A COMPARATIVE STUDY ON PHOTOCOPIER EMITTED OZONE DETECTED UNDER DIFFERENT EXPOSURE PERIODS

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This research paper hereto entitled:

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ABSTRACT

Breathing in ozone can trigger a variety of health complications. During photocopying, ozone is produced during the charging and discharging of the drum, but it is uncertain whether the amount of ozone emitted reaches an unhealthy level.

This study was conducted to confirm ozone emission from photocopiers and measure amount of ozone using the Schoenbein Paper method. Specifically, it aimed a) to measure the amount of ozone (in parts per billion) emitted by photocopiers, b) to compare the amount of ozone detected under the exposure times 1 hour versus 8 hours and c) to compare the amount of ozone detected between the three sites.

The Schoenbein Paper method was used to measure ozone concentrations in three sites. Paper strips were coated in a mixture of potassium iodide, distilled water and cornstarch, dried, then exposed on site for 1-hr and 8-hr periods. Color change and relative humidity were recorded, and used to obtain ozone concentration values.

Results showed that there was a significant difference in the amount of ozone detected under exposure times I hour versus 8 hours. This means that exposure time affects the ozone concentration recorded by the Schoenbein paper over time.

TABLE OF CONTENTS

List of Tables

List of Plates

CHAPTER 1

INTRODUCTION

A. Background of the Study

Ozone is a molecule of three oxygen atoms bound together (www.howstuffswork.com). It is a highly reactive, unstable and toxic gas.

Ozone is found in two layers of the atmosphere: the stratosphere and the troposphere. It occurs naturally in small amounts in the earth's stratosphere, where it serves as the earth's protection from ultraviolet radiation.

While stratospheric ozone is beneficial, as it serves as a barrier between harmful UV rays, ozone is can be quite hazardous when found in the troposphere.

Ground-level ozone is produced in small amounts during lightning storms. However, due to chemical reactions with nitrogen oxides, coming from automobile exhaust and other industrial processes, the amount of ozone in the troposphere can rise to dangerously high levels.

Breathing in ozone can trigger a variety of health complications such as chest pains, coughing, throat irritation, and congestion, while also aggravating respiratory diseases like bronchitis, emphysema and asthma. Ground-level ozone can also reduce lung capacity and inflame the linings of the lungs. Repeated exposure may also permanently scar lung tissue (www.epa.gov). Unfortunately, the hazard of ozone exposure is not only limited to outdoors, but indoors as well.

Photocopiers are machines that operate by reflecting light from an item, such as a piece of paper, so that a copy of the original image is projected onto an

electrically charged drum or belt (www.workershealth.com.au). The surface of the drum is photosensitive, losing the electrostatic charge when exposed to light. The reflected light produces a pattern of charges, leaving a latent image of the original item. To attract the toner, the drum is subjected to a high voltage. The toner is then transferred to the paper, which moved through the photocopier's heated rollers, and printing a permanent copy of the image.

During photocopying, majority of ozone is produced during the charging and discharging of the drum, though ozone is also produced by ultraviolet transmission from the photocopier lamp (www.workershealth.com.au). However, it is uncertain whether the amount of ozone emitted reaches an unhealthy level.

This study aims to confirm ozone emission from photocopiers and measure amount of ozone using the Schoenbein Paper method.

B. Statement of the Problem and Objectives

This study aims to confirm ozone emission of photocopiers and measure amount of ozone using the Schoenbein Paper method. Specifically, it aims

1. To measure the amount of ozone (in parts per billion) emitted by photocopiers.

2. To compare the amount of ozone detected under the exposure times 1 hour versus 8 hours.

3. To compare the amount of ozone detected between the three sites.

C. Hypothesis of the Study

There is no significant difference in the amount of ozone detected under different exposure times.

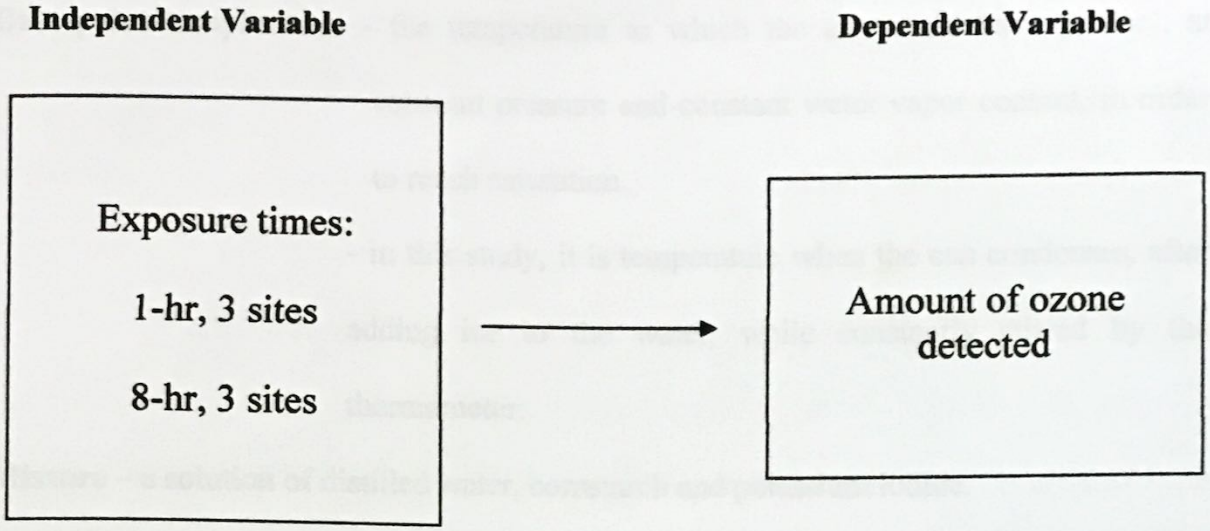
There is no significant difference between the amounts of ozone detected between sites, under different exposure times.

D. Significance of the Study

Ozone can cause a variety of symptoms and conditions. At a concentration of 0.1 ppm, it can cause irritation in mucous membranes of the eyes, nose and throat, and at 1 ppm, it can headache, dizziness and severe fatigue (www.lhc.org.uk). Chronic exposures or exposures at higher concentrations will cause permanent lung damage, and other health problems.

If the amount of ozone detected reaches or goes beyond the maximum allowable level (0.075 ppm for the 8-hr period, 0.12 ppm for the 1-hr period), it can be deduced that photocopiers emit ozone in a quantity where it is no longer acceptable in a working environment. Proper measures can then be implemented to ensure the safety of the workers.

E. Research Paradigm



F. Scope and Limitations of the Study

This study evaluated the differences between the amounts of ozone detected under different exposure times, using Schoenbein paper.

Since this method is based on a color change scheme, errors may occur during the comparison between the paper after exposure and the color chart. Accidental exposure to sunlight anytime during testing period may also speed up change in color, and contribute to error.

Materials were borrowed from the PSHS-WV laboratory, where the preparation of the Schoenbein paper will also be done. Testing was done in West Visayas State University and Philippine Science High School.

G. Definition of Terms

Dew point temperature - the temperature to which the air would have to cool, at constant pressure and constant water vapor content, in order to reach saturation.

- in this study, it is temperature when the can condenses, after adding ice to the water, while constantly stirred by the thermometer.

Mixture – a solution of distilled water, cornstarch and potassium iodide.

Schoenbein Color Chart – a chart used as a reference for interpretation of color change in Schoenbein Paper.

Schoenbein Number – the number which corresponds to the color change in the Schoenbein Color Chart.

Schoenbein Paper – an indicator used to measure ozone concentration in air.

Potassium Iodide – a white crystalline compound with a salty taste

Relative Humidity – the percentage of water vapor in air

Relative Humidity Schoenbein Number Chart – a chart used for obtaining ozone concentration, by using the Schoenbein Number and relative humidity values.

CHAPTER 2

REVIEW OF RELATED LITERATURE

The review of related literature consists of two (2) topics, mainly;

A. Ozone

Ozone is a colorless gas. It is a poisonous allotrope of oxygen, formed naturally in the ozone layer from atmospheric ozone, either by electrical discharge or exposure to ultraviolet radiation. It is also produced in the lower atmosphere by photochemical reaction of certain pollutants. At room temperature, ozone is a pale blue gas with a pungent odor. It condenses to a dark blue liquid at -112°C and freezes at -193°C. While it is very unstable in water, with only a half life of 20 minutes; however, it is quite stable in air, where it has half life of 12 days.

Ozone is a powerful oxidizing agent. It can oxidize many organic compounds and is used commercially as bleach for waxes, oils, and textiles, and as a deodorizing agent. Because it is a powerful germicide, it is also used to sterilize air and drinking water.

Ozone is found in two layers in the atmosphere: the stratosphere and the troposphere.

Formation of Ozone

Ozone occurs naturally in small amounts in the earth's upper atmosphere, the stratosphere, about 15 to 30 kilometers from the surface of the earth. This part of the atmosphere is called the ozone layer, which protects the earth from the sun's harmful

ultraviolet light. The ozone found in this layer is produced by photochemical reactions involving oxygen. When diatomic oxygen (O2) in the stratosphere absorbs ultraviolet radiation with wavelengths less than 240nm, it breaks apart into two oxygen (O) atoms. The resulting oxygen atoms combine with oxygen molecules to form ozone (O3).

Ground-level ozone reaches from the ground to about 14.5 kilometers above the earth. As of December 2008, the tropospheric concentration of ozone is 34 parts per billion (cdiac.ornl.gov), but concentrations may vary from place to place, and from time to time. In a study conducted during 1998 until 2000, the average 8 hourly seasonal ozone concentrations at various urban, suburban and rural sites of Varanasi varied from 10 to 45 ppb during winter and 21 to 59 ppb during summer season. Ozone concentration was highest at rural sites with no specific sources of pollutants, and during the summer time, due to meteorological factors (high solar radiation, longer day light period, warm weather, stagnant wind patterns and low humidity). A detailed monitoring programme conducted at a rural area of Varanasi (2004 – 2006) showed average daytime ozone concentrations of 56, 42 and 32 ppb during summer, winter and rainy seasons, respectively. Upon comparison of this data from earlier monitoring records for the same area, it was observed that average ozone concentrations increased by 32% during summer reason, 41% during winter season, and 36% during rainy season from previous recorded data (1989-1990). A diurnal maximum of ozone concentration was found to occur during the early afternoon in winter and during the late afternoon in summer. The night time ground level ozone concentrations were 8 to 13 ppb throughout the year. (isebindia.com)

Tropospheric ozone is usually formed as a result of chemical reactions between oxygen and volatile organic compounds (mainly from automobile exhaust) and

nitrogen oxides (mainly come from industries and power plants) in the presence of sunlight (www.airvictoria.org). In addition to the presence of volatile organic compounds and nitrogen oxides, there are other factors which contribute to the formation of ground-level ozone, such as solar insulation, cloud cover, high temperatures, wind directions, low wind speeds, low levels of precipitation and the positions of fronts (www.wmcac.org). Solar insulation (or sunlight) is required to initiate the photochemical reactions that lead to the formation of ozone. This correlates to cloud cover, since the amount of cloud cover affects the amount of sunlight that reaches ground level. Higher temperatures enhance ozone formation and increase the evaporative emissions of volatile organic compounds.

Wind direction also affects ozone formation, as well as wind speed. Wind direction, especially those from the south or southwest, can bring warmer weather and increase ozone levels. Low winds speeds allow the accumulation of ozone precursors, and also increase ozone formation.

Dry weather allows ozone to remain in the air, so low levels of precipitation also contribute to ozone formation.

The position of fronts are also considered in ozone formation, because of their potential to affect other factors, such as cloud cover, amount of precipitation and changes in air mass.

Effects of Ozone

Ozone can trigger a variety of health problems such as chest pains, coughing, throat irritation, and congestion, and can worsen bronchitis, emphysema and

asthma. When breathed into the airways, ozone interacts with proteins and lipids on the surface of the cells or present in the lung lining fluid. Ozone also reacts with the biomolecules in the lungs, particularly those containing thiol or amine groups or unsaturated carbon-carbon bonds. Epithelial cells lining the respiratory tract, the main target of ozone and its products, become injured and leak intracellular enzymes such as lactate dehydrogenase into the airway lumen, as well as plasma components. These cells also release a variety of inflammatory mediators that can attract PMNs into the lung, activate alveolar macrophages, and initiate a train of events leading to lung inflammation.

When we breathe air unpolluted by human activities, we usually take in about 10 to 15 parts of ozone per billion parts of air (earthobservatory.nasa.gov). However, pollution has greatly elevated ozone concentrations over time, reaching to as much as 125 ppb in the summer,

Aside from its adverse effects on humans, ozone also affects vegetations and ecosystems (www.epa.gov). This leads to a reduction in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests and other environmental stresses, like harsh weather.

Ozone can also damage various compounds (www.epa.sa.gov.au). It can cause the cracking of rubber and paint, reduction in the tensile strength of textiles, and the fading of dyed fabrics.

B. Schoenbein Paper Method

Schoenbein Paper is an ozone test paper, first developed by Christian Friedrich Schoenbein (teachers.sduhsd.k12.ca.us). This paper is coated with a mixture of water, starch and potassium iodide. When exposed to air, the following chemical reaction takes place:

$$2KI + O3 + H2O \rightarrow 2KOH + O2 + I2$$

When ozone is present in air, it will oxidize the potassium iodide on the Schoenbein paper, producing iodine. The resulting product, iodine, reacts with starch, producing a purple or brownish color. The shade of color on the Schoenbein paper reflects the amount of ozone present in the environment. The resulting color change is then compared to the Schoenbein Color Chart, which is used to obtain the Schoenbein Number.

Air temperature and the dew point temperature are also measured. These two values are used to obtain the relative humidity.

$$RH = 100\left(\frac{112 - 0.1T + Td}{112 + 0.9T}\right)^8$$

Figure 1. Formula for obtaining relative humidity.

The Schoenbein number is then used to obtain the ozone concentration, using the Relative Humidity Schoenbein Number Chart. The Schoenbein Number is plotted on the x-axis, and then traced up to the average humidity closest to the recorded

relative humidity on the chart. Then that point is traced towards the y-axis, where it would give the approximate ozone concentration recorded.

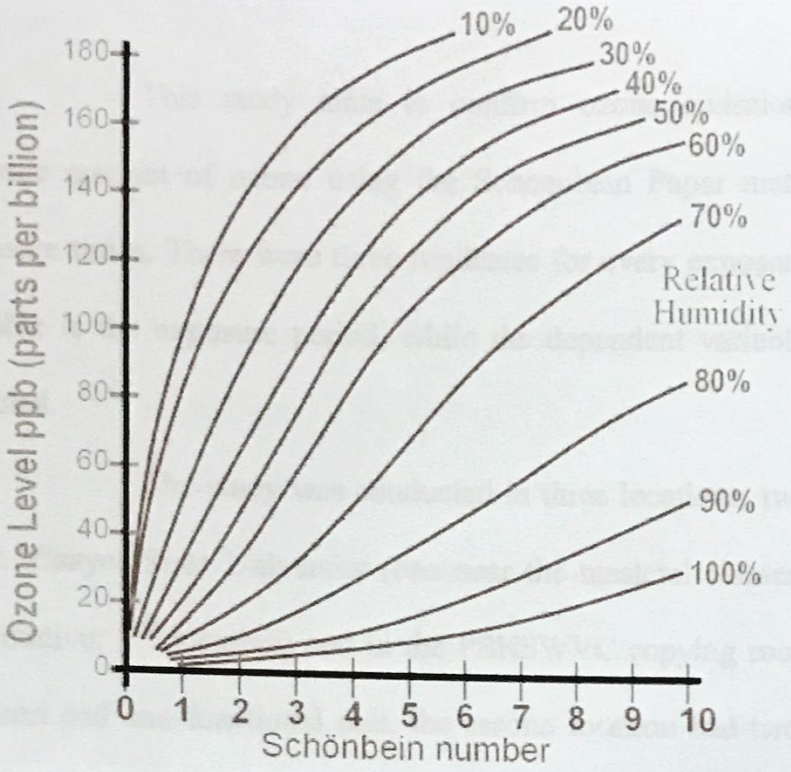


Figure 2. Relative Humidity Schoenbein Number Chart

The test is affected by several factors: humidity and sunlight. High humidity and direct sunlight causes the Schoenbein paper to speed up its reaction, resulting in darker color.

CHAPTER 3

METHODOLOGY

This study aims to confirm ozone emission from photocopiers and measure amount of ozone using the Schoenbein Paper method, under 1-hr and 8-hr exposure times. There were three replicates for every exposure period. The independent variable is the exposure period, while the dependent variable is the amount of ozone detected.

The study was conducted in three locations; two photocopying centers in West Visayas State University (one near the masteral classes; 1st location, the WVSU cooperative; 2nd location) and in the PSHSWVC copying room (3rd location). The first location had one functional unit, the second location had two functional units, and the third had one functional unit. All locations were open air, except the third location. The study was done on January 30, 2009 in the first location and on February 9, 2009 in the second and third locations.

A. List of Materials

Hotplate	Top-load Balance	Plastic zip-top bags	Oven
250 mL beaker	2.5" x 1.5" Filter papers	Plastic wrap	Tin Can
Stirring rod	Spray bottle	Corn starch	Ice Cubes
Modified metal tray	Potassium Iodide, KI	Distilled water	Thermometer

Lab equipment and potassium iodide were provided the PSHS-WVC SRA. Corn starch was bought in a local department store and distilled water was bought in a pharmacy.

B. Procedures

Preparation of Schoenbein Paper

Two hundred milliliters of distilled water was measured, and then added 20.0 grams of cornstarch. While stirring, 1.0 gram of potassium iodide was added. The resulting mixture was heated on a hotplate (medium setting), preheated at a high setting for five minutes. The mixture was removed from heat when it formed a translucent gel, and allowed to cool.

After the mixture has cooled, it was used to coat the filter paper. The filter paper was then dried in the oven.

Recording Relative Humidity

Air temperature was recorded using a thermometer. For dew point temperature, was tin can was filled with water, and then slowly added ice cubes. The water was then stirred using a thermometer, while added with ice cubes. Temperature was recorded when the can condensed.

Relative humidity was computed using the following equation

$$RH = 100\left(\frac{112 - 0.1T + Td}{112 + 0.9T}\right)^{8}$$

where,

T = air temperature

Td = dew point temperature

Testing

The paper strip was sprayed with distilled water and suspended at the testing site, away from sunlight. Paper strips were collected after the 1-hour and 8-hour exposure times.

The paper strips were then placed inside a sealable, airtight container. Color change was recorded. The values of humidity and ozone concentration were corrected using the Relative Humidity Schoenbein Number Chart.

C. Statistical Analysis

The means of the recorded ozone concentrations per exposure period for each site was calculated. Unpaired T-Test was used to determine if there is a significant difference in the means of recorded amount of ozone detected under each exposure period. One-Way ANOVA was used to determine if there is a significant difference in the means of recorded amount of ozone per site, in each exposure period.

CHAPTER 4

RESULTS AND DISCUSSION

A. Results

This research was conducted to determine if the amount of ozone emitted by photocopiers reached harmful levels.

This study aims to confirm ozone emission from photocopiers and measure amount of ozone using the Schoenbein Paper method.

In this study, it was hypothesized that there is no significant difference in the amount of ozone detected under different exposure times.

Of the two exposure periods, the highest recorded amount of ozone was recorded under the 8-hour standard (132 ppb) and lowest in the 1-hour standard (13 ppb). The 8-hr exposure period in the third location (S3, 8-hr exposure) had the highest mean for ozone concentration (131.67), and the 1-hr exposure period in the second location (S2, 1-hr exposure) had the lowest mean for ozone concentration (16).

Table 1 shows the results.

Table 1. Means of ozone concentrations from the three sites under 1-hr and 8-hr exposure periods.

Treatment		Mean (±) SD
WVSU Masteral	(1hr-exposure)	49
	(8-hr exposure)	84
WVSU Cooperative	(1hr-exposure)	16
	(8-hr exposure)	20
PSHS Copying Room	(1hr-exposure)	69
	(8-hr exposure)	132

Results of the T-Test Independent Means show that there is a significant difference in the amount of ozone measured by the Schoenbein paper between the 1-hr and 8hr exposure periods.

Table 2. T-Test Independent Means on the ozone concentrations of the 1hr and 8-hr exposure period (a=0.05, p= 1.746).

Amount of Ozone	T-value	T-critical	Interpretation
	1.876581953	1.746	Significant

Results of the One-Way ANOVA show that there is a significant difference in the amount of ozone detected between the three sites (8-hr exposure).

Table 3. One-Way ANOVA on the ozone concentrations between the three sites under the 8-hr exposure period (a=0.05).

	Sum of Squares	df	Mean Square	F-ratio	Significance Level	Interpretation
Between groups	18731.6	2	9365.78	826.4	4.732E-08	Significant
Within groups	68	6	11.3333			
Total	18799.6	8				

Results of the Tukey's pair wise comparison show that the ozone concentrations for the 8-hr exposure period of Site 1 varies significantly with those of Sites 2 and 3, Site 2 with those of Sites 1 and 3, and Site 3 with that of Site 1 and 2.

Table 4. Tukey's pair wise comparisons on the three sites for 8-hr exposure period (a=0.05).

	p-computed	p-significant	Interpretation
Site 1 versus Site 2	0.0002269	0.05	Significant
Site 1 versus Site 3	0.0002273		Significant
Site 2 versus Site 3	0.0002269		Significant

Results of the One-Way ANOVA show that there is a significant difference in the amount of ozone detected between the three sites (1-hr exposure).

Table 5. One-Way ANOVA on the ozone concentrations between the three sites under the 1-hr exposure period (a=0.05).

	Sum of Squares	df	Mean Square	F-ratio	Significance Level	Interpretation
Between groups	4298	2	2149	18.63	0.002667	Significant
Within groups	692	6	115.333			
Total	4990	8				

Results of the Tukey's pair wise comparison show that the ozone concentrations for the 1-hr exposure period of Site 1 varies significantly with of Sites 3, Site 2 with of 3, and Site 3. Site 1, however, does not vary significantly with Site 3.

Table 6. Tukey's pair wise comparisons on the three sites for 1-hr exposure period (a=0.05).

	p-computed	p-significant	Interpretation
Site 1 versus Site 2	0.02198	0.05	Significant
Site 1 versus Site 3	0.1351		Not Significant
Site 2 versus Site 3	0.002418		Significant

B. Observations of the Sites

Site 1: WVSU, near masteral classes

Testing was done on January 30, 2009. The location had one functional unit. The site was open-air, and had adequate ventilation. No precipitation was observed during implementation. The area was located inside a building. Photocopying operation was scarce.

Site 2: WVSU Cooperative

Testing was done on February 9, 2009. The location had two functional units. The site was open-air, and had adequate ventilation. No precipitation was observed during implementation. The area was shaded and windy. Photocopying operation was kept busy.

Site 3: PSHSWV copying room

Testing was done on February 9, 2009. The location had three units, but only one unit was used during the duration of the study. No precipitation was observed during implementation. The site was enclosed, but the set up was placed on the window, which was kept open during the whole duration of the experiment. The set-up also was in a position wherein it came in contact with sunlight. Photocopying operation was scarce.

C. Discussion

This study aims to confirm ozone emission from photocopiers and measure amount of ozone using the Schoenbein Paper method. Specifically, it aimed a) to measure the amount of ozone emitted by photocopiers, in parts per billion, b) to compare the amount of ozone detected under the exposure times 1 hour versus 8 hours, and c) to compare the amount of ozone detected between the three sites.

Of the two exposure periods, the highest recorded amount of ozone was recorded under the 8-hour standard (132 ppb) and lowest in the 1-hour standard (13 ppb). The 8-hr exposure period in the third location (S3, 8-hr exposure) had the highest mean for ozone concentration (132), and the 1-hr exposure period in the second location (S2, 1-hr exposure) had the lowest mean for ozone concentration (16).

One-Way ANOVA test shows that there is a significant difference in the amount of ozone detected between the three sites in both exposure periods (1-hr, 8-hr).

The Tukey's pairwise comparison test shows that the ozone levels at Site 1 and Site 3 at 1-hr exposure are not significantly different, but are significantly different between Site 1 and Site 2, and between Site 2 and Site 3 (1-hr). Under the same test, ozone levels are significantly different between Site 1 and Site 2, Site 2 and Site 3, and Site 1 and Site 3 for the 8-hr exposure period.

Of the three locations, the third location had the highest mean for ozone concentration, both in the 1-hour exposure period (69) and the 8-hour exposure period (132), and also the highest values for both 1-hour exposure period (78 ppb) and 8-hour exposure period (132). The recorded amounts are considerably greater than the maximum allowable concentration (75 ppb) set by EPA, for the 8-hr standard. However, it cannot

be concluded that the concentration of ozone is harmful for the staff, since some errors (exposure of strips to sunlight, occasional cloud cover) during the implementation of the study have to be considered.

After the experiment, it was confirmed that photocopiers emit ozone, since ozone concentrations exceeded the present troposphere ozone concentration (34 ppb). All sites have exceeded this value, except for Site 2, wherein the highest concentration was only 24 ppb in the 8-hr exposure period. This was probably due to an error in obtaining the dew point temperature.

The standard deviations for each exposure period was high, indicating that there might have been errors during the implementation of the study. These errors may have been caused during measurement of dew point temperature and interpretation of color change in the Schoenbein paper, as well as during the correction of values, using the Schoenbein Number Chart.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

A. Summary

This study aims to confirm ozone emission from photocopiers and measure amount of ozone using the Schoenbein Paper method. Specifically, it aimed

1. To confirm ozone emission from photocopiers.

2. To measure the amount of ozone emitted by photocopiers, in parts per billion.

3. To compare the amount of ozone emitted under different exposure periods.

It was hypothesized that there was no significant difference in the amount of ozone emitted by photocopiers under different exposure periods.

This study was able to establish the following findings:

1. It was confirmed that photocopiers emit ozone.

2. There is a significant difference between the amount of ozone measured by the 1-hr and 8-hr standards.

3. There is a significant difference in the amount of ozone detected between Site 1 and Site 2, and between Site 2 and Site 3, but no significant difference between Site 1 and Site 3 (1-hr exposure).

4. There is a significant difference in the amount of ozone detected between the three sites (8-hr exposure).

5. In this study, it was found out that the recorded emitted ozone concentration is directly proportional to the exposure time (i.e., emitted ozone increases as exposure time increases).

6. It was also noted that in this study that varying conditions such as presence or absence of proper ventilation, frequency of use of photocopiers, etc. affect the recorded ozone concentration.

B. Conclusion

The results of the study confirm that photocopiers emit ozone.

There is a significant difference between the amount of ozone measured by the 1-hr and 8-hr standards.

There is a significant difference in the amount of ozone detected between the three sites (1-hr exposure).

There is a significant difference in the amount of ozone detected between the three sites (8-hr exposure).

Recorded emitted ozone concentration is directly proportional to the exposure time (i.e., emitted ozone increases as exposure time increases).

Varying conditions such as presence or absence of proper ventilation, frequency of use of photocopiers, etc. affect the recorded ozone concentration.

C. Recommendations

It is recommended that future studies be conducted in closed photocopying centers and a more accurate means of measuring ozone emission be used.

APPENDIX

Figure 3. Set up in WVSU Cooperative, February 9, 2009. (1-hr and 8-hr exposure)

Figure 4. Schoenbein paper strip after 8-hr exposure. (WVSU Cooperative, February 9, 2009)

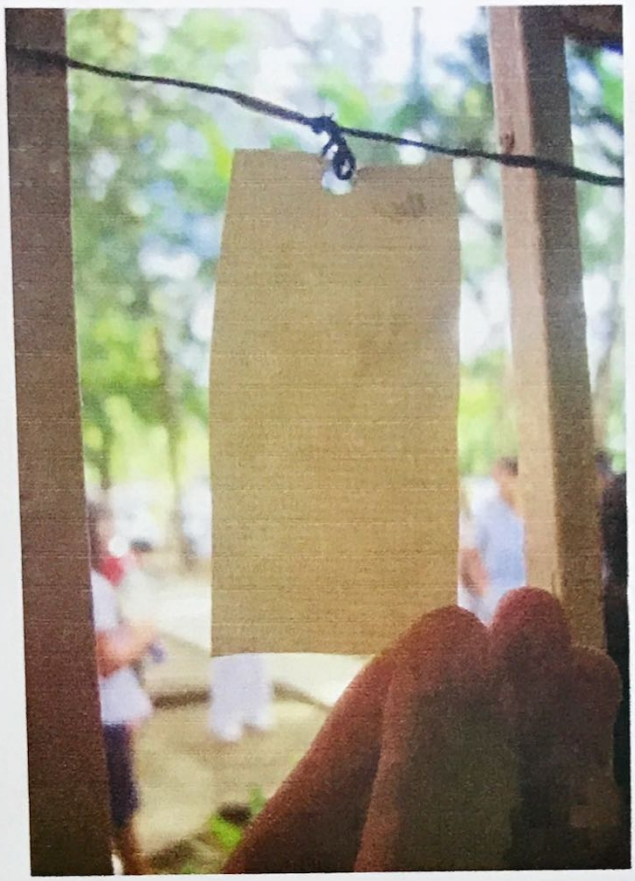


Figure 5. Schoenbein paper strip after 1-hr exposure period. (WVSU Cooperative, February 9, 2009)

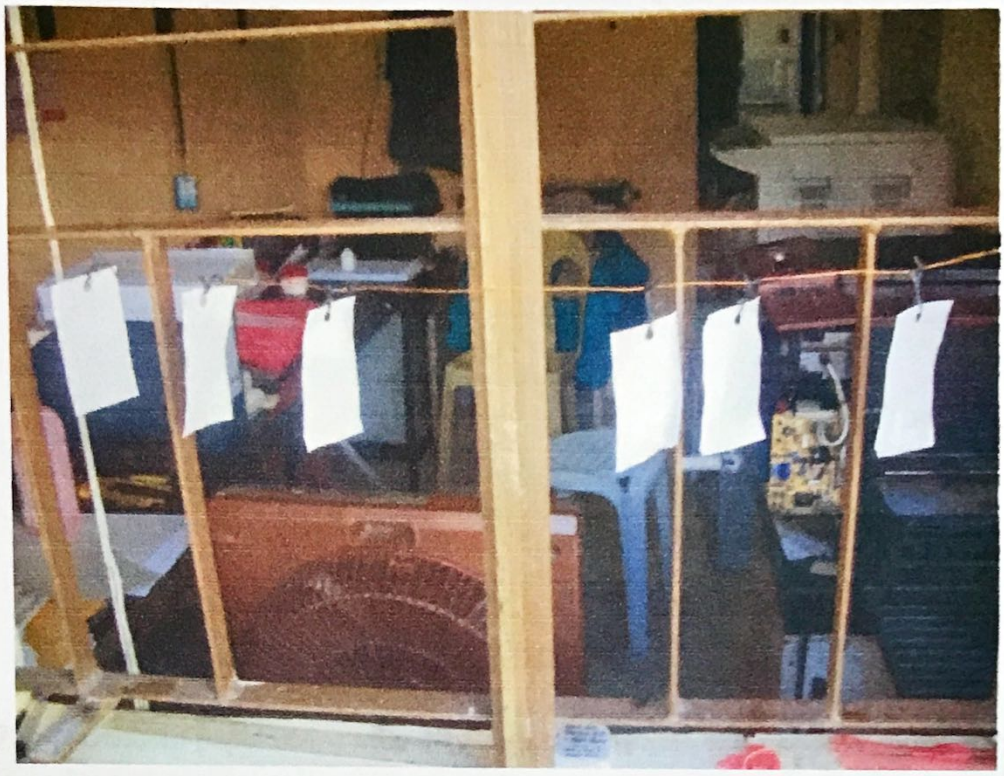


Figure 6. Set up in PSHSWV copying room, February 9, 2009. (1-hr and 8-hr exposure)

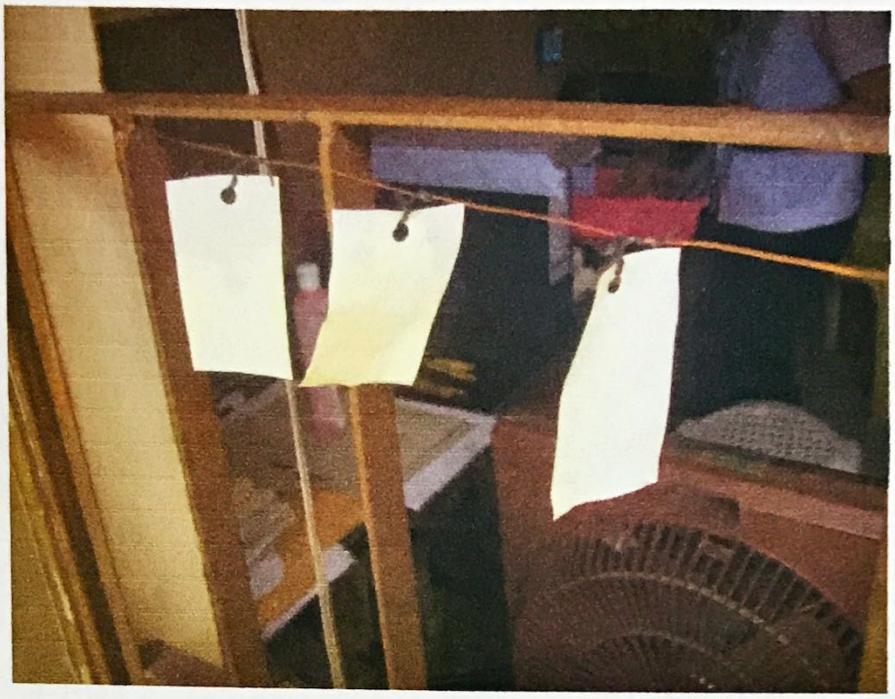


Figure 7. Schoenbein paper strips after 1-hr exposure. (PSHSWV copying room, February 9, 2009)

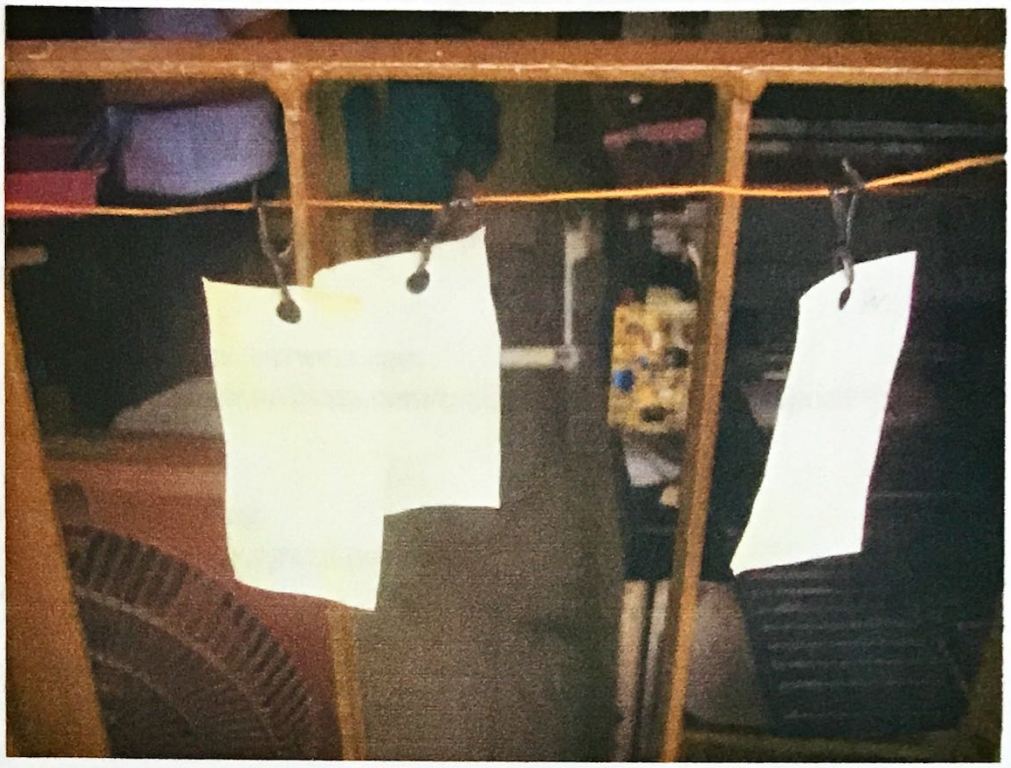


Figure 8. Schoenbein paper strips after 8-hr exposure. (PSHSWV copying room, February 9, 2009)

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