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ASSESSMENT OF CARBON MONOXIDE EMISSION FROM DIFFERENT BRANDS OF SPLIT AIR-CONDITIONERS

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ABSTRACT

The detection and assessment of pollutants emitted from electrical appliances has become a great area of interest to environmentalists as a means of being aware of the sources which contribute to the outdoor air quality. In this study, carbon monoxide emission was assessed from the source, which was the outdoor unit of working split air-conditioners. Five (5) brands (B1, B2, B3, B4 and B5) of twenty-five (25) split air-conditioners prominent in Covenant University were selected, five split air-conditioners per brand. The exhaust air from the outdoor unit was monitored for one (1) hour at two (2) minute intervals using the GM8805 Benetech carbon monoxide monitor. The data obtained were analysed and the daily mean, weekly mean, monthly mean and yearly mean contributions of each brand to the ambient carbon monoxide emission were determined. The results of individual contributions to ambient carbon monoxide emission, on yearly basis, obtained were: 35376 ppm for brand 1 (B1), 57552 ppm for brand 2 (B2), 54384 ppm for brand 3 (B3), 115632 ppm brand 4 (B4) and 672144 ppm for brand 5 (B5). The air conditioner with the highest contribution to ambient carbon monoxide concentrations was B5 at 672144 ppm on a yearly basis. It was concluded that split air-conditioners also contribute emissions into ambient air.

Keywords: Air emissions; Carbon monoxide emission; electrical appliances; split air-conditioners

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1. INTRODUCTION

Electrical appliances are known to release harmful chemical substances generated from the heating of these appliances during their working periods (Atsuo & Yasunori, 2007). Numerous studies have gauged the environmental effects of different electrical appliances both practically and in literature (Gallego-Schmid et al., 2016). A general consensus exists within the research community regarding the threat of global warming resulting from the change in climate due to release of gases into the air from the combustion of fossil fuels (Oladokun & Odesola, 2015). Numerous sources are credited with the generation of electricity, the most common being the combustion of fossil fuels with the aim of converting thermal energy into mechanical motion and ultimately to electricity (Mohammed, 2009).

Initial studies have reported the emission of chemical pollutants from home electrical appliances for example the characteristics of chemical substances released from electrical space heaters were studied and their emission rates were quantitatively determined (Atsuo & Yasunori, 2007). Also pollutants released by new electric ovens have been reported and significant levels of formaldehyde surpassing exposure guidelines were reported for two ovens (Atsuo & Yasunori, 2007). A recent study of the environmental impact of electrical appliances, vacuum cleaners in particular, shows that vacuum cleaners are an area needed to be acted upon in the reduction of the negative environmental impact (Gallego-Schmid et al., 2016).

As the temperature of the planet rises, the use of air conditioners has become a near necessity. This results in a vicious chain because with the use of air conditioners comes a higher heating of the environment, this happens due to the emission of carbon into the atmosphere (Rajesh et al., 2013). The impact of this on the environment is its contribution to the full blown problem of global warming. In comparison to other electrical devices, air conditioners consume a higher amount of energy (Rajesh et al., 2013).

Over the years, an increase in the use of air conditioning has been observed and as a result of the effects of global warming in order to mitigate heat related illness and death (Zhonghua et al., 2016) without adequate consideration of the impact of the air conditioners on the environment. Research on the effect of the heat emission from air conditioners on the external thermal environment is popular (Mengtao & Hong, 2016). The heat released affects both the temperature of the environment and the energy consumption of the air conditioners in the surrounding environments, these effects can also be reduced or aggravated by the positioning of the external unit of the air conditioner (Mengtao & Hong, 2016).

Research on the emission of carbon from air conditioning units is already well known (Rajesh et al., 2013; Mengtao & Hong, 2016; Zhonghua et al., 2016). These researches are yet to specify exactly what form of carbon emissions are detected from the air-conditioning units. These carbon emissions are known to increase the effect of global warming (Rajesh et al., 2013) and studies have shown that global warming is caused by gases popularly known as greenhouse gases, examples of these gases include: CO_2, N_2O and CH_4 (Mohammed, 2009).

Few studies on the impact of air conditioning systems on the environment have been conducted in the time past, but not specifically on the split air-conditioners. The goal of the study was to assess exhaust air from the external units of the split air-conditioners for carbon monoxide emission.

2. EXPERIMENTAL

2.1. Study area

The study area is Covenant University, located in Canaanland, Ota, Ogun State (Figure 1). This is found in the southwestern region of Nigeria. It covers an approximate area of 1.46 km^2 (square kilometers) and runs an approximate distance of 5.08 km. The area lies between the Latitudes 6°39'47.3"N and 6°40'17.4"N and Longitudes 3°09'48.2"E and 3°09'02.2"E. The total population of inhabitants is estimated to be about 7912 persons, with a breakdown showing 11.5% staff and 88.5% students (Olugbamila, 2012). The climate of this area is tropical and is characterized by wet and dry seasons. The temperature ranges from a high of 31^{o}C to a lower temperature of 24^{o}C (NOAA, 2018).

Figure 1 A map of the study area Covenant University (Google Maps, 2018)

2.2. Material and method

A user friendly GM8805 benetech carbon monoxide monitor was used to measure the CO concentrations from the split air-conditioners at their various locations around the buildings on the Covenant University Campus. The carbon monoxide monitor was switched on and allowed to countdown for 10 seconds, in order to get all internal systems ready. A platform or surface was mounted at a level appropriate for each split air-conditioners selected for the study. The GM8805 benetech carbon monoxide monitor was positioned at an appropriate distance, 30 cm away from the outer unit of each of the split air-conditioners to avoid temperatures above 50^{o}C i.e. temperature of the spent air coming from the outer units of the split air-conditioners. Readings were taken at 2 min interval for 60 min from each of the split air-conditioners.

3. RESULTS AND DISCUSSION

Emissions from the outdoor unit of split air conditioners in the Covenant University campus were monitored for the determination of the contribution of CO emission from the identified split air-conditioners to ambient air. The data collected for the CO emission were analysed for the average hourly, weekly, monthly and yearly contribution to the ambient air.

3.1. Mean concentrations of CO emission

The mean concentrations of CO emission from the sampled split air-conditioners are summarized in Tables 1 to 5. For B1 split air-conditioners, the mean concentrations of CO emission ranged from 1.00 ppm to 8.75 ppm, while the mean concentrations of CO emission ranged between 1.00 ppm and 16.75 ppm for B2 split air-conditioners. The mean concentrations of CO emission from the sampled B3 split air-conditioners ranged between 2.50 ppm and 12.75 ppm; those of B5 split air-conditioners ranged between 10.25 ppm and 163.50 ppm while those of B4 split air-conditioners ranged between 5.50 ppm and 19.50 ppm.

Table 1 Means of Concentrations of CO Emission from B1 Split Air-conditioners

B1 Split Air-conditioners	CO (ppm)
B11	3.50
B12	1.00
B13	8.75
B14	1.50
B15	2.00

Table 2 Means of Concentrations of CO Emission from B2 Split Air-conditioners

B2 Split Air-conditioners	CO (ppm)
B21	1.50
B22	16.75
B23	1.00
B24	6.00
B25	2.00

Table 3 Means of Concentrations of CO Emission from B3 Split Air-conditioners

B3 Split Air-conditioners	CO (ppm)
B31	2.50
B32	4.50
B33	12.75
B34	3.50
B35	2.50

Table 4 Means of Concentrations of CO Emission from Daikin Split Air-conditioners

B4 Split Air-conditioners	CO (ppm)
B41	19.50
B42	8.25
B43	12.25
B44	9.25
B45	5.50

Table 5 Means of Concentrations of CO Emission from B5 Split Air-conditioners

B5 Split Air-conditioners	CO (ppm)
B51	10.25
B52	163.50
B53	75.50
B54	33.00
B55	36.00

The average hourly mean concentration of computed for CO emitted from the split air-conditioners are shown in Tables 1 to 5. Table 1 represents the average hourly mean of CO emitted from B1 split air-conditioners. The emission concentrations obtained were 3.50 ppm, 1.00 ppm, 8.75 ppm, 1.50 ppm, and 2.00 ppm. The emission concentrations in comparison with the Nigerian ambient air quality standard of 10ppm (FEPA, 1999) do not exceed the limit of CO to be emitted hourly. The highest average value, 8.75 ppm, is emitted from $B1_3$. According to Hampson and Dunn, (2015) in the study of carbon monoxide poisoning from portable types electrical generators, the discrepancies in the concentrations of CO emitted is be credited to the age of the electrical appliances, which in this case split air-conditioners. Aside from the age of the split air conditioners, it was observed during the selection of samples that the size of the refrigerant differed from 1.01 kg to 1.78 kg and this is also a probable factor affecting the concentrations of CO emission. Table 2 presents the hourly mean of CO emitted from B2 split air-conditioners. The emission concentrations obtained were 1.50 ppm, 16.75 ppm, 1.00 ppm, 6.00 ppm and 2.00 ppm. In comparison with the Nigerian ambient air quality standard (NAAQS) the only emission which exceeds the limit of 10 ppm is the highest emission from $B2_2$, 16.75 ppm.

Table 3 presents the average hourly mean concentrations of CO emitted from B3 split air-conditioners. The emission concentrations obtained were 2.50 ppm, 4.50 ppm, 12.75 ppm, 3.50 ppm and 2.50 ppm. In comparison with NAAQS the emission which exceeded the standard was that of $B3_3$ at 12.75 ppm. Table 4 presents the average hourly mean concentrations of CO emitted from B4 split air-conditioners. The emission concentrations obtained were 19.50 ppm, 8.25 ppm, 12.25 ppm, 9.25 ppm and 5.50 ppm. In comparison with NAAQS the emissions which exceed the set standard are from SAC_{D1} and $B4_3$ at 19.50 ppm and 12.25 ppm respectively.

Table 5 presents the average hourly mean concentrations of CO emitted from B5 split air-conditioners. The emission concentrations obtained were 10.25 ppm, 163.50 ppm, 75.50 ppm, 33.00 ppm and 36.00 ppm. In comparison with NAAQS it was observed that all the emissions of the B5 split air-conditioners exceeded the NAAQS. Finally the B5 split air-conditioners are seen to have the highest average hourly mean CO concentrations while the B1 split air-conditioners have the lowest average hourly mean. The difference in the emission ranges can also be credited to the difference in brands.

3.2. Contributions of CO emission to ambient air

Contributions of CO emission from the identified split air-conditioners into the ambient air on daily, weekly, monthly, and yearly basis are summarized in Tables.6 to 10. The results showed that B1 split air-conditioners contribute least, to ambient CO emission while B5 split air-conditioners contribute most on daily, weekly, monthly and yearly basis.

Table 6 Contribution of CO Emission from B1 Split Air-conditioners into the `Ambient Air

B1 Split Air-conditioners	Daily CO Emission (ppm)	Weekly CO Emission (ppm)	Monthly CO Emission (ppm)	Yearly CO Emission (ppm)
B11	28.00	140.00	616.00	7392.00
B12	8.00	40.00	176.00	2112.00
B13	70.00	350.00	1540.00	18480.00
B14	12.00	60.00	264.00	3168.00
B15	16.00	80.00	352.00	4224.00
Total	134.00	670.00	2948.00	35376.00

Table 7 Contribution of CO Emission from B2 Split Air-conditioners into the Ambient Air

B2 Split Air-conditioners	Daily CO Emission (ppm)	Weekly CO Emission (ppm)	Monthly CO Emission (ppm)	Yearly CO Emission (ppm)
B21	12.00	60.00	264.00	3168.00
B22	134.00	670.00	2948.00	35376.00
B23	8.00	40.00	176.00	2112.00
B24	48.00	240.00	1056.00	12672.00
B25	16.00	80.00	352.00	4224.00
Total	218.00	1090.00	4796.00	57552.00

Table 8 Contribution of CO Emission from B3 Split Air-conditioners intothe Ambient Air

B3 Split Air-conditioners	Daily CO Emission (ppm)	Weekly CO Emission (ppm)	Monthly CO Emission (ppm)	Yearly CO Emission (ppm)
B31	20.00	100.00	440.00	5280.00
B32	36.00	180.00	792.00	9504.00
B33	102.00	510.00	2244.00	26928.00
B34	28.00	140.00	616.00	7392.00
B35	20.00	100.00	440.00	5280.00
Total	206.00	1030.00	4532.00	54384.00

Table 9 Contribution of CO Emission from B4 Split Air-conditioners into the Ambient Air

B4 Split Air-conditioners	Daily CO Emission (ppm)	Weekly CO Emission (ppm)	Monthly CO Emission (ppm)	Yearly CO Emission (ppm)
B41	156.00	780.00	3432.00	41184.00
B42	66.00	330.00	1452.00	17424.00
B43	98.00	490.00	2156.00	25872.00
B44	74.00	370.00	1628.00	19536.00
B45	44.00	220.00	968.00	11616.00
Total	438.00	1752.00	9636.00	115632.00

Table 10 Contribution of CO Emission from B5 Split Air-conditioners into the Ambient Air

LG Split Air-conditioners	Daily CO Emission (ppm)	Weekly CO Emission (ppm)	Monthly CO Emission (ppm)	Yearly CO Emission (ppm)
B51	82.00	410.00	1804.00	21648.00
B52	1308.00	6540.00	28776.00	345312.00
B53	604.00	3020.00	13288.00	159456.00
B54	264.00	1320.00	5808.00	69696.00
B55	288.00	1440.00	6336.00	76032.00
Total	2546.00	12730.00	56012.00	672144.00

Tables 6 to 10 show the contribution of each split air conditioner to the outdoor ambient air daily, weekly, monthly and yearly. Table.6 presents the daily, weekly, monthly and yearly contribution of CO emission in ppm from B1 split air-conditioners. The total daily contribution was obtained as 134.00 ppm obtained for an operational time of eight (8) hours which is the average working hours, total weekly contribution as 670.00 ppm from a five (5) working days per week, total monthly contribution of 2948.00 ppm from a four (4) working weeks and a total yearly contribution of 35376.00 ppm for a twelve (12) months in a year. From this we can say that the concentration of CO contributed to the outdoor air is 35376.00 ppm in a year which is an alarmingly high concentration to be contributed from an average of one brand of five split air-conditioners in a year.

Table 7 presents the daily, weekly, monthly and yearly contribution of CO emission in ppm from B2 split air-conditioners. The total daily contribution was obtained as 218.00 ppm obtained for an operational time of eight (8) hours which is the average working hours, total weekly contribution as 1090.00 ppm from a five (5) working day week, total monthly contribution of 4796.00 ppm from a four (4) working weeks and a total yearly contribution of 57552.00 ppm for a twelve (12) months a year. From this we can say that the concentration of CO contributed to the outdoor air is 57552.00 ppm in a year which is an alarmingly high concentration to be contributed from an average of one band of five split air-conditioners in a year. It is also seen that B2 split air-conditioners contribute a larger portion than the B1 split air conditioners, both of which when summed up amount to an even higher concentration. Table 8 presents the daily, weekly, monthly and yearly contribution of CO emission in ppm from B3 split air-conditioners. The total daily contribution was obtained as 206.00 ppm obtained for an operational time of eight (8) hours which is the average working hours, total weekly contribution as 1030.00 ppm from a five (5) working day week, total monthly contribution of 4532.00 ppm from a four (4) working weeks and a total yearly contribution of 54384.00 ppm for a twelve (12) month year. From this we can say that the concentration of CO contributed to the outdoor air is 54384.00 ppm from five split air-cnditioners. It is also seen that B3 split air-conditioners contribute less than B2 split air-conditioners but more than the B1 split air conditioners

Table 9 presents the daily, weekly, monthly and yearly contribution of CO emission in ppm from B4 split air-conditioners. The total daily contribution was obtained as 438.00 ppm obtained for an operational time of eight (8) hours which is the average working hours, total weekly contribution as 1752.00 ppm from a five (5) working day week, total monthly contribution of 9636.00 ppm from a four (4) working weeks and a total yearly contribution of 115632.00 ppm for a twelve (12) month year. From this we can say that the concentration of CO contributed to the outdoor air is 115632.00 ppm from five B4 air-conditioners in a year, higher than the previous brands discussed. Table 10 presents the daily, weekly, monthly and yearly contribution of CO emission in ppm from B5 split air-conditioners. The total daily contribution was obtained as 2546.00 ppm obtained for an operational time of eight (8) hours which is the average working hours, total weekly contribution as 12730.00 ppm from a five (5) working day week, total monthly contribution of 56012.00 ppm from a four (4) working weeks and a total yearly contribution of 672144.00 ppm for a twelve (12) month of a year higher than that of the previous brands. The concentration of CO contributed by just the five B5 split air-conditioner is about nine (9) times the concnetration of the yearly contribution of five B1 split air-conditioners given as 35376.00 ppm which is also the lowest contributing split air-conditioners to the CO emission into the ambient air. .

4. CONCLUSION

The conclusion that can be drawn from this study is that air-conditioners do in fact emit carbon monoxide. The concentration of carbon monoxide emitted from each air-conditioner varies as a result of either the external or internal factors. Only the B5, one out of the five studied brands emits carbon monoxide which exceeds both the hourly and daily averaging limit. All the other brands still emit carbon monoxide, but at levels which on exposure for a period of 1-24 hours are not considered harmful. Further research should be carried out on the influence of the refrigerant and ages split air-conditioners on the levels of carbon monoxide emission. Study comparing the amount of CO emitted by split air-conditioners and window unit air-conditioners should be conducted.

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