2019) suggest that it is advisable to use a few small sized and least complex tools when measuring indoor environmental parameters for classrooms for children. This would prevent interference in teaching and learning activities and accidents. Each parameter has various tools of different makes to measure with. A review of the literature on IEQ assessment framework gives a few tools that were used for assessment. Rickenbacker *et al.* (2019) and Hameen *et al.* (2020) used the following to measure IAQ in mixed facilities: Graywolf 3016 Handheld airborne particle counter (Counting efficiency: 50% at 0.3, 100% at > 0.45); The Graywolf Advanced Sense Probe; Graywolf FM-801 formaldehyde (HCHO), Graywolf IAQ-610 (with accuracy: CO, ± 2 ppm < 50 ppm, ± 3%rdg > 50 ppm; CO2, ± 50 ppm, ± 3%rdg. For visual comfort, Hameen *et al.* (2016) used Luminance map generated by the photos taken with the fish-eye lens [Nikon camera Coolpix 8400 and FC/E9] Post-processed by Photolux 2.0 software. For thermal comfort Hameen *et al*. (2020) employed the use of different tools for different components: for temperature, Graywolf IAQ-610 and HOBO (Accuracy: ± 0.3 °C); for relative humidity (%), Graywolf IAQ-610 and HOBO (Accuracy: ± 2% at < 80%); Omega OS643 radiant temperature meter for radiant temperature, and Fluke TI50FT-20 Thermographic camera for air infiltration through walls. Hameen *et al* (2020) measured sound for acoustic comfort with Bruel & Kjaer Hand-held Analyzer Type-2250 (Range: 20 dB - 140 dB). Other studies on IEQ assessment produced many different tools used for the different parameters.

Pajek *et al.* (2017) for instance used Testo 445 (for Temperature, Relative humidity, and Ventilation), Testo 535(Carbon monoxide, Carbon Dioxide), Raytek Raynger MX (Temperature of surface) and Voltcraft DT 8820 (outside Noise levels, Daily illuminance) to measure the indoor environmental quality of children's playhouses. There are tools that can measure many parameters concurrently or consecutively; one such example is the Air Mentor which is a 6-in-1 indoor pollutant concentration monitor (Model No.:8096-AP) carbon dioxide (CO2), volatile organic compounds (VOCs), along with carbon monoxide (CO), particulate matter, (PM2.5 and PM10), temperature and relative humidity. (Orola, 2020). To ensure accuracy, there is a need for validation through calibration. (Hameen *et al.,* 2020; Haverinen-Shaughnessy & Shaughessy, 2015). It is advised by Rodriquez and Medina (2019) that multi-channel data loggers have been mentioned above are suitable measuring options because they record time-based information and can measure different parameters simultaneously. An interesting observation from the literature points to the fact that there are numerous tools now on the market that can be used for measurement, provided the values can be validated. It was rare to find the same type of tools being used by different researchers for the same components. Heinzerling *et al.* (2013) observed that it is difficult to find accurate, easy-to-use, and inexpensive measurement equipment in IEQ performance evaluation.

From the philosophy of monitoring by Reay and Swifft-Hook (1979 (pp618)) ten (10) factors were suggested in a checklist to guide the selection of methods and instruments for monitoring. This suggestion is still relevant in modern day monitoring and measurement practices. The list is as follows

a. **Sensitivity and limits of detection**. This refers to the limits and capacities of

measurement of the available methods and tools can accommodate.

b. **Time resolution**. This refers to the possible operating time of available methods and tools and whether they align with the study objectives. Heinzerling *et al.* (2013) suggest that objective measurement depends on finding a representative period and interpreting the results accurately.

c. **Accuracy and precision**. This refers to the tendency of results from measurement to be reasonably close to real pollutant concentrations given by a reference method. It also refers to the probability of getting equivalent results with the same method on repeated measurements.

d. **Specificity.** This is the ability of a prospective method to exclusively measure the particular pollutant of interest without any considerable influence from the presence of other materials in the concentrations.

e. **Reliability**. The ability of the tools to operate accurately and without trouble for extended periods and the sensitivity of the method or tool to environmental conditions or voltage fluctuations. Attention should be paid to the tools' frequency of need for calibration or maintenance. Concerns about sensor accuracy/calibration and cost in IEQ assessment make it important to choose the right tools (Heinzerling *et al.,* 2013; Gyimah *et al.,* 2019)

f. **Field or laboratory analysis**. This looks at where the results are obtained, whether on a monitoring site or at a laboratory for analysis. Attention must be paid to the unit cost of analysis if to be done at a laboratory.

g. **Versatility**. The ability of the sampling or measuring tool to be used for more than one pollutant if the need arises.

h. **Staff**. The required number and availability of staff needed for measurement.

i. **Data output**. The ability of an instrument to provide results in a form or with a frequency compatible with the other data being collected and with the user's needs.

j. **Price**. Consideration of price in the whole endeavour of measuring IEQ parameters.

The above listed must be considered in relation to the aim and objectives of IEQ assessment.

Hameen *et al*. (2020) spell out differences in the following areas between the measurement of IEQ conditions in offices and those of schools. The varied heights of desks in interior spaces, increase in metabolic rates, activities and movements of occupants, spot measurements, dynamic workstations, acoustic interference, age of occupants, data entry. A consideration of these differences serves as a guide in the design and implementation of assessment of IEQ in classrooms in basic schools.

Duration of measurement

Duration of measurements of IEQ components in classrooms in basic schools are varied. They range from a day to a year or more depending on the objectives of the study.

Whether one should measure all the time or only at intervals depends very much on what one wants from the data (Reay & Swift-Hook, 1979). (Rickenbacker *et al.,* 2019) measured air quality for three days at each location within 8hr period at random times; and also did continuous measurement to find out overnight values in IAQ concentrations. The World Health Organization (2011) recommends 5 days in winter and five days in summer as the duration for measuring IAQ

in classrooms in Europe, and within the times of occupancy. ASHRAE also recommends that measurement of IAQ must be done at the time of occupancy. Measurement of IAQ and thermal comfort components may take up a considerable percentage of time used in measurement. This is because whilst lighting and acoustics can be taken on the spot, some of the pollutants need to be measured over a period as dictated by set standards. De Guili *et al.* (2012) however, used spot measurements to measure temperature, air velocity, relative humidity, carbon dioxide concentration and illuminance levels in assessing seven schools in a study on children's impression about buildings in which they studied. Barret *et al.,* (2015) also employed spot measurements to measure lighting levels, carbon dioxide concentration, temperature, relative humidity, and noise levels in classrooms in a study to establish whether there is an impact of school buildings on primary school pupils' learning rates. Hameen *et al.,* (2020) from studies of over 1700 tests and measurements throughout the course of a longitudinal study and ongoing measurements studies suggest the use of an average of 20 minutes for measurement in each classroom in a school building (figure 1).This is to avoid distraction of teachers and students in the classrooms. Ackley's (2021) study into measurement of IEQ in national schools in New Zealand revealed that measurements of IEQ in schools by different authors covered a duration of between 20 mins and 3 mins whilst some authors used spot measurements. This is in agreement with Godish's (2001) suggestion that one time sampling can be used for routine assessment of IEQ to reduce cost, where one time sampling is sufficient.

It is important to conduct IEQ field measurements in schools by performing the measurements with minimal disruption to students and teachers in the classrooms. However it is recommended that occasional continuous measurements may be needed in situations where anomalies are detected after a spot measurement is performed. It may also be beneficial to perform a continuous measurement in response to further investigation of IEQ results (Hameen *et al.,* 2020)

Standards for Assessment

The measurement results of IEQ components must be validated by comparing them to a benchmark or standard set by a recognised body (Gyimah *et al*., 2019). In studies conducted on the assessment of IEQ in classrooms in basic schools, the standards mainly used for validation are those of the ASHRAE Standards 62.1-2007; ASHRAE Standard 55-2010; USEPA Air Quality Standards; IESNA Lighting handbook; Building Bulletin 93 and 101; CEN European Committee for Standardisation 13779; and WHO. Other standards developed by countries for their use have been used as well; for instance used the Thailand Department of labour Protection and Welfare Ministry of Labor (TDLPW), (2006), while Pajek *et al.,* (2017) also used Slovenian national guidelines together with some international guidelines to validate their results. Studies conducted in Africa e.g., Ghana and Nigeria have used ASHRAE for validation since there are no national standards for IEQ levels in classrooms in basic schools. (Gyimah *et al.,* 2019; Toyinbo, 2019; Abanyie, 2014), even though Ghana has standards for ambient air quality and noise levels. The problem with these benchmarks however is that they were set up using results from temperate regions and from assessing adults in either working environments or even higher educational environments. As a result, measurements taken in tropical areas hardly fall within these standards (Sripongpun *et al.,* 2016; Rodriquez *et al.,* 2019). ASHRAE has been used widely by researchers who assess IAQ and thermal comfort, together with Occupational Safety and Health Administration (OSHA), American Conference of Governmental Industrial

Hygienists (ACGIH), National Institute for Occupational Safety and Health (NIOSH). ACGIH, however belongs to a group of standards that have technical criteria that been specifically established for working adults within specific lengths of exposure and therefore not advisable to apply to the general public (Sola, 1998). Other standards: Illuminating Engineering Society of North America (IESNA); EN15251and American National Standards Institute (ANSI) have been used in the measurement of Lighting and Acoustics. Apart from Building Bulletin from United Kingdom and the European Union's EN 15251which covers the four predominant components of IEQ one hardly finds all the guidelines and requirements in one standard. Standards and requirements tailored for classrooms in basic schools are few, especially in the case of developing countries and countries with tropical climatic conditions. The Ghana building codes refer to ASTM D5197, D5466, D6196, D6345 and ISO 7708 for assessment of IAQ: ASTM E413, E336, E90 for assessing acoustic levels in completed building. there is however ANSI/ASA S12.60-2010/Part 1 or 2009 Part 2 for assessment of acoustics in classrooms (Ghana Building Code 2018).

FINDINGS

1. There are limited studies on assessment of IEQ in classrooms of basic schools, in Ghana.
2. Authors have used qualitative and quantitative data collection methods in IEQ assessment in classrooms in basic schools. The use of both quantitative and qualitative methods is accepted for use in the assessment of IEQ in classrooms since they give holistic results.
3. The main IEQ parameters assessed are AIQ, Visual Comfort, Acoustic Comfort and Thermal Comfort
4. There are differences between the assessment of IEQ in classrooms in basic schools and other places like offices, commercial buildings, and hospitals.
5. There are different methods for measuring IEQ parameters in terms of tools, standards, and duration. There is no established one-size-fits all assessment method for universal use.
6. The use of small sized tools is recommended for the measurement and monitoring of IEQ in classrooms in basic schools to reduce or prevent distraction.
7. The questionnaire survey used for children is supposed to be different from that used for adults due to the difference in level of understanding.
8. Results from IEQ measurements in buildings in tropical climatic regions do not conform with international standards like ASHRAE because of the climatic regional differences. They are however used by researchers and assessors as benchmarks.
9. Existing IEQ standards were established using adults and buildings occupied by adults and may not agree with results from children or areas occupied by children.

CONCLUSION

The continuous study of IEQ in classrooms in basic schools is important because of the linkage between IEQ and occupants' health. The methods to be adopted for the assessments of classrooms in basic schools will include quantitative and qualitative methods. These will include observation, survey, and measurement. The strategies used will depend on the aim of the assessment. Due to the presence of various ways of assessing indoor spaces, there is a need to establish a framework that will serve as a reference

material for IEQ assessments in Ghana to enable the further development of policies and tools that will ensure the provision of a healthy environment for occupants of classrooms in basic schools.

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