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SEASONAL ASSESSMENT OF RELATIVE HUMIDITY, AMBIENT AIR TEMPERATURE AND CO_2 CONCENTRATION LEVEL IN SCHOOL BUILDINGS OF KIGALI-RWANDA

Elisephane IRANKUNDA[1+]
Dieudonne Tuyisabyimbabazi[2]

[1]*The East African University (TEAU), School of Computer Science and Information Technology, Kenya.*
Email: elisephane@gmail.com
[2]*University of Rwanda, College of Science and Technology, Rwanda.*
Email: tuyisabyedeus@gmail.com

(+ Corresponding author)

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ABSTRACT

Numerous researches on air quality have shown that schools settled in poor ambient air quality regions, the later can negatively affect health of people at the school including students, teachers and other staff members. In Kigali city, most of the schools are naturally ventilated given their surroundings, school car-parks, school occupancy and number of people attending school daily. The seasonal assessment of relative humidity, ambient air temperature and co_2 concentration levels in school buildings of Kigali was the main objective of this paper. This research was carried out within three schools located in different parts of Kigali city and having dissimilar construction designs. Sampling activities were performed during both dry and rainy seasons by using air visual nodes instruments. Results indicated that the level of ambient air temperature for dry season and rainy season was in the range of (21-27) °C and (18-25) °C respectively for the three schools. The carbon dioxide concentration for the schools was in the range of (350-450) ppm for dry season and (400-550) ppm for rain season. The relative humidity of rainy season was higher than that of dry season. The result values found exceeded the recommended values of World Health Organization guidelines of 18 °C for temperature and 350 ppm for CO_2. This paper suggests that school-car-parks and school-kitchens should be remote from schools. Waste-materials at school should be well managed and their disposal should be away from school-location. Schools should be surrounded by trees and gardens for better air quality within schools.

Contribution/Originality: This study is one the few studies which have investigated the seasonal changes in relative humidity, ambient air temperature and carbon dioxide concentration level in school buildings in Rwanda.

1. INTRODUCTION

Good air quality is an important characteristic of life, the quality of air inside offices, homes, class rooms, shops, hospitals, public and private buildings where people spend most of their time doing different duties is a significant feature to determine health status of such people (Bakó-Biró *et al.*, 2012; Chithra and Nagendra, 2012; Almeida and de Freitas, 2014; Tomić *et al.*, 2014). Nowadays most of vulnerable groups are young children and old-adults; they spend most 100% of their time indoors and are highly attacked by respiratory diseases such as allergies, pulmonary diseases and asthma (Kurmi *et al.*, 2010).

Outdoor air quality behavior within school-buildings is a significant subject of concern based on its positive or negative impacts on school activities. The quality of air in schools affects the learning activities of students, teaching methods and performance of staff in their activities (Mendell and Heath, 2005).

Air pollutants have great health effects especially on young (Nursery, Primary, and Secondary level) students who are easily attacked by respiratory diseases, mostly asthma and allergies. These effects decrease their performance and attendance in class, which result in failure of students in addition to schools', parents' and government's money expenses for students health care (Torres *et al.*, 2002; Mendel and Heath, 2004).

Ambient air temperature is considered as a serious aspect as it has effects on the comfort, performance and productivity of everyday people's activities in general. In schools, the control of air temperature can enhance the memory ability of students to focus and learn their subjects well; it is the same for teachers and other school-staff-members, they perform well their duties. Low or high relative humidity has impact on human being. High levels of humidity encourage the development of molds and microbes responsible for asthma and allergy, while low levels of relative humidity contribute to the growth of air particles like spores and dust which result in irritation of eyes. High levels of carbon dioxide (CO_2) concentration, an air pollutant, can cause discomfort to health associated with headaches and fatigue (Daisey *et al.*, 2003; Mansour, 2014).

In schools several factors can influence quality of air, namely school car-park, School-kitchens, School-electronic equipments, school-construction design associated with its ages, school-teaching supplies, school-waste materials deposition and school-surroundings (Daisey *et al.*, 2003; Raysoni *et al.*, 2011).

Gaps concerning air pollution data set in Rwanda were identified. There is a small number of publications on indoor and outdoor air quality, and personal exposure assessment studies. Especially few present studies are related to traffic emissions and ambient air quality for specific areas including industries and commercial areas (Rugigana *et al.*, 2016). This study comes-up as a contribution to reveal the statement of air quality within school buildings. The main objective is to evaluate the levels of ambient air temperature, relative humidity and CO_2 concentration levels within school buildings of Kigali city by using portable air quality machinery during both dry and rain seasons.

2. METHODOLOGY

2.1. Research Area Description

Kigali, the capital city of Rwanda is located at the center of the country geographically at latitude of 1º 57' South and longitude 30º04' East. This city presents a rapid population growth associated with an increase in infrastructures, industries, transport activities and economic activities. All the above mentioned aspects contribute to the increasing number of schools within Kigali city (Henninger, 2009; Henninger, 2013; Kumie *et al.*, 2014).

This research was conducted in three schools of Kigali city Figure 1 namely: School_1; School_2 and School_3. School_1, is a boarding mixed (boys and girls) secondary-school located at (S: 01.992897; E: 030.097025; Alt: 16010m), the geographical coordinates were established in 1995. Teaching activities start at 08h: 00 and end at 17h: 00 during weekdays, while in weekends students do self-studies and revision. At the time of sampling activities, the total number of students was 1703. School_2 is a boarding mixed (boys and girls) secondary-school located at (S: 01.967284; E: 030.098225; Alt: 1368m), the geographical coordinates were established in February, 1997. Teaching activities start at 08h: 00 and end at 17h: 00 during weekdays, while in weekends students do self-studies and revision. School_2 is located in residential areas where we have many people living around the schools. At the time of sampling activities, the total number of student was 1600. School_3 is a day mixed (boys and girls) secondary-school located at geographical coordinates: (S: 01.954489; E: 030.058840; Alt: 1548m). Teaching activities start at 08h: 00 and end at 17h: 00 during weekdays. The school has also nursery and primary level students. This school is surrounded by commercial buildings. At the time of sampling activities, the total number of student was 2011. The Figure 1 illustrates Kigali city map, where the arrows show the location of school-1, school-2 and school-3.

Figure-1. Location of sampled school in Kigali city.

2.2. Data Collection and Analysis

The main goal of this paper is to assess seasonal levels of outdoor air temperature, CO_2 concentration and relative humidity in school buildings of Kigali city. For each school, sampling activities were performed during both dry and rainy seasons. Data were collected for long dry season which covers the months of June, July, August and September (JJAS), for short dry season covering January and February (JF). The sampling was also during short rainy season covering months of October, November and December (OND). In dry season we considered three rounds of sampling where students are in schools during day time. The first round was conducted in two first successive weeks of July, second round in two successive weeks of August and the last round in two successive weeks of February of 2018. For rainy season we considered the first two weeks of September, October and November of 2018 for first, second and last round respectively where the student are also in schools during day time. Air Visual Nodes instruments were used to collect data of ambient air temperature, concentration level of CO_2 and relative humidity (RH). After sampling activities all collected data were analyzed using statistical methods. The following Figure 2 illustrates the sampling activities at the field during data collection.


Figure-2. Sample of captured photo from sampling activities where the student was in class. Air Visual Node instruments used in data collection.

3. RESULTS AND DISCUSSION

This section discusses all findings from this study, where air quality details of the considered three schools namely School_1, School_2 and School_3 are also discussed in this section. The average values from round-sampling for all schools by considering dry and rain season are presented in Table 1 and the corresponding graphical representations are in Figure 3 and Figure 4, which illustrate round sampling average values of ambient air temperature and CO_2 concentration levels.

Table-1. Results from round-sampling by considering all season in all school.

Seasons	Rounds	Schools	Temperature (°C)	Relative humidity (%RH)	CO_2 (ppm)
Dry	1	School_1	25.553	58.345	393.365
		School_2	25.771	58.308	413.941
		School_3	24.536	45.107	393.405
	2	School_1	20.993	68.402	425.973
		School_2	23.574	48.523	432.431
		School_3	23.174	49.85	415.246
	3	School_1	26.408	65.119	392.319
		School_2	25.825	59.817	396.233
		School_3	23.726	56.652	395.953
Rain	1	School_1	19.492	76.629	489.377
		School_2	22.326	70.023	479.450
		School_3	20.462	75.159	438.023
	2	School_1	20.056	78.541	593.231
		School_2	21.293	74.270	395.893
		School_3	22.202	72.275	481.212
	3	School_1	19.353	82.439	496.990
		School_2	21.804	72.501	489.671
		School_3	20.976	81.995	447.6287

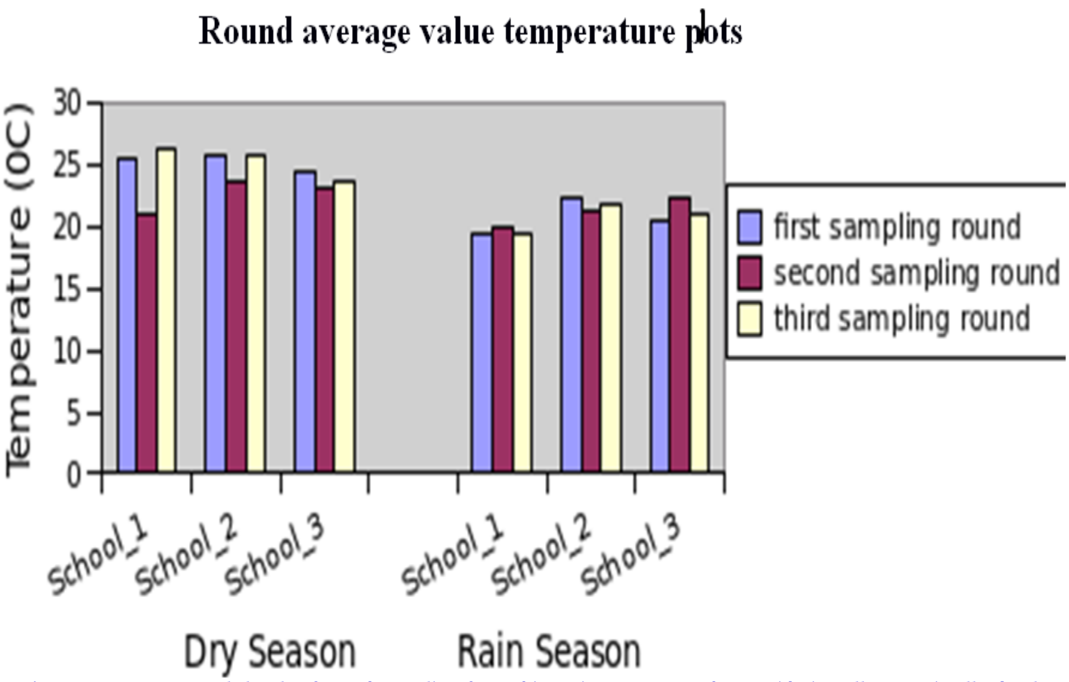

Figure-3. Average result levels of round-sampling for ambient air temperature by considering all season in all schools.

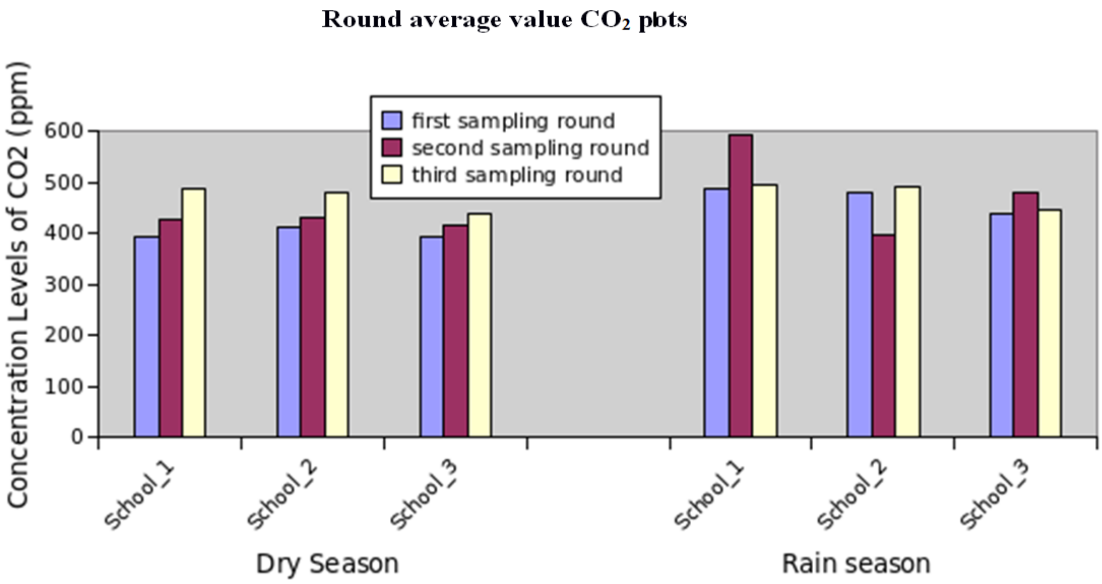

Figure-4. Average result levels of round-sampling for ambient CO_2 concentration by considering all season in all schools.

The Figure 3 depicts the results of the round-sampling of ambient air temperature by considering rain and dry season in all school. It indicates generally that the level of temperature for rainy season is law compared to that for dry season while Figure 4 illustrates the round-sampling for ambient CO_2 concentration by considering rainy and dry season in all school. The figure indicates generally that the level of ambient CO_2 concentration of the rainy season is high compared to that of dry season. Considering each school's levels with respect to season we have the following discussion.

The results from sampling activities in school_1 show that in dry season the average levels of ambient air temperature and CO_2 are 24.32ºC and 403.89 ppm respectively while relative humidity is 63.956%. For rainy season the average levels of ambient air temperature and CO_2 are 19.634ºC and 526.533 ppm respectively and relative humidity is 79.20%. The results show that dry season is warmer than rainy season. The results indicate that dry season has a lower relative humidity compared to rainy season. CO_2 concentration levels are higher during rainy season than during dry season.

The results from sampling activities in school_2 show that in dry season the average levels of ambient air temperature and CO_2 are 25.057ºC and 414.202 ppm respectively while relative humidity is 55.55%. For rainy season the average levels of ambient air temperature and CO_2 are 21.808ºC and 455.005 ppm respectively and relative humidity is 72.265%. These results show that the dry season is warmer than rainy season. Relative humidity in dry season is lower than that of to rainy season. Carbon dioxide concentration levels increase more during rainy season compared to dry season.

Results from sampling activities in school_3 show that in dry season the average levels of temperature and CO_2 are 23.812ºC and 401.535 ppm respectively and relative humidity is 50.536%. For the rainy season the average levels of temperature and CO2 are 21.214ºC and 455.621 ppm respectively and relative humidity is 76.476%. The results show that dry season is warmer than rainy season. There are lower levels of relative humidity in dry season than in rain season, whereas CO_2 concentration levels increase more during rainy than during dry season.

All the above variations are due to meteorological parameters and human activities of the place where school is located and the school surroundings like forest, threes and gardens. Carbon dioxide concentration levels variation is due to poor management of waste materials from schools or around the schools, emissions from school bus-parking, emissions from school kitchens and emissions from school surroundings.

Table-2. The seasonal average values for the selected Schools.

Seasons	Schools	Temperature (°C)	CO_2 (ppm)	Relative humidity (% RH)
Dry	School_1	24.318	403.886	63.955
	School_2	25.056	414.202	55.549
	School_3	23.812	401.535	50.536
Rain	School_1	19.634	526.532	79.203
	School_2	21.808	455.005	72.265
	School_3	21.213	455.621	76.476

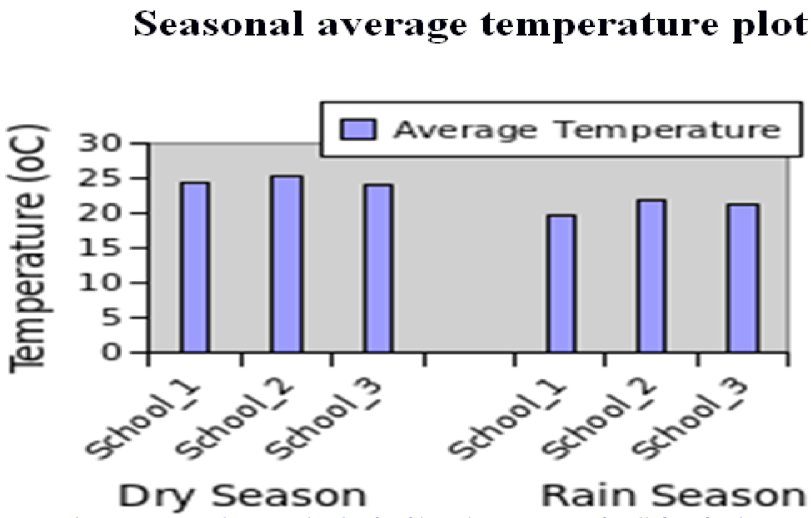

Figure-5. Seasonal average levels of ambient air temperature for all the schools.

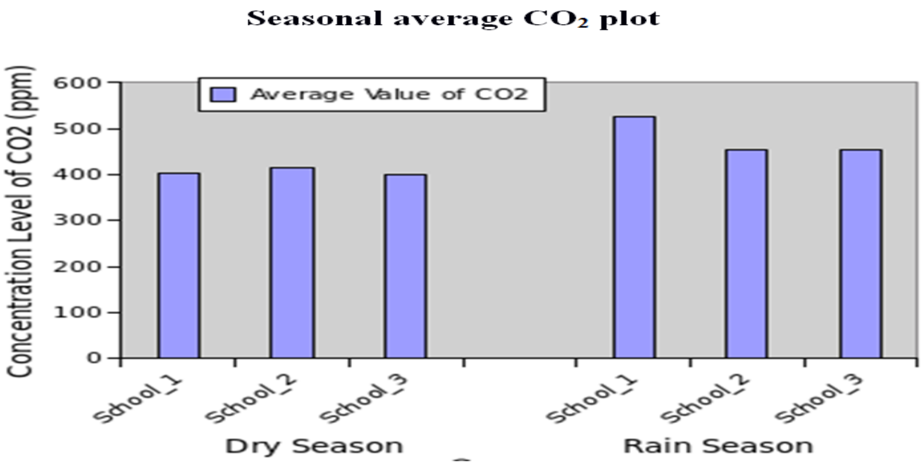

Figure-6. Seasonal average levels of CO_2 concentration for all the schools.

The graphical representation of seasonal ambient air temperature averages values for all school are given in Figure 5 where Figure 6 shows the graphical representation of seasonal CO_2 concentration averages values for all selected schools and Table 2 indicates measured seasonal average values of ambient air temperature, CO_2 concentration and relative humidity for all considered schools.

4. CONCLUSION

This research is conducted into three schools locates in different parts of Kigali the capital city of Rwanda with different construction designs. Two of the schools are boarding schools and one is day-school based. Sampling activities in the schools were conducted in two seasons (dry and rainy) and the following are output results: the levels of ambient air temperature in dry and rain season are in range of (20-30) °C and (18-25) °C respectively for all the schools. While concentration level of carbon dioxide (CO_2) are in range of (350-450) ppm in dry season and (400-550) ppm in rainy season. Relative humidity is in rain season is higher compared to that of dry season for each school. The result values from the sampled schools exceed the recommended values of World Health Organization guidelines which are 18 °C for temperature and 350 ppm for CO_2 .This research come up with the following recommendations: if possible school-car-parks should be away from school compounds, school-kitchens should be away from schools, school-waste-materials should be well managed and away of school-compounds and schools should be surrounded by trees and gardens. All the recommended actions above will increase the level of best air quality within schools. The later will enhance the ability of students to focus and learn their subjects, it will help school-staff-members to perform their duties well and stay healthy; resulting in development of school and the country in general.

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