Ozone Emission by Commercial Photocopy Machines in Rivers State University of Science & Technology, Nigeria

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Abstract; Ozone emission from photocopying machine has been identified as an indoor air pollution that is dangerous to photocopying machine operators and customers that are very close to the machine during operation. A total of two hundred and thirty nine commercial photocopying machines of different types and models were identified in the Rivers State University of Science & Technology (RSUST), Port Harcourt, Nigeria. 63% of this number is located at the University shopping complex, 11.7% at the student parliament, 10.0%, 7.9%, 3.7%, 2.9%, 0.84% and 0.4% were the percentage concentration of photocopy machines in Faculty of Law, Faculty of Sciences, Faculty of Engineering, Faculty of Technical and Science Education, Postgraduate School and Central Library respectively. 89% of the machines were purchased as fairly used, 4.2% brand new and 6% of unknown purchase state. Background concentration of 0.02ppm was recorded for Develop, Minolta, Agfa and Sharp photocopiers. It was only Canon that had zero background emission. All makes and models recorded concentration value above USEPA permissible limit of 0.075ppm at 100mm. Develop had the highest concentration value at this distance with 0.01ppm, followed by Minolta and sharp, whose concentration values were 0.09ppm, next is Agfa with 0.08ppm at same distance. At 600mm Develop and Minolta had concentration of 0.04ppm and 0.03ppm while Agfa had 0.02ppm.

Key words; Photo copy machines, Ozone emission, RSUST Environment, Operators.

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1 Introduction

Photocopiers are essential pieces of office equipment in modern time. These machines are used in duplicating documents. It produces a replicate of the original paper. Plain paper photocopier operates by reflecting light from the original item so that an image is produced onto a photo receptor which is an electrically charged drum or belt. During this process, pollutants, including Ozone, hydrocarbons, volatile organic compounds (VOCs) and dust which are dangerous to the environment are released. During the process of photocopying, Ozone (O_3), an unstable form of oxygen, is the main pollutant released. Ozone has a half life of six minutes in office environment. It is a highly toxic gas and is the most serious health risk from photocopiers. Ozone is usually produced during charging and discharging of the drum and paper. It is also produced from ultraviolet emission from the photocopier lamp. So, commercial operations of photocopy machines are highly exposed to the sweet smelling pollutant, Ozone; which is dangerous to human health.

[14] stated that there are basically two types of ozone, the good and bad ozone. The good ozone is found in the upper atmosphere (stratosphere about ten to thirty miles above the earth surface). The

good Ozone serves as a protective layer or barrier to the earth, preventing the ultra violet rays from the sun from reaching the earth while the bad ozone is found in the lower atmosphere (ground level).

[8] stated that Ground level ozone is not limited to outdoor but can also be found an indoor problem especially in some office equipments e.g. photocopying machines, laser printers, and even high voltage electrical appliances. Ground level ozone is not environmentally friendly whether indoor or outdoor.

Most research work carried out in this part of the world concentrates on stratospheric ozone depletion. Little or no work has been done as regards to ozone production from photocopying machines. Hence, this research is significant because the health of photocopy operators and their customers are highly susceptible to ozone emission hazard if not checked or controlled.

[6] states that ozone emission from office equipment like photocopying machines is determined by the amount of voltage over the corona wires (Ozone production spot in photocopy machines). He further stated that ozone trapped inside the toner cartridge can destroy the charge generation and the transfer layer as well as the polymeric coating on the toner drum surface. This is because the chemicals which make up these photoactive layers are all susceptible to ozone. He went further to state that laser printers and copier operators need to be aware of ozone gas and its potential harmful effects on the environment during photocopying.

[5] showed that the use of direct contact charging rollers replacing corona wires have shown to be effective to prevent the formation of electrical area and ozone. In his studies, he stated that copier emit ozone between $4\mu g/m^3$ to $300\mu g/m^3$ per copy, but maintenance of copiers reduces emission rates to $< 1\mu g/m^3$ to $54\mu g/m^3$ per copy.

2 Effects of ground level ozone on human health

The main concern on ground level ozone is its effects on man and his environment. The main health concern on exposure to ground level ozone is its effects on respiratory systems especially on lungs [15]. The report shows that several factors contribute to effects of ozone on human, which include, the ozone concentration in the atmosphere, the duration of exposure, average volume of air breathed per minute and the length of time between short – term exposure etc. Besides, children are more susceptible to ground level ozone damage to the respiratory system as children breathe more air than adult and their respiratory system are still developing.

Clinical studies have documented an association between short term exposure to ground level ozone concentrations of $200\mu g/m^3$ - $500\mu g/m^3$ and mild temporary eye and respiratory irritation as indicated by symptoms such as cough, throat dryness, eye and chest discomfort, thoracic and headache due to ozone exposure to human. Lungs damages however have been noted to be relatively mild at concentrations of 360 $\mu g/m^3$ hourly. Temporary decrement in pulmonary functions in children at hourly average ground level ozone concentrations of 160 $\mu g/m^3$ – 300 $\mu g/m^3$ was also noted [11, 14].

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[7] demonstrated an association between ground level ozone and concentration and mortality rates in respiratory cases in Sydney, stating that concentration of 0.12ppm can increase hospital admission and consequently increase financial expenses of asthmatic patients. [9] found no correlation between ground level ozone pollution and reduced lung functions suggesting the possibility of a lower threshold value for effect of chronic ground level ozone exposure.

[14] shows that short term exposure of ground level ozone to elevated concentration of ozone up to several hours can cause respiratory irritation and changes in lungs functions. Besides, short term impacts, the potential for irreversible damage to the lungs from repeated exposure over a longer period of time has been a health concern. [3] found an association between accelerated loss of lungs function over a longer period of time (five years) and high oxidant levels in the atmosphere.

Statistical studies in ninety five (95) urban communities in the United States found significant association between ozone level and premature death. The studies also estimated that one third reduction in urban ground level ozone concentration would save about four thousand lives per year [2].

[8] also discovered that an increase of 100ppb (parts per billion) in the daily ground level ozone was associated with 0.53% increase in mortality rate; this percentage corresponds to three thousand seven hundred and sixty seven (3767) deaths annually in some urban cities in United State. Many factors such as age, gender, disease, nutritional status, smoking and genetic variability may contribute to the differential health effects of ozone exposure.

[13] shows that asthmatics experiences to moderate exposure of ground level ozone would limit their activity and increase their frequency of medication. [1] suggested that reducing the threshold value of ground level ozone from 0.08ppm to 0.06ppm will have relatively small significant effect on human health.

3 Effect of ground level ozone on plants

Early research into the impact of air pollutants on plants were primarily concerned with obvious acute injury symptoms recorded by leaf on plants and crops over ozone concentration of 0.05ppm in London, during their study in fifty three (53) rural sites. The highest lead injury indices were recorded during the greatest amount of sunshine. [4] reported that there were chronic effects of ozone on crops using the biological indicator plants and the open – top chamber techniques. Ozone damage to plants and crops can occur without any visible sign, as ozone enters plant leaf through it gaseous pores (stomata) just as other atmospheric gases do in normal gas exchange. It dissolves in the water within the plants and reacts with other chemicals causing variety of problems. Thus, this reaction retards photosynthesis and consequently show poor crops growth [4].

Ground level ozone concentration are alarming in some large metropolitan areas, these include China, Japan, Korea, Taiwan , Thailand and some Asia countries were its peak concentration ranges from 90ppb – 220ppb. It further shows that ground level ozone causes about 90% leaf injury to plants and 30% growth reduction. Similar report was made for Egypt in Africa. Besides, the agriculture damage as a result of ground level ozone, effects in plants and crops in Japan was estimated to exceed several billions of dollars [16].

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Ground level ozone is a serious threat to food security and pollution control especially in hilly and mountainous areas where it's more frequent. However, it is impossible to make any realistic prediction of the distribution of elevated concentration of ozone because of its highly episodic nature [6].

5 Research methods.

The study area, the Rivers State University of Science and Technology (RSUST) is located in Port Harcourt, Nigeria. It lies on latitudes $4^0 50^1$ N and $7^0 00^1$ N and between longitudes $4^0 45^1$ E and $7^0 00^1$ E of the equator. Rivers State University of Science and Technology is bounded to the South by the Eagle Island, to the East by mile three market and to the North by Mgbuosimini.

It has a uniform temperature throughout the year of between 20^0C to 31^0C. The institution accommodates lecture halls, student hostels, offices, cafeterias, libraries, filling station etc. Zone A of the institution accommodates the shopping complex, Faculty of Technical and Science Education, Zone B of the campus houses Post Graduate School and power house, Zone C contains the Faculty of Engineering, Student Parliament, Faculty of Law, Faculty of Science, Central Library etc, Zone D accommodates staff quarters, Zone E, Staff Primary School while zone F and G accommodates convocation arena and University Agricultural Farm, respectively.

4 Data collection

Two methods of data collection were employed to obtain primary data in this research. These are the use of direct measurement of ground level ozone emission from photocopy machines using ozone monitor model EZ-IX (Fig. 1) and oral interviews of photocopy operators and technicians.

Fig. 1. Ozone Monitor Model EZ - 1X

6 Sampling methods

Ozone concentration in thirty different makes and models of photocopy machines within the area of study were measured at different time and days during school hours. The eco-sensor ozone monitor model EZ – IX was calibrated according to manufacturer's instruction. The monitor was charged for twenty four hours. Before readings commenced, the monitor was allowed to warm-up for 45 minutes.

First, the background ozone concentration for each of the machines was noted and the number of copies made before the backgrounds concentration was also recorded. Readings were taking at different distances from the point source. The distances at

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which measurement were taken are 100mm, 200mm, 300mm, 400mm, 500mm and 600mm.. All readings were taking at equilibrium. The doors and windows were closed. Doors and window opening were sealed properly with paper.

7 Theory

The mass balance equation for ozone emission (E) was used [10] :

$$Vdc/dt = q_o C (I.F) + q_1 C_K (I.F_1) + q_2 C + q_3 C_h - q_1 C_1 - q_4 C_1 - q_5 C_5 + E/A - D \text{ ----- } 1$$

Where:

V = is the room volume in m^3

C = The room concentration ppm

C_0 = The outdoor concentration ppm

C_n = The indoor concentration in hall ways or other indoor areas adjacent to the room all in ppm.

$I.F_0$ = The make up air filter efficiency

$I.F_1$ = The recirculation air filter efficiency

q_0 = Make up air flow rate m^3/min

q_1 = The recirculation air flow rate m^3/min

q_2 = The infiltration air flow rate from outdoors m^3/min

q_3 = The infiltration air flow rate m^3/min

q_4 = The exhaust air flow rate m^3/min

q_5 = The infiltration air flow rate. m^3/min

E = The source emission μg/min

D = The indoor decay ppm – m^3.min

A = The conversion factor between μg/m^3 to ppm.

Since tests were conducted until ozone concentration reached equilibrium

$$V \frac{dC}{dt} = 0 \text{ ----------2}$$

The air flow rates, q_0, q_1, q_2, q_3, q_4 and q_5 were zero because the rooms were sealed. Solving equation 1 for indoor pollutant source emissions under these conditions gives,

$$E = A.D \text{ ---------- } 3$$

The personal interview helped in providing accurate data like the age of the machine and the purchased state. This is to confirm if the machine was purchased as brand new or fairly used.

8 Results and discussion

Table 1 below shows the type and the total number of commercial photocopying machines within the locations in the University. This table shows that

concentration of photocopier is high within the shopping complex and low in the central library.

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Table 1; Summary of commercial photocopying machines in the various areas of RSUST

S/N	Location	Agfa	Canon	Develop	Sharp	Minolta	Total
1	Shopping Complex	2	13	21	10	103	149
2	Student parliament	-	2	1	12	13	28
⅔	Faculty of Engineering	2	2		2	3	9
4	Faculty of Law	-	3	1	9	11	24
5	Faculty of Science	1	5	-	4	9	19
6	Faculty of Technical & Science	-	1	-	-	6	7
7	Post Graduate School	-	-	-	-	2	2
8	Central Library	-	-	-	-	-	1
	Grand Total						239

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9 Average number of copier brands in relation to background ozone concentration

Table 2 below shows total number of copier brands and background ozone concentration in the university.

Table 2; Average number of copies per brand before background ozone

Brand	Average No.	Background Emission (PPM)

Agfa	68	0.02
Develop	58	0.02
Minolta	63	0.02
Sharp	81	0.02
Canon	200	0.00

During measurement it was observed that there was variation of number of copies made in relation to background ozone concentration. From Table 2, Sharp was observed to have eighty one (81) copies before background ozone concentration was recorded. Agfa recorded sixty eight (68), Minolta sixty three (63), Develop fifty eight (58) respectively with background concentration of 0.02. ppm. Canon was observed to have zero value, in spite of running the copies up to two hundred (200).

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Table 3; Average emission against distance for different brand copiers

Distance (mm)	Emission (ppm)					Allowable permissible limit (USEPA, 2005)
	Agfa (Series1)	Develop (Series2)	Canon (Series3)	Minolta (Series4)	Sharp (Series5)	
100	0.08	0.10	0.00	0.09	0.09	0.075
200	0.07	0.09	0.00	0.07	0.08	0.075
300	0.06	0.08	0.00	0.06	0.06	0.075
400	0.04	0.07	0.00	0.05	0.05	0.075
500	0.03	0.06	0.00	0.04	0.03	0.075
600	0.02	0.04	0.00	0.03	0.02	0.075

The expression of correlation between concentrations and distances is as plotted in Fig 2. All the brands of copiers show similar trend of

decreasing emission from 100mm to 600mm although higher than the allowable permissible level

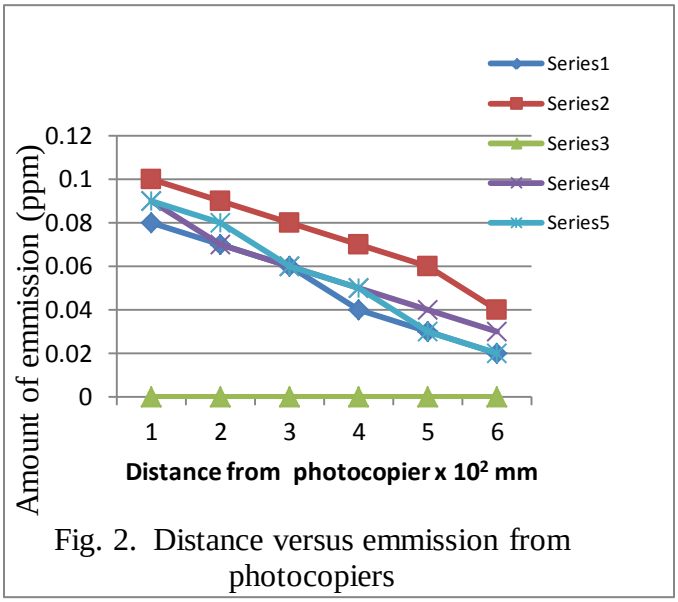

Fig. 2. Distance versus emmission from photocopiers

of USEPA (2005).

The maximum concentration of 0.08ppm for Agfa was at the distance 100mm. This maximum concentration is 0.005ppm higher than the [12] allowable permissible limit. Besides, the concentrations between the distances range of 200mm to 600mm lies in the allowable permissible limit. Its minimum concentration was at 0.02ppm at 600mm

The maximum concentration of Develop was 0.10ppm at 100mm, 0.09ppm at 200mm and 0.08ppm at 300mm. These concentrations are higher than the allowable permissible limit and the difference between these values and the permissible limit ranged from 0.025ppm to 0.005ppm. The lowest concentration was 0.04ppm at 600mm which is below the permissible limit.

The maximum concentration of 0.09ppm at 100mm for Minolta is 0.015ppm higher than the allowable permissible limit. At 200mm the concentration was 0.07ppm which is 0.005ppm below the permissible limit. At 300mm, 400mm, 500mm and 600mm, the concentrations were 0.06ppm, 0.05ppm, 0.04ppm and 0.03ppm respectively which is within permissible limit.

The maximum concentration of 0.09ppm at 100mm for Minolta is 0.015ppm higher than the allowable permissible limit. At 200mm the concentration was 0.07ppm which is 0.005ppm below the permissible limit. At 300mm, 400mm, 500mm and 600mm, the concentration was 0.06ppm, 0.05ppm, 0.04ppm and 0.03ppm respectively which is within permissible limit.

10 Conclusion

The brand, Develop, has one of the highest emission concentration in the ranging 0.10ppm to 0.04ppm. The emission concentration of Minolta was also high. Minolta had concentrations ranging from 0.09 ppm to 0.02ppm. Operators say it is cheap and easy to maintain. Sharp has similar concentrations. Agfa has concentration range of 0.08ppm to 0.02ppm. Canon has zero readings in all the distances. Investigation from photocopy technicians revealed that it was as a result of the presence of rollers in Canon photocopying brands which replaced the corona wires. The roller uses a little heat compared to corona wires. Besides, the Canon has activated carbon fiber inside the machine which traps ozone

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emission. This makes Canon brand of photocopying machine virtually ozone .

In view of the findings of this study, it is recommended that the RSUST authorities should allocate spacious and well ventilated accommodation to operators in the areas designated as business centres. That operators doing bulk copying should set the machines and stay 600mm away from the point source or exhaust, since increase distance reduces emission concentrations. The operators and students should be properly educated on the danger of staying in unventilated places/offices during bulk photocopying operations as ozone is dangerous to human health.

References

[1] Adam, W. C. (2006): Comparison of Chamber 6-6hr exposure to 0.04ppm – 0.08ppm ozone vis square – wave and triangular profiles on pulmonary responses, Inhalation Toxical 18, 127-136.

[2] Bell ML, Ebisu K, Belanger K. (2007). Ambient air pollution and low birth weight in Connecticut and Massachusetts. Environ Health Perspect. 115:1118–1124. [PMC free article] [PubMed]

[3] Detels, R. (1987): The UCLA Population Studies of Chronic obstructive Respiratory Disease Chest, Journal of American Medical Association 1, 1 -3. 92, 594 – 603.

[4] Earth Observatory, (2007): The Ozone we breath. http:// www earth observatory.nasa.gov/library/ozone_we breath/ozone_we_ breath5,html.

[5] Hetes R, Moore M, Northelm C. (1995). Office equipment: Design, indoor air emissions, and pollution prevention opportunities. US EPA Project Summary, EPA/600/SR-95/045; Research Triangle Park, North Carolina. 1995

[6] Lee, S. C. Sanches, L. HO K. F. (2001) characterization of VOCs Ozone and Pm10 emission from office equipment in an environment building and Environment, Journal of Air Pollution Control Association 34, 1023-1034.36, 837 – 842.

[6] Marco, F, Sara A, Gabriella C, (2008), Integrating Monitoring networks to obtain estimates of groundlevel ozone concentration. Journal of Air Pollution Control Association 34, 1015-1025.

[7] Morgan, G., Corbett, S., and Wlodarczyk, J., 1998, “Air Pollution and Hospital Admissions in Sydney, Australia, 1990 to 1994”, *Am. J. Public Health,* 88(12), 1761-1766.

[8] Mundel E. J. (2004): Ozone Pollution raises death Risk. Health Day Report Nov. 17. 2004.

[8] Nisson, A. Nostrabadi A. R. Lagesson H. V., Murgia N. Leanderson, Tageeson C. (2002), Novel technique for measuring low molecular chemicals in indoor dust, indoor built environ, Journal of Air Pollution Control Association.11,153-161.

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[9] Schwatz Joel (1989), Lung Functions and Chronic Exposure of Air Pollution. A Cross – Sectional Analysis of NHANESS II, Environmental Research 50, 309 – 321.

[10] Selway M. D, Allen R. J and Wadden R. A (1980), Ozone Production from Photocopying Machines. American Industrial Hygiene Association Journal 41:455-9.

[11] United State Environmental Protection Agency, (1996), Air Quality Criteria for Ozone and related photochemical oxidant. Research Triangle Park, NC, EPA/600/AP-93/004aF-CF, 1-3.

[12] United State Environmental Protection Agency, (2005). Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter , EPA-454/R-05-001

[13] United States Environmental Protection Agency, (2006) Emission Standards Reference Guide, F-1564.

[14] United States Environmental Protection Agency (1999), Ozone Monitory Mapping and Public Outreach Office of Research and Development, Washington, D. C. 20460, 9 – 18.

[15] United States Environmental Protection Agency, (2007) Review of the National Ambient Air Quality Standards for Ozone, Policy Assessment of Scientific and Technical Information OAOPS Staff Paper, EPA (452) R – 07/03.

[16] Yu – chi Weng, Ni-Bin Chany, T. Y Lee (2008), Non-Linear time series analysis of ground level Ozone dynamics in Southern Triaan. Journal of Environmental Management, 87,405-414.

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