Tropospheric Ozone Pollution Investigation

I. Problem

How does the amount of traffic in different parts of my neighbourhood affect the tropospheric ozone level?

II. Hypothesis

Areas with more traffic have higher ozone present in the air. Tropospheric ozone formation occurs "primarily from photochemical reactions between two major classes of air pollutants, volatile organic compounds (VOC) and nitrogen oxides (NOx)". These chemicals are mainly released through motor vehicle exhaust and industrial emissions in urban areas. The photochemical reactions of NOx help create atomic oxygen which is reactive and combines with molecular oxygen, O_2, to form ozone (O_3) Therefore, if there is more traffic in an area, there are more exhaust fumes and so a higher level of ozone. A confounding variable here might be the type of vehicle, for example, a street that receives a lot of bus/truck traffic will likely have higher levels of ozone than a street within the same neighbourhood that receives mostly car traffic (this difference may be even more marked if these cars are newer models, as in a wealthy residential neighbourhood). However, this study will focus only on number of vehicles per unit of time.

III. Background

("The Diesel Con")

My interest in this topic comes from the brown haze that often covers Lima and how it makes my eyes itch and my asthma worsen. Ozone pollution is not unique to Lima but the geography and climate, combined with urbanization and high traffic, make tropospheric ozone pollution a significant local problem for the health of its residents. "The effects on the human respiratory system such as inflammation of the airways, decrements of lung function, coughing, throat irritation, and in the long term, potentially death". Ozone levels in Lima are described as "primarily due to the high number of aging cars and the oversupply of old, poorly maintained public transport vehicles". These old vehicles, which do not have catalytic converters to reduce levels of NOx in exhaust fumes, produce much more pollution than the modern cars found in more wealthy cities. Additionally, the age of cars may vary substantially from one neighbourhood to another. A report, issued by Airelimpio.org.pe, comparing the year 2000 with 2011indicates that there are decreases in almost all air pollutants being monitored, including ozone. However, the World Health Organization classifies Lima as the Latin American city with the worst air pollution. Moreover the same article notes significant differences between one area of Lima and another. Many cities in more economically developed countries have invested in public transport networks that use electric buses or trams that do not release polluting gases directly into the city environment. This makes their levels of pollution from vehicles lower. Nevertheless, pollution by tropospheric ozone can also be considered a global issue.

IV. Variables

Experimental variable	Named variable	Units (if applicable)	Equipment or procedure for measurement/control
Independent variable	Area: different places in my neighbourhood	Number of cars	Systematic sample: according to their variety in traffic – low to high.
Dependant variables	Ozone level	Schonbein Number	Colour of the ozone strip on Schonbein Number chart.
Controlled variables	Time ozone strips were exposed	Hours	Eight hours (for each area – three trials).
	Time for counting cars	Minutes	Number of cars passing the strips. Two minutes (for each area).
	Time and day strips were placed	Minutes	Due to climatic factors, strips were all tested on the same day.
	Exposure to sunlight/ozone	–	All the strips were placed in areas that received sunlight. Inside strips also received sunlight.
	Cornstarch and potassium iodide on each strip	Grams	The strips were dipped into the cornstarch and potassium iodide solution for five seconds.

V. Materials

- 5 g Cornstarch
- 7 g Potassium iodide
- 40 ml distilled water
- Plastic pipette
- 50 ml beaker
- 10 ml graduated cylinder
- Electric balance
- Tar dish
- Scoopula

- (1) 15 cm test tube
- Typing paper
- Ziploc bag
- Scissors
- Tape
- Computer (for humidity)
- Stopwatch
- Camera

I. Method

Making of strips

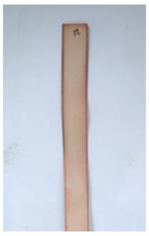
Risk assessment: Potassium iodide is a potentially hazardous chemical. Handle using protective latex gloves and wear a dust mask. “Class D2A causes skin and eye irritation. Harmful if inhaled or swallowed. Dust is irritating to respiratory tract. May cause teratogenicity effects. Can cause adverse reproductive effects.”

When the strips are placed outdoors they should be accompanied by a sign that indicates that they are part of an experiment and should not be handled.

1. A piece of white typing paper was cut into (21) 2.5 x 15 cm strips. The tips of these strips were then numbered from 1–21 (seven different variations, three trials each).

Strips of paper

2. Prepare ozone-measuring solution. Measure 6.5 g of potassium iodide into tar dish. Pour into a 15 cm test tube.
3. Dilute with 30 ml of distilled water poured into the test tube. Mix to dissolve potassium iodide into the water.
4. Measure 4.0 g of the cornstarch. Pour into the test tube with the potassium iodide solution and mix.
5. Dip the strips of paper into the solution for 5 seconds each and then set on a table to dry.
6. Once dry, place inside a sealed plastic Ziploc bag and store in the dark



Treated paper

Experiment

1. Visit each pre-decided location in the neighbourhood: kitchen; outside of apartment (residential street); post near stoplight; intersection after stoplight; post near shopping centre's main road; post near supermarket parking lot; post near residential street.

   These sites were chosen because they had different perceived levels of traffic.

Kitchen	None (control)
Outside of apartment (residential street)	Low
Post near stoplight	Medium
Intersection after stoplight	High
Post near shopping centre's main road	Medium
Post near supermarket parking lot	High
Post near residential street	Low

   Record time of each visit and take a picture.

2. Place three strips at eye level on a post/wall in the area using tape. Add a safety warning to passers-by not to touch the strips.
3. Record the number of cars that pass the post in a period of two minutes.
4. Repeat steps 1–3 for the seven different locations.
5. After eight hours revisit the seven locations, collect the strips and place in location-labelled Ziploc bags.
6. Photograph the strips immediately after collection in order to accurately show the colour changes.

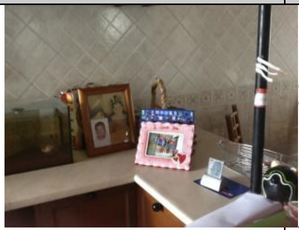
Example of a strip exposed to ozone pollution

VII. Data collection and processing

Table 1: Placement/collection times of the strips, traffic count and humidity.

Location	Time strips were placed (hour/minute)	Humidity (%)	Number of cars that passed in two minutes (vehicles)	Time strip was removed (hour/minute)	Total time exposed (hour/minute)	Observations
Kitchen	11:32	77	0	7:30	**7:58**	Location under a roof, but still exposed to sunlight.
Outside of apartment (residential street)	11:41	77	5	7:32	**7:51**	Location on the mountain curve; exposure to sunlight; in a residential area.
Post near stoplight	11:43	77	33	7:35	**7:52**	Place with lots of cars near a traffic light. (Varying traffic depending on the hour.)
Intersection after stoplight	11:52	77	19	7:42	**7:50**	Intersection near traffic light and residential area. Very sunny.
Post near shopping centre's main road	12:01	77	42	7: 47	**7:46**	Location with lots of cars. Sunny. Near a shopping mall.
Post near supermarket parking lot	12:14	77	17	7:56	**7:42**	Very sunny, right by the entrance of the supermarket parking lot.
Post near residential street	12:19	77	4	8:02	**7:43**	Relatively calm residential area near a supermarket.

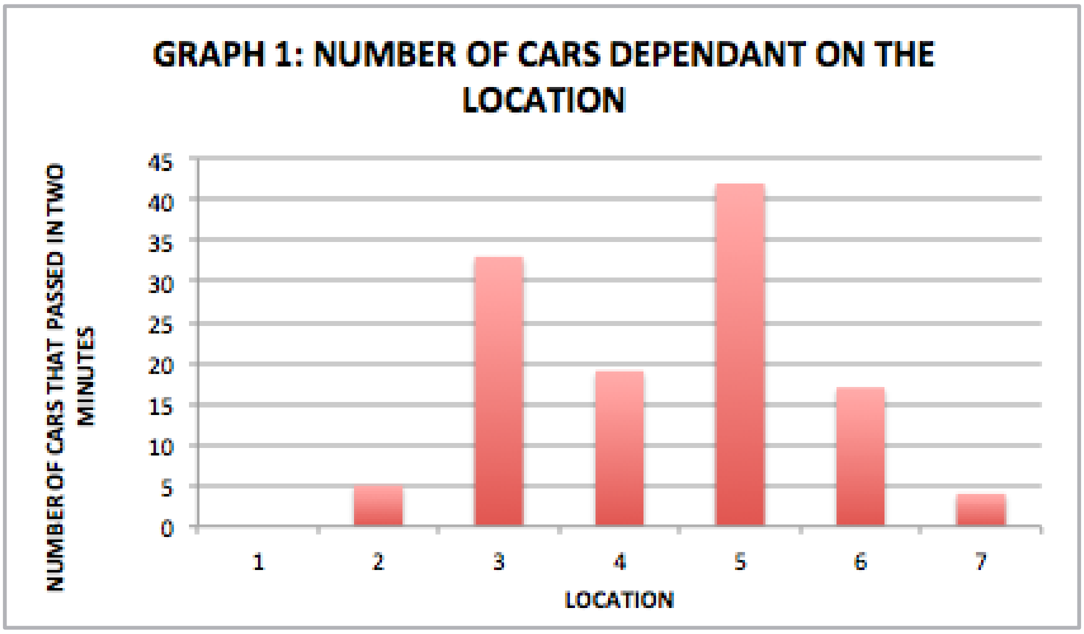
Table 2: Visual results of experiment

Variation	Area surrounding strip	Strip before exposure	Strip after eight hours of exposure
1 Kitchen			
2 Outside of apartment (residential street)			
3 Post near stoplight			
4 Intersection after stoplight			
5 Post near shopping centre's main road			
6 Post near supermarket parking lot			

7 Post near residential street			

VIII. Data presentation

Graph 1: Schonbein Number of the different locations

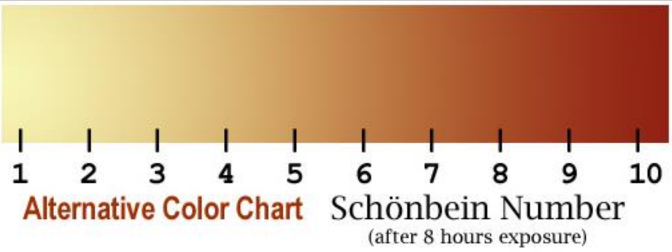


Description of graph
The graph above outlines the amount of traffic there was in the seven different areas chosen to analyse. From this graph, one can simply see how the areas picked were varied in their amounts of traffic, which is what was needed for this experiment in order to see a clear relationship in ozone levels and traffic.

Schonbein Number calculations

In order to see what areas had a larger level of ozone numerically, I translated the colour results to a number result by using the Schonbein Number colour chart. This was done visually (by eye), which definitely increases the uncertainty and level of inaccuracy in the experiment.

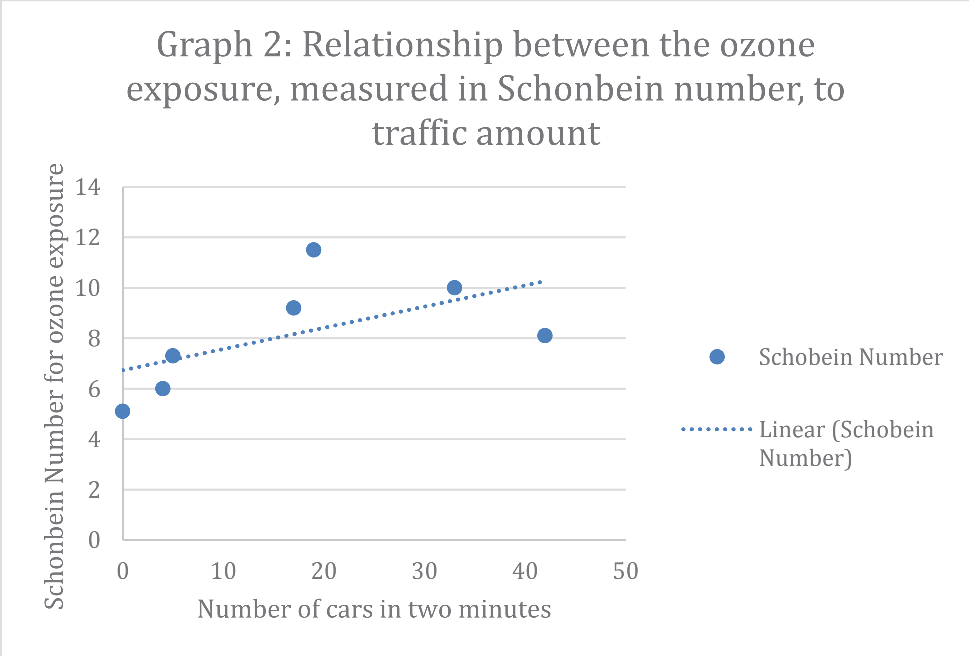
Table 3:



Location	Schonbein Number for each strip	Average Schonbein Number
Kitchen	5.1, 5.3, 4.9	5.1
Outside of apartment (residential street)	7.4, 7.3, 7.2	7.3
Post near stoplight	10.0, 10.0, 10.1	10.0
Intersection after stoplight	11.5, 11.4, 11.5	11.5
Post near shopping centre's main road	8.1, 8.1, 8.2	8.1
Post near supermarket parking lot	9.2, 9.3, 9.2	9.2
Post near residential street	5.8, 6.0, 6.2	6.0

Table 4: Schonbein Number in relation to the amount of traffic

Area	Amount of traffic (number of cars that passed in two minutes)	Average Schonbein Number
1 Kitchen	0	5.1
7 Post near residential street	4	6.0
2 Outside of apartment (residential street)	5	7.3
6 Post near supermarket parking lot	17	9.2
4 Intersection after stoplight	19	11.5
3 Post near stoplight	33	10.0
5 Post near shopping centre's main road	42	8.1



Description of graph
The graph above shows how the Schonbein Number is positively correlated to the number of cars in the areas. The relationship is not strong and there are fluctuations above and below the best-fit trend line. The use of three strips and an average Schonbein Number does strengthen the relationship seen.

Conclusion

From the data and results, we can conclude that my hypothesis was supported: as the number of cars increased, so did the Schonbein Number (ozone level), although the fluctuations show other uncontrolled factors may have an effect on the ozone levels. Analysing the data more closely, we can see how area 1, the kitchen, was the location with the lowest ozone level of 5.1 as expected and area 4, intersection after stoplight, was the one with the highest ozone level of 11.5. The results for the highest ozone level were surprising, as I expected that the area with more traffic, near the shopping centre, would have the highest level of ozone but it was 8.1. Looking more closely, I realized that area was not as close to moving traffic as the other areas, and perhaps this explains the lower Schonbein Number. This is supported in area 6, post near supermarket parking lot, with the third highest level of ozone, 9.2, which is right next to moving traffic. This relationship can be seen displayed through Table 4 and graph 2, which relate the traffic and respective ground-level ozone levels.

IX. Evaluation/discussion

Strengths of the investigation

The strips did have colour changes that were consistent within the same area but differed across the areas. This suggests the ozone-measuring solution worked.

The sample size of seven different locations was large enough in this investigation to help answer my research question.

Weaknesses and limitations of the investigation

Having seven test areas provided plenty of data, but it would have been better to cover a wider area of Lima city where patterns in traffic flow are different, to see if there were larger variations in the ozone levels. However, this would mean having more people involved in placing strips around the city at the same time.

I chose to use three strips at each location, but I could have improved the results by increasing this number. There are factors other than ozone that might change the colour of the strip (such as light intensity from the sun) and so I could have tried to ensure that all the strips were facing the same direction and not affected by shade from nearby buildings during the day. Ideally I should have ensured that each set of strips was also an equal distance away from traffic, but meeting all of these constraints might have made the study impossible to carry out.

A major concern was the measurement of the number of cars, which I was only able to do for two minutes. It would be better to count the cars over the entire eight hours, but the only way to manage this would be either to have more people involved, or to use video to record all the traffic. A reasonable improvement would be to count cars for a longer time period such as one hour in each area, although variations over time (due to rush hour, for example) and differences in the types of vehicles might still be missed.

Another weakness was the use of the Schonbein Number, which was a subjective judgment. This could have been improved by either asking several people to make the judgment, or by using a colorimeter to actually measure the light intensity going through the strips before and after exposure. Having more strips at each site would also have helped to reduce this weakness.

Improvements

- Sample over a wider area in the city.
- Gather more data on the number of cars passing, and also monitor the types of vehicle.
- Use more strips at each site.
- Ensure that the locations where the strips are attached are as similar as possible in every way (apart from the traffic flow).
- Use a colorimeter to measure the colour of the strips, or another accurate ozone sensor.

X. Application/solution

As the USAs Environmental Protection Agency (EPA) states “Reductions in air pollution can be achieved by a variety of methods including pollution prevention, control technologies, and control measures, and may be implemented through regulatory, market-based or voluntary programs”.

The difficulty of finding a solution is the inertia of the local community to change and any perceived costs involved. In my opinion there is no single solution, and a mixture of community initiatives and local government incentives would work best. Technologies do exist to reduce NOx emissions (such as catalytic convertors), but it is unlikely that trying to enforce the introduction of these would help, as there would be prohibitive economic consequences. Instead, I suggest “ozone action days” once a month to encourage people to drive less and become smart drivers. Creating a leaflet with tips to clean up your dirty engine by changing how you idle would help inform the population. The city council could also collect and publish information about the ozone levels to help people be aware of the risks they face, at the same time as offering subsidies for using public transport on these action days. These changes should encourage the local residents to act, and so see the ozone levels in high traffic areas of Lima decline.

Word count: approx. 2200

XI. Bibliography

Airelimpio: http://www.airelimpio.org.pe/pdf/II-Estudio-de-Saturacion-de-Calidad-del-Aire-en-Lima-Callao.pdf

“Health Effects of Ozone in the General Population”. Environmental Protection Agency. Web. 25 May 2013. http://www.epa.gov/apti/ozonehealth/population.html

Material Safety Data Sheet: http://www.pestell.com/msds/Potassium%20Iodide%20MSDS.pdf

“Ozone Reduction Strategies – Tips to Reduce Ozone”. Environmental Protection Agency. 11 Jan. 2012. Web. 25 May 2013. http://www.epa.gov/airquality/ozonestrategy/tips.html

Peru21: http://peru21.pe/actualidad/oms-lima-tiene-aire-mas-contaminado-america-latina-2182172

“The Air We Breathe”. Chemistryland. 4 April 2008. Web. 25 May 2013. http://www.chemistryland.com/CHM107Lab/Exp03_DetectOzone/OzoneLab/OzoneLab.htm

“The Diesel Con” photograph. Zeronation. Web. 27 May 2013. http://www.zeronation.co.uk/wp-content/uploads/2014/05/38261905_carexhaust3001.jpg

“Tropospheric Ozone”. ScienceDaily. Web. 27 May. 2013. http://www.sciencedaily.com/articles/t/tropospheric_ozone.htm

"What is an Ozone Action Day?" Department of Energy and Environmental Protection. State of Connecticut. Web. 25 May 2013. http://www.ct.gov/deep/cwp/view.asp?a=2684&q=321800&depNav_GID=1744

"What is Ozone?" Environmental Protection Agency. Web. 25 May 2013. http://www.epa.gov/apti/ozonehealth/what.html

"World Meteorological Organization: air pollution severe in South American cities like Lima." Peruvian Times. 23. Mar. 2009. Web. 25 May 2013. http://www.peruviantimes.com/23/world-meteorological-organization-air-pollution-severe-in-south-american-cities-like-lima/2307/