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Indoor Household Air Quality Assessment: The case of the use of low cost sensor[†]

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Abstract: According to World Health Organisation (WHO) over 4 million people die world-wide in 2012. This was due to one of the indoor contributors - particulate matter (PM) of a diameter 2.5. The use of low-cost PM measurements is assisting individuals to take actions by providing personalized information on indoor concentrations in real time. The low-cost sensor – SentinAir used in this study was designed and developed by group of researchers from ENEA-Italian National Agency for New Technologies, Energy and Environment. Sustainable Development Department, Research Center of Brindisi, Italy. It measures PM (1, 2.5, 10), NO_2, SO_2, CO_2, O_3, temperature, and relative humidity. The aim of this study was to deploy the sensor into the indoor (kitchen) of a household with the view of assessing all the parameters over a period of thirty (30) days as a preliminary investigation measurement. The protocol of the sensor was strictly followed. The results (mean) depicted: PM 1 (17.80 $\mu g/m^3$), PM 2.5 (25.21 $\mu g/m^3$), PM 10 (27.61 $\mu g/m^3$), CO_2 (435.3 ppm), O_3 (24.75 ppb), NO_2 (66.52 ppb), SO_2 (48.04 ppb), temperature (34.1 °C), and humidity (64 %). When these results were compared with the WHO and National Environmental Standards and Regulations Enforcement Agency (NESREA) it was observed that the PM2.5 and 10 were within the 24 h guideline values of 25 and 50 $\mu g/m^3$ respectively. Although that of PM 2.5 may be a risk. There were significant influences of temperature and humidity on the pollutants. Food frying and baking generated the largest increase in PM, in the kitchen activity. Because the data is reproducible, it is recommended that this low-cost PM sensor be integrated into an indoor air-quality measurement network to assist individuals in managing their personal exposure.

Keywords: Indoor air; Particulate matter; Sensor network, Low-cost particulate matter sensor.

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1. Introduction

Ambient and indoor air quality are two of the top ten global factors that cause of causes of morbidity and mortality [1]. Humans nowadays spend nearly 90% of their time indoors, exposing themselves to indoor air pollutants for extended periods of time than those who spend most of their time outside [2]. As a result, it is critical to characterize and measure indoor air in order to know its constituents and, in the presence of potentially harmful concentrations of chemical species hazardous to people's health, recognize contributing factors (direct or indirect sources of pollutants) [3]. Indoor exposure was linked to several health issues in 2016, including respiratory diseases and 3.8 million deaths worldwide (World Health Organization (WHO), [4]. Carbon dioxide (CO2), carbon monoxide (CO), formaldehyde (CH2O), total volatile organic compounds (VOC), particulate matter (PM), and, at the microbiological level, bacteria and fungi are among the pollutants commonly measured in indoor air quality (IAQ) monitoring [4].

Low-cost sensors have emerged as a cost-effective alternative to precision equipment used in long-term air pollution monitoring in recent years [5-7]. Low-cost air pollution sensors have inadequacies and inconsistencies in terms of precision, consistency, and long-term reliability [6,8]. Low-cost sensors, on the other hand, make it possible for the deployment of a much greater number of units, and their mobility and small size make them acceptable for use in micro-environments where classical devices would be too problematic. The latter property, in particular, could make low-cost sensors very helpful for characterizing indoor air pollution.

SentinAir is a low—cost sensor that is novel to this part of Africa. It evaluates more parameters (pollutants and meteorological parameters) than many low-cost sensors on the market. As a result, when compared to other instruments, this one has a distinct advantage. The primary goal of this study is to monitor the pollutants (PM 1, PM 2.5, PM 10, CO2, O3, NO2, and SO2) as well as the meteorological parameters (temperature and relative density – RH) of an indoor environment chosen for this study.

2. **Materials and Methods**

The monitoring site, Oba Ile, is located in Akure, Ondo State, Nigeria (Latitude/Longitude: 7 16 04.4 N 5 14 29.1 E). The building is located in a residential area surrounded by unpaved roads (Figure 1). There were no known major point sources of emissions nearby.

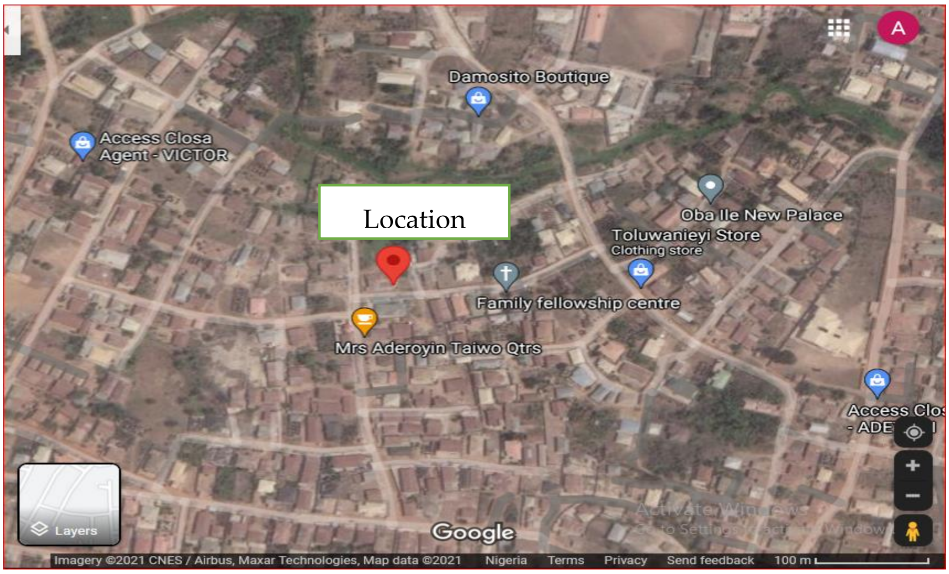
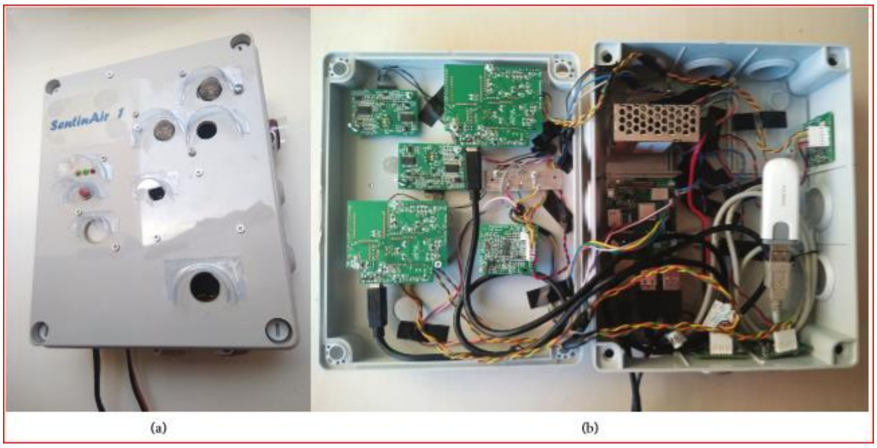


Fig. 1. The Goggle Map of the Study Location

For this study, SentinAir (Figure 2), a device designed and developed for data acquisition from various types of instruments, sensors, or devices [9,10], was used. The sensor protocol was strictly followed. For thirty-two (32) days, the sensor was monitored for PM

(1, 2.5, 10), NO2, SO2, CO2, O3, temperature, and relative humidity. The sensor box was placed on a rack about 4 meters above ground. The building was separated from the road only by a fence, putting the sensor package about 6 meters away from the nearest lane of traffic.



(a) (b)

Fig. 2. The figure shows (a) the complete set-up of the low-cost sensor, and (b) the inlet of the sensor showing the power charger and other parts

Sensor data were checked and analyzed at the end of the monitoring. The basic description, the Pearson sample correlation coefficient (r), the matrix plot, and the boxplot were all determined using Minitab version.

3. Results and Discussion

Table 1. The Basic Description

Parameters	PM1	PM2.5	PM10	SO2	NO2	O3	CO2
Mean	17.8	25.2	27.6	48.8	66.5	24.8	419.72
Std Dev.	5.3	7.8	11.7	23.0	45.0	9.2	102.0
Minimum	1.0	2.0	2.0	0.0	0.0	0.0	303.60
Maximum	34.0	51.0	161.0	79.0	282.0	79.0	1003.30
Skewness	-0.3	-0.2	3.2	-1.2	1.9	0.5	2.43
Kurtosis	0.1	-0.2	32.8	0.1	4.6	5.0	6.78
Ist Quartile	15.0	21.0	22.0	43.0	40.0	20.5	361.45
3rd Quartile	21.0	31.0	32.5	64.0	79.0	30.0	436.25

Units: PM1 - $\mu g/m^3$, PM2.5 - $\mu g/m^3$, PM10 - $\mu g/m^3$, SO2 – ppb, NO2 – ppb, O3 – ppb, CO2 - ppm

Table 1 shows the basic description of the parameters. The daily mean concentrations were averaged by hourly measurements, and monthly mean concentrations were respectively averaged by daily and monthly mean concentrations. The mean values of the pollutants are: PM 1 (17.80 $\mu g/m^3$), PM 2.5 (25.21 $\mu g/m^3$), PM 10 (27.61 $\mu g/m^3$), CO_2 (419.7 ppm), O_3 (24.75 ppb), NO_2 (66.52 ppb), SO_2 (48.04 ppb). In comparison with the WHO guidelines, PM1, PM2.5 (25 $\mu g/m^3$ – 24 h mean), PM10 (50 $\mu g/m^3$ – 24 h mean), SO2 (20 $\mu g/m^3$ – 24 h mean), NO2 (200 $\mu g/m^3$ – 1h mean), O3 (100 μg/m^3 – 8h mean). The maximum values of O3, NO2, and CO2 are 79, 282, and 1003.3 ppb respectively. The PM2.5 and PM10 levels are found to be in agreement, but the maximum values obtained are two and three times higher, respectively. The home is vulnerable to pollutants in and around as a result of the household combustion of polluting fuels from open fires or traditional kitchen equipment for cooking, heating, and lighting. This demonstrates that there is an increased risk of air pollution-related diseases such as acute lower respiratory infections, cardiovascular disease, chronic obstructive pulmonary disease, and lung cancer [11]. Also, the SO2 concentration is two times higher. The World Health Organization stated that a SO2 level of 500 μg/m^3 must not be surpassed for average periods of 10 minutes since health effects are found to be associated with inflammation of the respiratory tract, which causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis, and causes people more susceptible to respiratory problems. Short-term NO2 level exceeding 200 μg/m^3 are toxic gases that trigger inflammation of the airways. NO2 is the primary source of nitrate airborne particles, which contribute significantly to PM2.5 and, in the presence of ultraviolet light, ozone.

Table 2. The Correlation Coefficients of the Pollutants and the meteorological Parameters

	Temp	RH	NO2	O3	SO2	PM1	PM2.5	PM10	CO2
Temp	1								
RH	**-0.77**	1							
NO2	-0.31	0.39	1						
O3	0.24	-0.14	**0.63**	1					
SO2	**0.66**	-0.47	-0.30	0.28	1				
PM1	0.12	-0.15	0.20	0.30	0.01	1			
PM2.5	0.12	-0.15	0.19	0.30	0.01	**0.99**	1		
PM10	0.10	-0.16	0.18	0.28	0.01	**0.94**	**0.97**	1	
CO2	-0.13	0.32	**0.50**	**0.61**	0.27	0.06	0.07	0.05	1

Summarized in Table 2, the various parameters have variable correlations. From the table, it is observed that there are relationships (moderate) between temperature, RH (r=-0.77) and SO2 (r=0.66), although that of RH is a negative correlation, RH has weak correlations (r=0.32-0.39) with all the parameters. NO2 has moderate correlations with O3 and CO2 (r=0.63 and 0.50 respectively). SO2 has poor correlations with PM1, PM2.5, and PM10 (r=0.01-0.27). The results show a strong correlations between the PMs (r=0.94-0.97), poor correlations are observed in the cases of the PMs and CO2 (r=0.05-0.07). Table 2 shows that there is a weaker and moderate significant relation among both pollutant concentrations and meteorological parameters. At the 0.05 level, the PM correlations could be attributed to a positive relationship with global radiation. Photochemical reactions in the atmosphere are fueled by global radiation, forming of secondary particulate matter [12]. The relationship between RH and PM2.5 shows that RH does not play a significant role in fine particle scavenging. The positive correlation between temperature and O3 indicates that higher temperatures are beneficial to photochemical reactions [13].

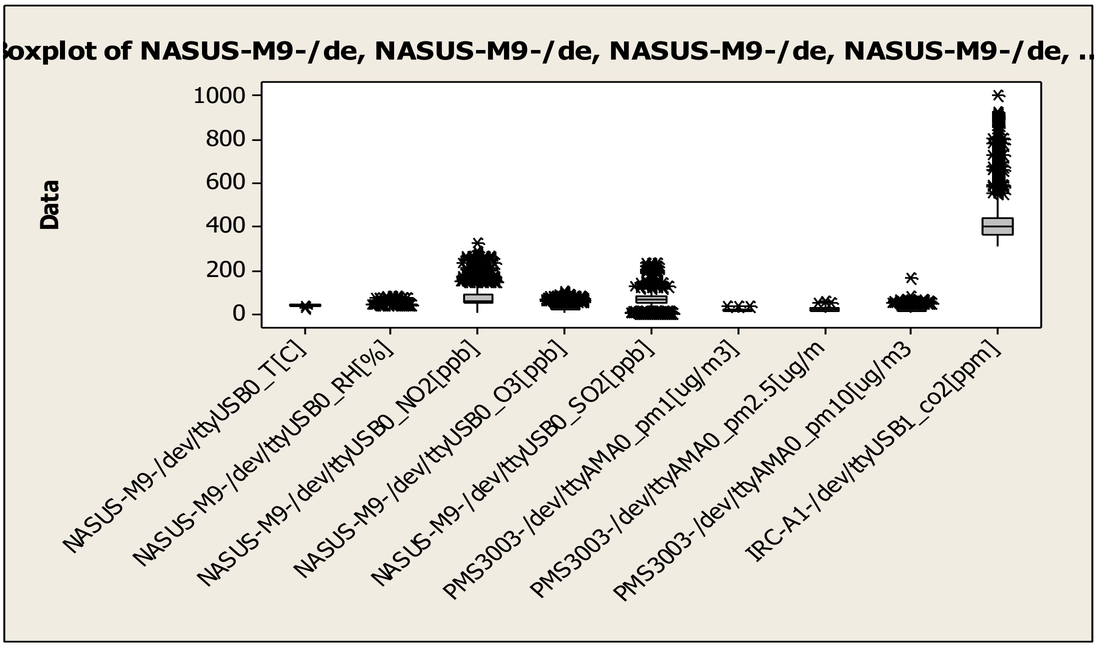


Fig. 3. The Boxplot of the pollutants and the meteorological parameters

Figure 3 illustrates the data levels in terms of the lower quartile, upper quartile, median, minimum, and maximum in all of the branches located using box and whisker plots. This confirms in this study the difference in regular air pollutant concentrations. The box plot essentially depicts a sketch of the allocation of the underlying data. The boxplot depicts the variances in regular pollutant levels. The representation of pollutants differs significantly, insinuating that pollutants vary depending on the activities in the building, especially in the kitchen.

4.0 **Conclusion**

This paper is part of the study conducted indoor of a building using a low-cost sensor. Pollutants – (PM1, PM2.5, PM10, CO2, SO2, NO2, and O3) and meteorological parameter (temperature and relative humidity) were monitored for 32 days using the sensor protocol. The mean PM2.5 and PM10 levels are found to be in agreement with the 24 h NESREA and WHO limits, but the maximum values obtained are two and three times higher, respectively. Also, the SO2 concentration is two times higher. The World Health Organization stated that a SO2 level of 500 $\mu g/m^3$ must not be surpassed for average periods of 10 minutes. The maximum values of O3, NO2, and CO2 are 79, 282 ppb and 1003.3 ppm respectively. The home is vulnerable to pollutants in and around as a result of the household combustion of polluting fuels from open fires or traditional kitchen equipment for cooking, heating, and lighting. This demonstrates that there is an increased risk of air pollution-related diseases such as acute lower respiratory infections, cardiovascular disease, chronic obstructive pulmonary disease, and lung cancer. The boxplot shows that the representation of pollutants differs significantly, indicating that the pollutants vary depending on the activities in the kitchen.

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