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Original Article

Influence of Air Pollution and Climate on Daily Health of Gabonese Students in the Capital (Libreville): A Pilot Study

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ABSTRACT

Air pollution is a global issue affecting billions of people, especially urban populations in low- and middle-income countries. Since air pollution is a health problem that also involves the climate, this study assessed the relationship between the individual health of 50 college students living in Libreville (Gabon) and air quality, temperature, and humidity using low-cost equipment. The study utilised 81 days of data from the air pollution monitoring network in Libreville. These data were paired with measurements of heart rate, breathing, and stress measured using 5 Garmin vívosmart® smartwatches. In addition to the environmental and health data, participants were also asked about their state of health and their lifestyle during the study. We found average concentrations of PM2.5 (25.25 µg/m3) and PM10 (29.50 µg/m3) that exceed the 24-h WHO air quality standards. The daily average of PM1 was around 17.84 µg/m3. Temperatures observed during the study period varied between 27 and 35 °C (mean = 30.15 °C), and humidity was around 51-77% (mean = 59.5%). Overall, the relationships between the environmental conditions and the health observations were negligible, with correlation coefficients $R \leq 0.36$. Despite their weakness, coefficients between 0.31 and 0.36 showed that stress levels are associated with temperature, PM2.5 and PM10. The average stress level was associated with PM10 ($R = 0.34$) and PM2.5 ($R = 0.36$). Finally, the study reveals that smokers, mosquito repellent users, and fan users have reduced breathing capacities compared to non-smokers, non-users of mosquito repellent products, non-users of fans, users and non-users of air conditioning. The study recommends the use of portable sensors to measure individual exposure to environmental parameters for similar studies, which will resolve the problem of spatial representativeness highlighted in this study. It is also recommended that Gabon's health policies incorporate early warnings of forecast high temperatures or pollution peaks, in order to limit health risks.

APA CITATION

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INTRODUCTION

Since the last century, the world has seen an evolution in digital technology in the field of health, particularly for measuring physiological parameters. When it comes to measuring weight, for example, we have moved from analogue scales, such as mechanical dial scales, to more accurate digital dial scales or impedance-meter scales that incorporate body mass measurements. As a result, the majority of devices used in hospitals and other healthcare facilities use digital scales to record health data.

In recent years, there has been an increase in the number of wearable technologies capable of automatically measuring individuals' psychophysiological markers. Aliverti (2017) pointed out that in the future, these portable diagnostic devices will be able to continuously monitor a patient's physiological or biochemical parameters, thanks to biomedical sensors embedded in them. This has led to an increase in the number of observational studies on people's state of health using inexpensive, mass-marketed smart wearable devices that record digital health data (Chakrabarti et al., 2022). Some recent studies looking at sleep disorders, cardiovascular risk, respiratory disorders and dysfunctions (Demichelis, 2018; Ramírez et al., 2019; Jhunjhunwala et al., 2020), respiratory and heart rate, and frequent allergic airway disorders (Natarajan et al., 2021) have been conducted using low cost, wearable devices such as smartwatches (Fitbit), connected wristbands (Jawbone UP3) and other devices with built-in e-health cards. Devices used in these studies have accompanying applications that synchronise and store the data in a cloud, process them, and, on some occasions, interpret them. This makes it possible to monitor human well-being (Yang, 2014; Aliverti, 2017) in the short, medium, or long term. In this respect, the study by Aliverti (2017) provides information on the types and categories of wearable devices, the integrated sensors, and their usefulness, whether for measuring body parameters or exposure to air pollution.

Air pollution is responsible for many deaths worldwide, and nine out of ten people breathe polluted air, according to a 2018 World Health Organization (WHO) report (WHO, 2018). Air pollution is a global public health issue (Maignant, 2015) mostly affecting the urban population. Air pollution is a result of the high concentration of socio-economic activities in cities (Faye et al., 2022). For example, a study by Owusu-Mfum et al. (2023) on air pollution in port cities of Houston, London, and Southampton showed that cities with intense port activities and increased road traffic have the highest concentrations of pollutants, regularly exceeding the standards set by national legislations. Other studies, such as those by Silva et al. (2021), Islam et al. (2021), Solberg et al. (2021), and Faye et al. (2022) have shown that the state of emergency caused by the COVID-19 pandemic, which began in 2020, disrupted human activities. This drop in socio-economic activities led to a reduction in air

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pollution levels and related illnesses during the containment period. This work illustrates the extent to which the cohabitation of populations with the activities responsible for air pollution facilitates the exposure of individuals to the many health risks associated with poor air quality. This being the case, urban populations are the most vulnerable because of the many pollutants they are exposed to on a daily basis. Biel et al. (2019) have studied the links between air pollution and the health of people living in cities, particularly with regard to respiratory and cardiovascular diseases. This study showed that any 7.9 $\mu g/m^3$ increase in $PM_{2.5}$ was associated with a decrease in heart rate. Similarly, Shah et al. (2013) associated increased hospitalisation and death due to heart failure with a 0.16 $\mu g/m^3$ increase in $PM_{2.5}$ and a 0.21 $\mu g/m^3$ increase in PM_{10}. Others (Gibelin, 2019) have shown the effects of air pollution on cardiovascular morbidity, particularly hypertension, heart failure and respiratory disorders. These effects are often associated with long-term exposures to $PM_{2.5}$ and PM_{10}.

In some instances, climate variables such as temperature or humidity have been shown to regulate concentrations of fine particles matter. As a result, studies by Xia et al. (2017) on ambient air pollution and cardiac arrest in Beijing showed the influence of meteorological conditions (temperature and humidity) on $PM_{2.5}$ and PM_{10} levels. The increase in $PM_{2.5}$ and PM_{10} caused by temperature and humidity variations led to the increase in cases of respiratory disorders and cardiac arrest in the elderly.

However, in other instances certain climate conditions can also be responsible for the same diseases attributed to air pollution (Mogou et al., 2022). Edou et al. (2022) and Mogou et al. (2022) have conducted studies on the relationship between air pollution, climate, and health impacts on urban populations. Thus, Edou et al. (2022) associated air pollution with 19% of deaths caused by lower respiratory tract infections between 1990 and 2022 in Libreville, compared with 11% for chronic obstructive pulmonary disease. The study by Mogou et al. (2022) associated 56% of upper respiratory tract infections with dry seasons and 52% of lower respiratory tract infections with rainy seasons in Soubré (Côte d'Ivoire) from 1988 to 2018. In addition, their analyses showed strong correlations between acute respiratory infections and temperature (0.65), humidity (0.67) and rainfall (0.81).

With regard to the studies cited above, the particularity of the present study is to assess the influence of environmental parameters (air quality, temperature, and relative humidity) on the daily health of young people in Libreville, using a participatory approach and low-cost sensors.

MATERIALS AND METHODS

Study Area

This study was conducted in Libreville, the capital and largest urban center in Gabon. Libreville is located on the north-western side of Gabon and is home to about 869,741 people, according to the 2013 census (Direction Générale de la Statistique, 2015). Libreville is located between coordinates 0.276° - 0.650° North and 9.298° - 9.790° East. The urban center comprises four communes, including Akanda, Libreville, Ntoum, and Owendo. It is bordered to the north by the Atlantic Ocean, to the east by the department of Komo Monda, and to the south and west by the Komo estuary. Its northern periphery is sheltered by the Akanda National Park, while the Mondah, a classified protected area, occupies its northeastern and eastern peripheries. To the south, notably beyond the Komo estuary, lies the Pongara National Park (Obiang et al., 2022). This territory is framed by protected areas, as shown in *Figure 1* below.

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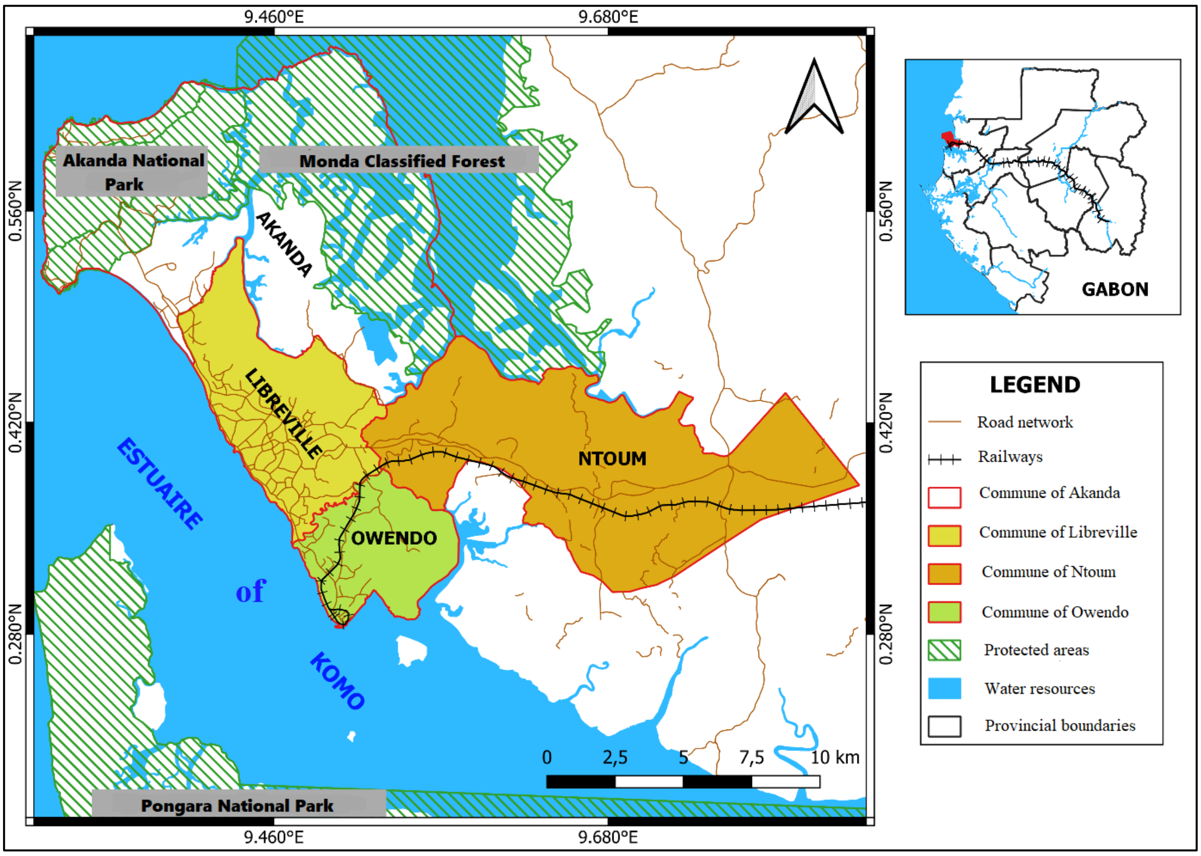
Figure 1: Location of the study area.



Source: Produced by authors using the 2013 version of the geographic database of Laboratoire de Géomatique, de Recherche Appliquée et de Conseils (LAGRAC) of the Omar Bongo University.

Participants Recruitment

The study involved a convenient sample of 50 undergraduate students from the Omar Bongo University (OBU) in Libreville. Students were recruited via word of mouth and announcements made by the *Science Au Pluriel* student association at OBU. The only inclusion criteria for participation in the study was the student status, with no restrictions on age, sex, or place of residence, and consent to take part in the study and complete the socio-demographic survey.

Tools And Data Collection

Three categories of data were collected for this study. These were air pollution and meteorological data from the city of Libreville, physiological health data from the participants, and socio-demographic data from the participants. These data were collected over a 12-week period, from 05 July to 23 September 2023.

Air pollution and meteorological data were collected using a network of PurpleAir-II-SD air quality monitors. These sensors measure a number of parameters, and those taken into account in this study are particulate matter concentrations (PM_1, $PM_{2.5}$ and PM_{10}), temperature and relative humidity. This network of air quality monitors has been operating since November 21st, 2021 and comprises 14 sensors spread across the four communes in Libreville. The data taken into account concerns only the study period from 05 July to 22 September 2023.

Physiological health data were collected using 5 *Garmin vívosmart® 5* smartwatches. These devices measure several health parameters, but the ones used in this study included heart rate, breathing, and stress. Before wearing the smartwatches, students were asked to install the Fitrockr Hub application on their smartphones. This application makes it possible to synchronise Garmin devices such as *vívosmart®* to view the

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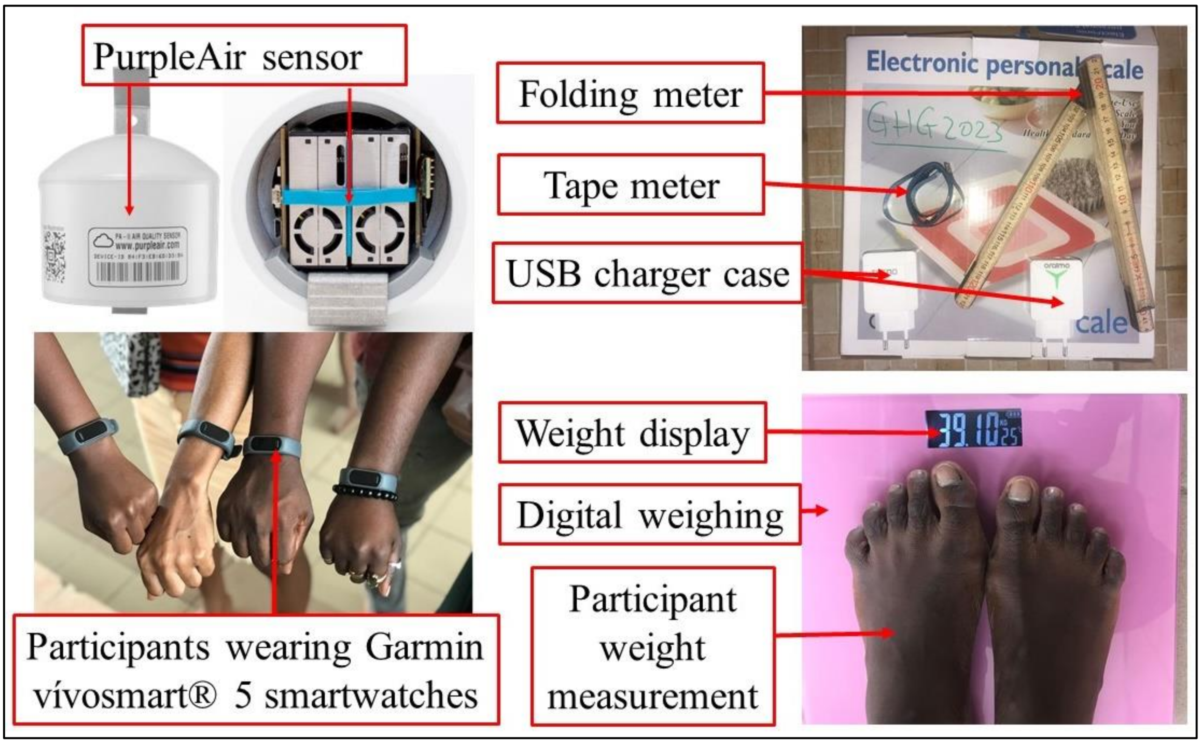
summary of health data in the smartphone. The *Fitrockr Hub application* also allows each user's data to be stored on the *Fitrockr Health Solutions server*, where the project administrator can view, process, and download it from his or her user account. After installing the Fitrockr Hub application in the smartphones, weight, and height measurements were taken using an electronic scale and a 2m folding meter. These parameters were required to register the participants before setting up their Fitrockr Hub application. Each student wore the smartwatch for one week, and all the data was downloaded in XLSX format at the end of the study.

Figure 2: Data collection tools for the study.



The socio-demographic data collected from the participants included sex, age, height, weight, health history, place of residence and use of insecticides, use of fans or air conditioning. A *Google Forms* questionnaire was sent to participants via a *WhatsApp* forum at the end of the study.

Data Analysis

Participants were coded from F1 to F26 for women and from M1 to M24 for men in order to facilitate information management. Participants were linked to data from air pollution measurement sensors based on their place of residence. Statistical analyses were carried out using the free trial version of the *JMP 17.2 .0* software to compare the independent and dependent variables. In this study, the dependent variables were the health data measured using the smartwatches (heart rate, breathing, and sleep quality), and the independent variables or predictors were the concentrations of particulate matter (PM_1, $PM_{2.5}$ and PM_{10}), meteorological data (temperature and relative humidity), and socio-demographic data. The Body Mass Index (BMI), considered to be a determinant of cardiovascular and respiratory disorders, was also calculated to assess participants' state of health. BMI was calculated by dividing the weight by the height squared. The result was expressed in kg/m² (Bernard, 2010).

Daily average concentrations of particulate matter, temperature, and relative humidity were calculated by municipalities using data from the only six sensors that were active during the study period. For the communes of Akanda and Owendo, only the monitors installed at the Ecole Nation des Eaux et Forêt (ENEF) and Alénakiri

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were functional. For Libreville, data from the sensors at Nzeng Ayong and the Ministry of Water and Forests were used. The two monitors in the commune of Ntoum (Zone économique spéciale de Nkok and Hôtel de ville de Ntoum) were operational and used for this study. These data were combined with the daily averages of physiological health data for each participant according to the commune of residence during the study period. We then carried out a two-phase analysis: descriptive and analytical. The descriptive analysis gave the general characteristics of the study population. These included their place of residence and weight status according to age, sex, and lifestyle. The analytical phase of the data consisted of studying the relationship between heart rate and respiratory disorders and the particulate matter concentrations (PM_1, $PM_{2.5}$ and PM_{10}), temperature and humidity. To measure this relationship between the dependent (heart rate and respiratory disorders) and independent variables (PM_1, $PM_{2.5}$, PM_{10}, temperature and humidity), we used the sample correlation test.

In order to observe whether the breathing difficulties observed in the participants were related to their lifestyle, we categorised the results of the health data according to information found in the literature, in particular the work of Basjaruddin et al. (2021) and the Fitrockr data dictionary (Fitrockr, s.d.). The data was cross-analysed using the graph mosaic method. Mosaics are a suitable form for representing frequencies or percentages based on the combination of several categorical variables (Le Guen, 2006; JMP Statistical Discovery, s.d.). This method was essentially applied to heart rate, breathing and stress status, cross-referenced with smoking status, insecticide use, mosquito use, fan use and/or air conditioning use. This method was supported by the Chi-2 test to determine whether the groups of variables were related or not.

RESULTS AND DISCUSSION

Socio-Demographic Characteristics and Health Status of Study Respondents

The participants in this study were female (52%) and male (48%) students aged18- 33 living in the greater Libreville area. 88% of the participants lived in the main commune (Commune de Libreville) of the Gabonese capital and 12% in neighbouring communes due to their distance from the Omar Bongo University. The survey data (Table 1) shows that 12% were smokers and all were men. As part of their daily routine, participants used fans (94%) and air conditioning (6%) to combat the heat and insecticides (48%) to control mosquitoes. The health status of the participants was assessed on the basis of their weight, height, and whether or not they were ill at the time of the study. These surveys concerned diseases that could affect heart rate and breathing. The participant's body mass indexes, determined using weight and height, varied between 16.18 and 33.2 kg/m², with an average of 22.67 kg/m². Based on these results (*Table 1*), 64% of the participants had a normal BMI, 10% were undernourished, and 26% were obese. Finally, as the study took place during the dry season, several participants suffered from colds, flu, coughing, wheezing and respiratory discomfort, as shown in *Table 1* below.

Air Pollution Variations

In the four communes of the Libreville urban agglomeration, average PM_1 concentrations ranged from 1.03 to 56.62 µg/m^3 over the study period. The highest concentration (27.07 µg/m^3) was observed in the commune of Ntoum and the lowest in Owendo and Libreville (13.72 and 14.47 µg/m^3), as shown in *Figure 3*.

The concentrations of $PM_{2.5}$ and PM_{10} over the study period were compared with the 24-h air quality standards contained in the World Health Organisation guidelines (WHO, 2021). These guidelines were updated in 2021 after those of 2005, as shown in *Table 2* below.

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Table 1: Socio-demographic characteristics and health status of respondents

Variable	Sub-variable	f	%	Min	Max	Avrg	StD Dev.
Participants	Men	24	48	*	*	*	*
	Female	26	52	*	*	*	*
Age	*	*	*	18	33	24.9	3.18
Body mass index (BMI)	*	*	*	16.18	33.2	22.67	3.92
BMI status	Undernutrition	5	10	*	*	*	*
	Normal weight	32	64	*	*	*	*
	Moderate obesity	3	6	*	*	*	*
	Overweight	10	20	*	*	*	*
Commune of residence	Akanda	1	2	*	*	*	*
	Libreville	44	88	*	*	*	*
	Ntoum	4	8	*	*	*	*
	Owendo	1	2	*	*	*	*
Smoking status	Smoker	6	12	*	*	*	*
	No-smoker	44	88	*	*	*	*
Fan using status	User	47	94	*	*	*	*
	No-user	3	6	*	*	*	*
Fan usage frequency	A few days a week	4	8.51	*	*	*	*
	Every day	43	91.49	*	*	*	*
Air conditioning usage status	User	3	6	*	*	*	*
	No-user	47	94	*	*	*	*
Air conditioning usage frequency	A few days a week	3	100	*	*	*	*
	Every day	0	0	*	*	*	*
Mosquito repellent usage status	User	24	48	*	*	*	*
	No-user	26	52	*	*	*	*
Mosquito repellent usage frequency	A few days a week	17	72	*	*	*	*
	Every day	7	28	*	*	*	*
Colds during the study	Yes	20	40	*	*	*	*
	No	30	60	*	*	*	*
Flu during the study	Yes	20	40	*	*	*	*
	No	30	60	*	*	*	*
Cough during the study	Yes	14	28	*	*	*	*
	No	36	72	*	*	*	*
Wheezing during the study	Yes	7	14	*	*	*	*
	No	43	86	*	*	*	*
Difficulty breathing during the study	Yes	13	26	*	*	*	*
	No	37	74	*	*	*	*

The information in *Table 2* and *Figures 4* and *5* show that the recommended levels for $PM_{2.5}$ and PM_{10} were exceeded on several days. Similar to PM_1, the highest $PM_{2.5}$ concentrations were found in Ntoum (29.85 µg/m^3) and Akanda (25.97 µg/m^3), as were those for PM_{10} (36.64 and 29.96 µg/m^3). Also, across all the municipalities, the results show several exceedances in $PM_{2.5}$, with a considerable drop from 03 September for the communes of Akanda, Libreville and Owendo. In the case of PM_{10}, the Libreville and Owendo monitors show particularly low levels of pollution compared with the daily level recommended by the WHO (2021); while for Akanda and Ntoum, several exceedances can be noted. The highest PM_{10} concentrations were observed on 10 July (111.91 µg/m^3) and 23 July (91.40 µg/m^3) in Libreville and in Ntoum on 10 September 2023 with a value of 73.89 µg/m^3.

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Figure 3: Changes in PM1 concentrations in Libreville from 05 July to 23 September 2023

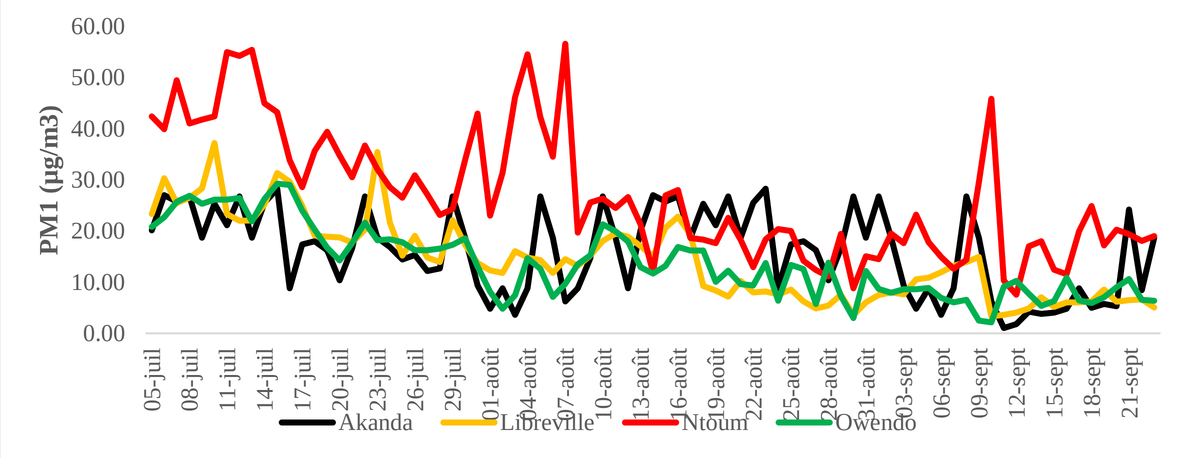


Table 2: Recommended air quality levels and intermediate targets

Pollutant	Duration	Intermediate target				Recommended level
		1	2	3	4	
$PM_{2.5}$ (µg/m^3)	24 hours	75	50	37,5	25	15
	Annual	35	25	15	10	5
PM_{10} (µg/m^3)	24 hours	150	100	75	50	45
	Annual	70	50	30	20	15

Source: WHO Air Quality Guidelines (WHO, 2021)

Figure 4: Changes in PM2.5 concentrations in Libreville from 05 July to 23 September 2023

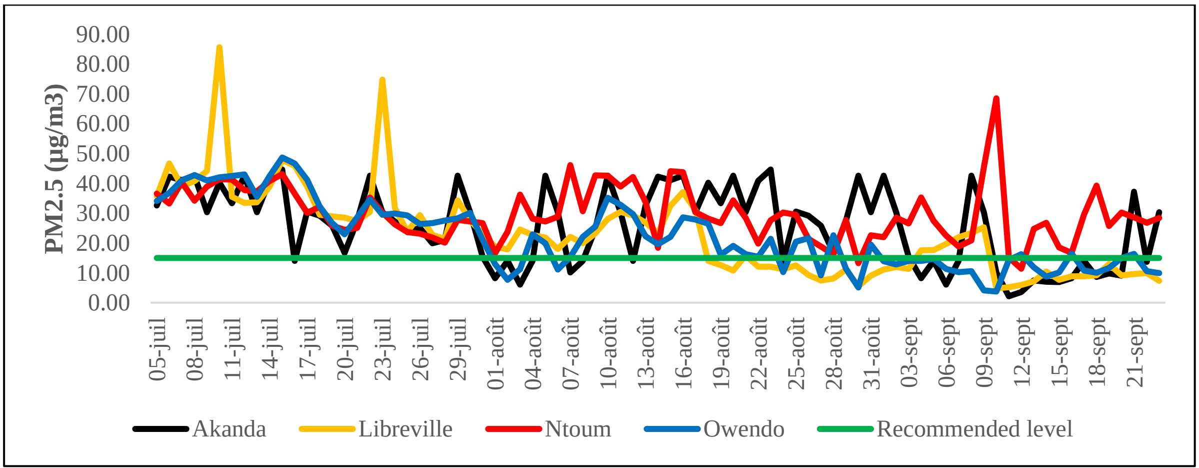
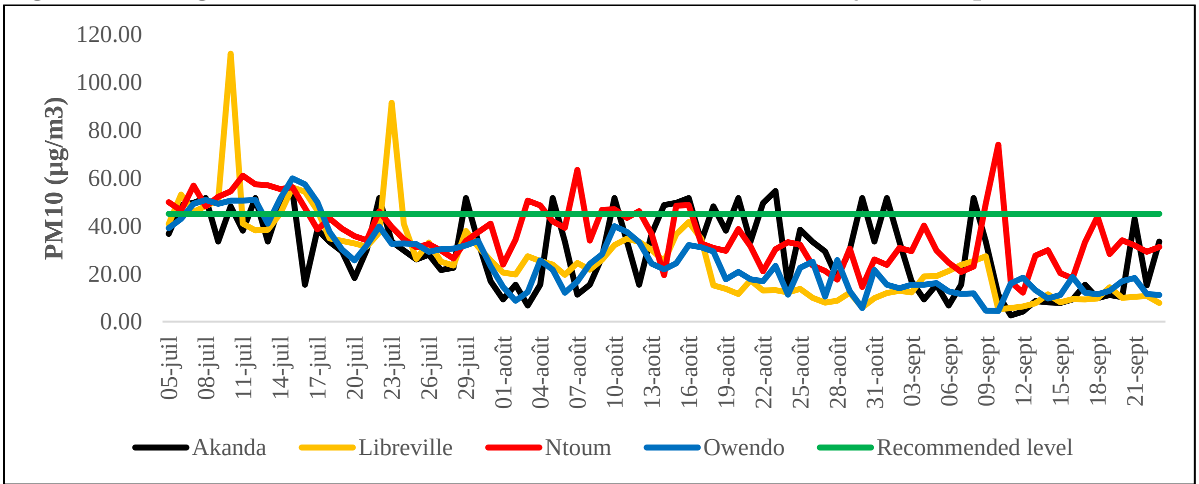


Figure 5: Changes in PM10 concentrations in Libreville from 05 July to 23 September 2023



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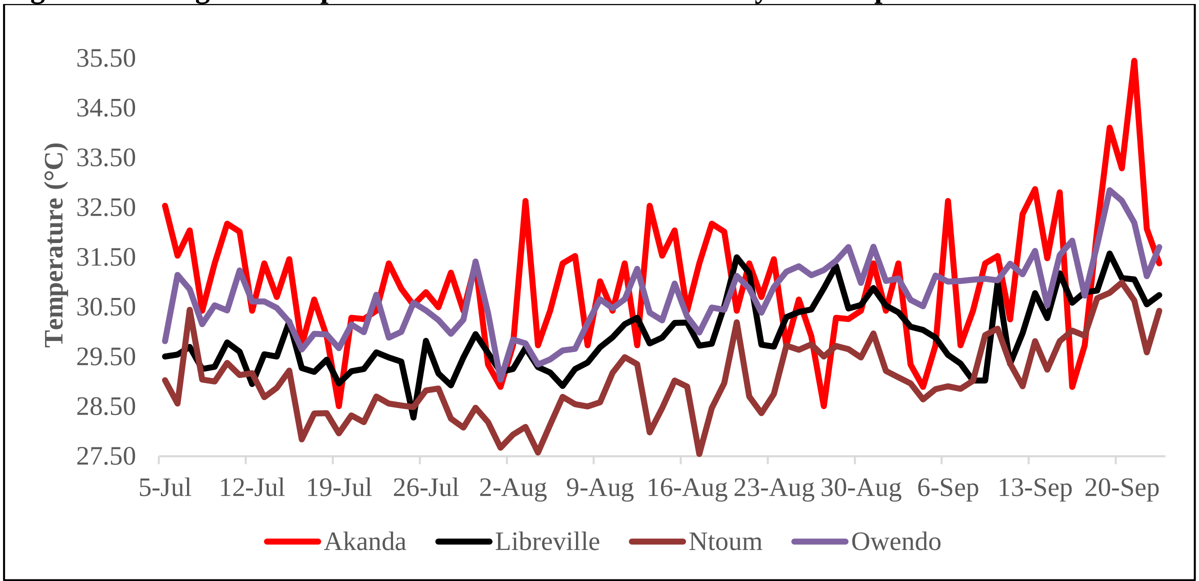
Variation of Meteorological Parameters

Purple Air monitors and measures four meteorological parameters, including temperature, relative humidity, dew point, and atmospheric pressure. Only the first two (temperature and humidity) were used in this study. Temporal variations in these two variables over the study period revealed the municipality of Akanda as having recorded the highest temperatures, with an average of 30.97 °C and a minimum and maximum of 28.51 °C and 35.45 °C. The maximum temperature in this municipality (35.45 °C) was reached on 21 September. After Akanda, Owendo had the highest average daily temperature, at 30.70 °C, a difference of 0.27 °C compared with the average temperature in Akanda. Temperature variations in Owendo ranged from 29.04 °C to 32.85 °C. In Ntoum and Libreville, average temperatures were around 29.02 °C and 29.92 °C, with minimums and maximums ranging from 27.54 °C to 31.58 °C, as shown in *Figure 6* below.

Figure 6: Changes in temperatures in Libreville from 05 July to 23 September 2023



Ambient humidity is an important environmental parameter similar to temperature, precipitation, or insolation. It is directly linked to temperature, so that the lower the temperature, the more humid the air becomes. This relationship can easily be seen in the data for the municipality of Akanda, where on 19 July, the temperature fell to 28.51 °C and humidity was 75%. On 21 September, the temperature was 35.45 °C and the humidity 56.69%. Humidity can damage human health, particularly in terms of respiratory tract infections (Mogou et al., 2022). While little is known about the recommended relative humidity ranges for outdoor environments, they are set at between 30 and 80% for indoor environments, depending on the season. This recommended range helps us to better understand the variations in this environmental variable in the communes of the Libreville conurbation. Overall, humidity in Libreville varied between 51.46 and 76.59%. The highest averages were found in Akanda (63.04%) and Ntoum (60.59%), while in Libreville and Owendo, they were 58.21 and 56.16%. In Owendo and Libreville, the time series show the smallest variations compared with the other localities, and only Akanda reached values close to 80% on three dates (19 July, 27 August, and 11 September 2023) (*Figure 7*).

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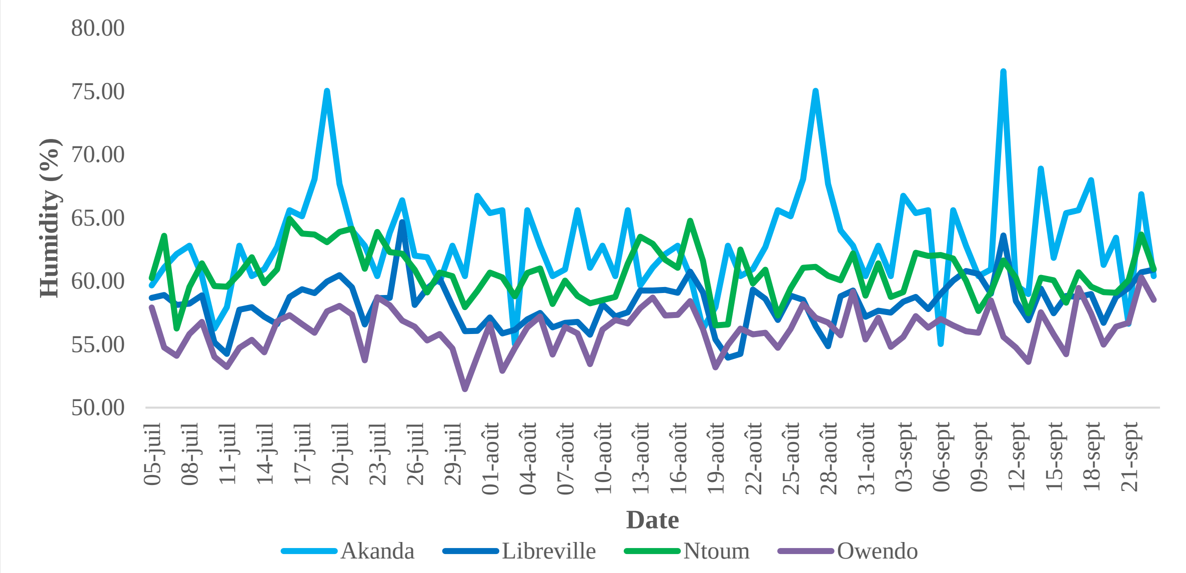
Figure 7: Changes in relative humidity in Libreville from 05 July to 23 September 2023



Correlation between Health Data, Meteorological Parameters and Air Pollution Levels

To establish the links between health data, meteorological parameters, and the levels of air pollution observed during the study period, it is worth recalling how heart rate, stress and breathing are assessed in order to identify whether or not the participants were in a high state of stress or breathing difficulty. The results of an analysis of a number of documents indicate that heart rate corresponds to the number of beats of the heart during a given period of time, and the number of beats per minute (bpm) is its unit of measurement. Heart rate varies under the influence of a number of parameters, such as age, sex, body shape, etc. According to N. C. Basjaruddin et al (2021), the normal heart rate is between 60 and 100 bpm. Values below or above this range constitute cardiac disorders known as Bradycardia (heart rate < 60 bpm) or Tachycardia (100 bpm < heart rate). However, heart rate can fall to very low levels, as low as 40 bpm in athletes and the elderly. Stress levels are often a function of heart rate. The health data dictionary on the Fitrockr platform (Fitrockr, s.d.) establishes four stress scores. Scores between 0 and 25 are considered non-stressful, 26-50 are considered low stress, 51-75 are medium stress, and 76-100 are high stress. A respiratory cycle comprises inhalation and exhalation, and the respiratory frequency is the number of cycles per minute. According to Capodilupo (2021), in adults, it is between 12 and 20 cycles per minute (breaths/min). Values below this range are referred to as slow breathing (breaths/min < 12) or fast breathing (20 < breaths/min).

Results of our analyses presented in *Figure 8* and *Table 3* show that the average mean and maximum heartbeats of the participants ranged from 47 to 140 bpm. This means that some participants experienced heart problems during the experiment. The bulk of the heart rate data (90%) is concentrated around 60 to 90 bpm for the mean values. This indicates a low rate (10%) of people with heart problems. On the other hand, most of the maximum values are between 110 and 140 bpm. These extreme values may reflect particular environmental conditions. Average stress levels also show a higher concentration above the calm threshold. Meanwhile, the maximum values for heart rate show a phase of decrease towards the most extreme values. In the case of maximum stress, they increase continuously. Breathing data ranged from 8 to 13 breaths/min, and 75% were below normal. This indicates that a number of participants experienced respiratory problems during the study period.

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Figure 8: Statistical distribution of health data.

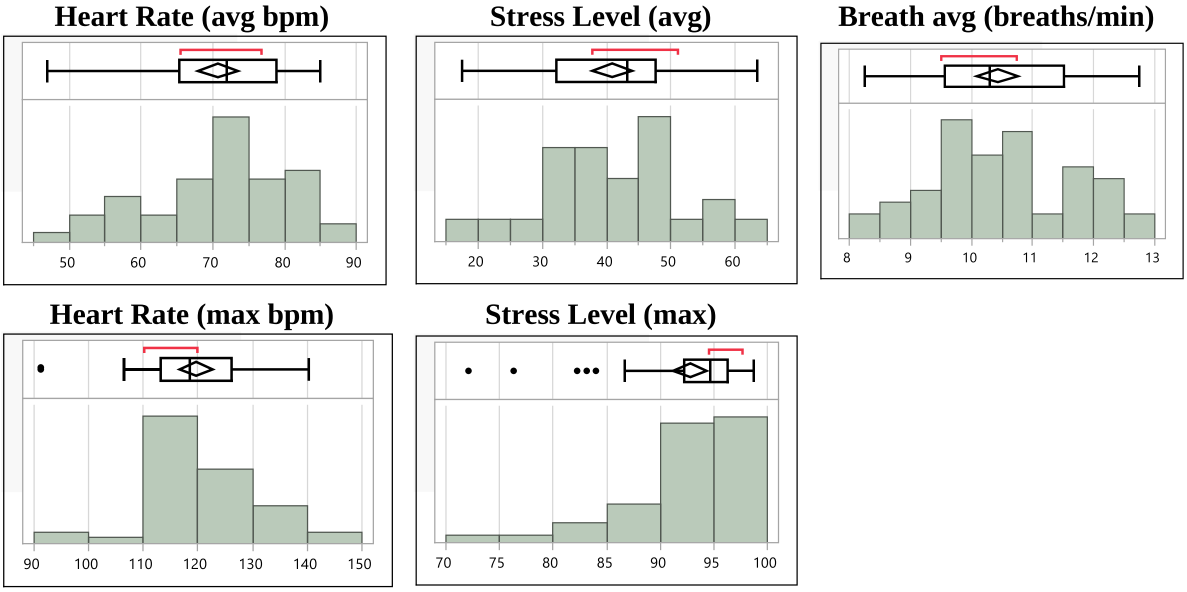

Table 3: Statistical summary of health data

	Heart Rate (avg bpm)	Heart Rate (max bpm)	Stress Level (avg)	Stress Level (max)	Breath avg (breaths/min)
Minimum	47	91	18	72	8
Maximum	85	140	63	99	13
Average	71	120	41	93	10
Standard deviation	9,873	10,458	10,687	5,461	1,167
Standard error of average	1,396	1,479	1,511	0,772	0,165

Given that the participants experienced cardiac and respiratory problems as well as stress, analysis of the relationships between these health data and the environmental parameters will help to understand the specificities noted above. *Figure 9* shows that the relationships between the health observations and the environmental data are mostly negligible ($R \leq 0.3$). However, there were some weak relationships between 0.31 and 0.36, such as that between temperature and the maximum stress level (R = -0.31). Apart from temperature, there was also a correlation of 0.33 between the maximum stress level and $PM_{2.5}$, 0.34 between the average stress level and PM_{10}, and a correlation of 0.36 between the average stress level and $PM_{2.5}$ and between the maximum stress level and PM_{10}. These results indicate a probable effect of temperature and $PM_{2.5\text{-}10}$ on stress in the study population.

Although correlations below 0.3 are considered negligible, some are close to this limit (R = ± 0.15-0.29). The P-value analysis (*Table 4*) reveals that stress is the variable influenced by all the environmental parameters and that humidity is the one that does not explain the participants' state of health. Temperature had a greater influence on average heart rate (R = -0.29; P-Value = 0.0386) and maximum stress (R = -0.31; P-Value = 0.0263). For particle concentrations, $PM_{2.5}$ and especially PM_{10} have the greatest impact on heart rate and stress.

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Figure 9: Scatterplot matrix of the link between health and environmental data.

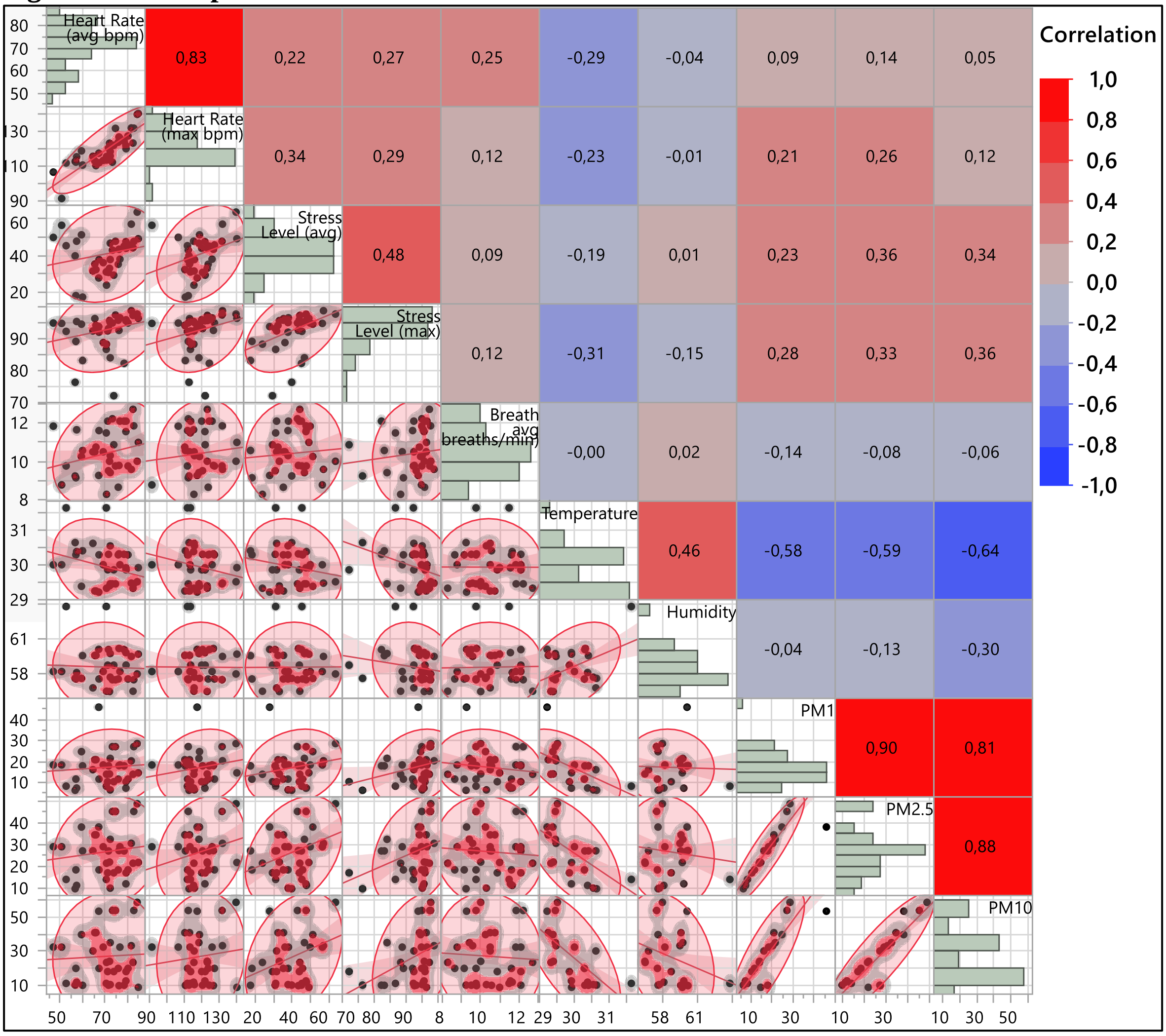

Table 4: P-Value of health and environmental data

Parameters	Heart Rate (avg bpm)	Heart Rate (max bpm)	Stress Level (avg)	Stress Level (max)	Breath avg (breaths/min)
Temperature	0,0386	0,1077	0,1793	0,0263	0,983
Humidity	0,7636	0,9613	0,9652	0,2905	0,8989
PM_1	0,512	0,1397	0,1005	0,0457	0,3181
$PM_{2.5}$	0,3412	0,0662	0,0096	0,0181	0,5987
PM_{10}	0,7382	0,4154	0,0163	0,0092	0,6863

Relationship Between Health Data and Lifestyle

Graph mosaic analysis and the Chi-2 test were applied to the participants' four main lifestyle habits: smoking status, use of mosquito repellent, fan use and/or use of air conditioning. Each health parameter (heart rate, breathing, stress) was observed as a function of gender and lifestyle habits. The detailed results are presented in *Tables 5* and *6*.

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Table 5: Relationship between state of health, smoking, and use of mosquito repellent

Variable	Heart rate status	
Gender	**Man**	**Female**
No smoking / no use of mosquito repellent	Bradycardia = 14,3% Regular = 85,7%	Bradycardia = 0% Regular = 100%
No smoking / use of mosquito repellent	Bradycardia = 25% Regular = 85,7%	Bradycardia = 25% Regular = 75%
Smoking / no use of mosquito repellent	Bradycardia = 0% Regular = 100%	*** ***
Smoking / use of mosquito repellent	Bradycardia = 0% Regular = 100%	*** ***
	Breath status	
No smoking / no use of mosquito repellent	Slow breathing = 78,6% Breath normal = 21,4%	Slow breathing = 80% Breath normal = 20%
No smoking / use of mosquito repellent	Slow breathing = 100% Breath normal = 0%	Slow breathing = 75% Breath normal = 25%
Smoking / no use of mosquito repellent	Slow breathing = 40% Breath normal = 60%	*** ***
Smoking / use of mosquito repellento	Slow breathing = 0% Breath normal = 100%	*** ***
	Stress status	
No smoking / no use of mosquito repellent	Calm= 14,30% Low stess = 71,4% Moderate stress = 14,30%	Calm= 0% Low stess = 80% Moderate stress = 20%
No smoking / use of mosquito repellent	Calm = 25% Low stess = 75% Moderate stress = 0%	Calm = 6,20% Low stess = 68,8% Moderate stress = 25%
Smoking / no use of mosquito repellent	Calm = 25% Low stess = 75% Moderate stress = 0%	Calm = 25% Low stess = 75% Moderate stress = 0%
Smoking / use of mosquito repellent	Calm = 0% Low stess = 100% Moderate stress = 0%	Calm = 0% Low stess = 100% Moderate stress = 0%

As can be seen from the results of the mosaic of graphs, only the non-smoking participants using mosquito repellents all experienced a drop in breathing (P-Value = 0.025), with a frequency of 100% for men and 75% for women. Although a drop in breathing was also observed among air conditioning users (72.7% ; P-Value = 0.122) and all the people who said they used a fan, these lifestyle habits were not significantly linked to their breathing difficulties. The same was true for the 40% of smokers who experienced a drop in breathing (P-Value = 0.111) during the study. Finally, with the exception of the non-smoking participants using the mosquito repellent, variations in heart rate and stress were not statistically linked to the lifestyle habits of the participants in this study.

This pilot study on the influence of air pollution, temperature and humidity on the daily health of Gabonese students living in Libreville was carried out by combining data from several instruments (PurpleAir-II-SD air quality monitors, Garmin vívosmart® 5 smartwatches, electronic personal scale, folding meter and tape meter). These instruments have already been used in numerous studies, such as the one by Koch et al. (2023) and Barteit et al. (2023) for individual health indicators. During the study period, PM_1 levels ranged from 1.03 to 56.62 µg/m^3, $PM_{2.5}$ levels from 2.17 to 85.63 µg/m^3 and PM_{10} levels from 2.59 to 111.91 µg/m^3. $PM_{2.5}$ levels were consistently above WHO air quality guidelines, making it the pollutant of greatest concern. The same applies to PM_1, even in the absence of

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regulations (AirQ, n.d.), given its effects on heart and lung function, as mentioned by (Camfil, 2019; Département Prévention Cancer Environnement, 2023), this pollutant is just as worrying as $PM_{2.5}$.

Table 6: Relationship between state of health, fan use and air conditioning use.

Variable	Heart rate status	
Gender	**Man**	**Female**
No use fan / no use Air conditioning	Bradycardia = 0% Regular = 100%	*** ***
No use fan / use Air conditioning	*** ***	Bradycardia = 8,7% Regular = 91,3%
Use fan / no use Air conditioning	Bradycardia = 13,6% Regular = 86,4%	*** ***
Use fan / Use Air conditioning	Bradycardia = 0% Regular = 100%	Bradycardia = 66,7% Regular = 33,3%
	Breath status	
No use fan / no use Air conditioning	Slow breathing = 0% Breath normal = 100%	*** ***
No use fan / use Air conditioning	Slow breathing = 72,7% Breath normal = 27,3%	*** ***
Use fan / no use Air conditioning	Slow breathing = 100% Breath normal = 0%	Slow breathing = 73,9% Breath normal = 26,1%
Use fan / Use Air conditioning	*** ***	Slow breathing = 100% Breath normal = 0%
	Stress status	
No use fan / no use Air conditioning	Calm= 0% Low stess = 100% Moderate stress = 0%	*** *** ***
No use fan / use Air conditioning	*** *** ***	Calm = 6,20% Low stess = 68,8% Moderate stress = 25%
Use fan / no use Air conditioning	Calm = 13,6% Low stess = 77,30% Moderate stress = 9,10%	Calm = 4,40% Low stess = 73,2% Moderate stress = 17,4%
Use fan / Use Air conditioning	Calm = 0% Low stess = 100% Moderate stress = 0%	Calm = 0% Low stess = 33,30% Moderate stress = 66,7%

The overall results of the analyses show that humidity has no influence on the health parameters considered in this study, and the drop in breathing is not linked to any environmental parameter. In this respect, the study by Koch et al (2023) was unable to link cardiac disorders to the humidity index. However, their results showed that nocturnal cardiac function was affected on nights of heavy rainfall (> 20 mm). In addition, they found that mean heart rate values were very low when individuals were exposed to high temperatures, but this effect was not statistically significant. For other environmental parameters, the results of the analyses revealed links between mean heart rate and temperature (R = -0.29; P-Value = 0.0386), mean stress with $PM_{2.5}$ (R = 0.37; P-Value = 0.0096) and PM_{10} (R = 0.34; P-Value = 0.0163), and maximum stress with temperature (R = -0.31; P-Value =0.0263), PM_1 (R = 0.28; P-Value = 0.0457), $PM_{2.5}$ (R = 0.33; P-Value = 0.0181) and PM_{10} (R = 0.36; P-Value = 0.0092). The study by Cole-Hunter et al (2015) showed that variations in heart rate were often greater in individuals when $PM_{2.5}$ concentrations were low, in contrast to this study which shows that heart rate increases with each parameter that is significantly correlated with it. This result is in agreement with that obtained by Buregeya et al (2020), showing that a 1 µg increase in the inhaled dose of $PM_{2.5}$ is associated with an increase in the

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variation in heart rate. However, according to these authors, this relationship holds true for long-term exposure to air pollution.

CONCLUSIONS

The study assessed the influence of air pollution, temperature, and humidity on the daily health of Gabonese students living in Libreville. Overall, we observed variations in particle concentrations that exceeded WHO air quality standards. Temperatures varied between 27 and 35 °C, and humidity was around 51-77%. The influence of these environmental conditions on the heart rate, breathing and stress observed in the participants was studied. The results revealed relationships between health observations and environmental data that were negligible overall ($R \leq 0.3$) and weak relationships ranging from 0.31 to 0.36. In addition, it was noted that maximum stress was associated with temperature ($R = -0.31$) and $PM_{2.5}$ ($R = 0.33$). The average stress level is associated with PM_{10} ($R = 0.34$) and $PM_{2.5}$ ($R = 0.36$). A number of relationships between lifestyle habits and the daily health of participants were also identified. In this respect, it was found that smokers, mosquito repellent users, and fan users had reduced breathing. Although the results of this study reveal weak links between health parameters, environmental data and lifestyle habits, more significant results can be obtained by associating groups of individuals with the environmental measurement monitors closest to where they live if all 14 monitors are active at the time of the study. In addition, the use of portable pollution sensors could improve these results as health and pollution data would be measured at the individual level. Thus, although the results obtained here are not very significant, there is a problem of spatial representativeness of temperature, humidity and pollutant data that should be taken into account for future studies. Finally, in view of the significant effect of temperature on heart rate and stress level, an early warning bulletin should be incorporated into Gabon's health policies when high temperatures are forecasted. This recommendation also applies to atmospheric pollutants.

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