Ozone Levels in Southern Indiana

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WHAT IS OZONE?

Ozone is a gas composed of three oxygen atoms (O_3). Ozone occurs naturally in the upper atmosphere, known as the stratosphere, in low concentration. One form of pollution in the lower atmosphere is ozone. The phrase "Good up high; Bad nearby" is commonly heard and refers to the fact that ozone is good in upper atmosphere and bad in the lower atmosphere. Ozone depletion up high and pollution down low have become popular topics in environmental health today.

Naturally occurring stratosphere ozone (O_3) prevents UV radiation emitted by the sun from reaching Earth's surface. The formation of ozone in this region of the atmosphere begins with the photodissociation of oxygen molecules by solar radiation at wavelengths below 240nm. After the dissociation of the oxygen molecules, the oxygen atoms combine with oxygen molecules and other inert molecules in the air to form ozone. The problem comes in to play when the upper atmospheric ozone begins to dissociate allowing UV radiation to reach earth's surface. This occurs when ozone dissociates into oxygen molecules and oxygen atoms. These three reactions can be seen below:

$$\mathbf{O_2 + h\nu\ (\lambda<240nm) \rightarrow O + O}$$

$$\mathbf{O + O_2 + M \rightarrow O_3 + M}\ (\text{M is some inert substance such as } N_2)$$

$$\mathbf{O_3 \rightarrow O + O_2}$$

This natural ozone layer is very thin. It is estimated that if all the natural ozone gas were compressed against the Earth the layer would only be about 3 mm thick. Although ozone concentration is very small, its purpose is essential for life as it serves as a protective shield against UV radiation, which can induce skin cancer, cause genetic mutations, and destroy crops and other vegetative forms. Hence, natural ozone in the stratosphere is the "good" ozone.

The "bad" ozone is found near Earth in the troposphere because of the rising level of pollution. The ozone layer present near Earth's surface is created by chemical reactions between oxides of nitrogen (NO_x) and volatile organic compounds (VOC) in the presence of sunlight. Natural O_2 molecules do not contribute to the formation of ozone as a wavelength of approximately 240nm is required to break an oxygen-oxygen bond into oxygen radicals. Only wavelengths of light greater than 350nm reach near Earth's surface though. Therefore, NO_2 serves as the perfect ingredient to provide oxygen radicals in the formation of low-atmosphere ozone because NO_2 is the only atmospheric molecule with a bond that is weak enough to be broken by wavelengths of light in the troposphere. A wavelength of approximately 400nm is sufficient to break the N-O bond in NO_2 molecules. After NO_2 molecules are broken apart into NO and O atoms, which yield ozone, VOC's act to essentially restart the process resulting in more NO_2 molecules floating around the atmosphere.

NO_2 + hv (wavelength<400nm) → NO + O

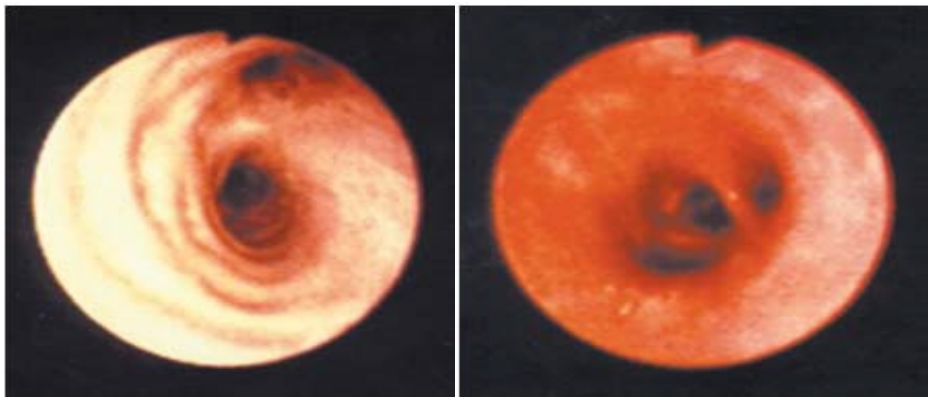
$O + O_2 + M \rightarrow O_3 + M$

NO + ROO → RO + NO_2

Plenty of NO_2 and VOC's are being emitted to the atmosphere today. Some of the major sources of NO_x and VOC's are emitted from industrial facilities, electric facilities, exhaust from motorized vehicles, gasoline vapors, etc. It is estimated that motor vehicles supply the largest contribution of NOx to the atmosphere. Roughly 56% of all NOx is believed to come from this exhaust. Similarly, approximately 50% of all VOC's are believed to come from industrial facilities alone.

EFFECTS OF OZONE

The most negative effects caused by ozone in the troposphere are seen in people's lungs. Ozone can influence the lung's lining, and repeated episodes of inflammation may cause permanent changes in the lung. Chest pain, coughing, throat irritation, and congestion are all effects of the presences of ozone in the lower atmosphere and can be illustrated in the images below. Bronchitis, emphysema, and asthma may become problematic to the average healthy person. In addition to affecting humans and other animals, ozone has begun to greatly alter vegetative life and the ecosystem. Agricultural crop yield has greatly been reduced in recent years and it is estimated that $500 million of crop production has been lost annually. A lot of vegetative life becomes much more susceptible to pests and disease with the presence of ozone. Forests, National Parks, and other natural habitats are shrinking with the rapidly rising ozone presence.



Healthy Lung Airway **Inflamed Lung Airway**

OZONE LEVELS IN RURAL BLOOMINGTON

With the production of much more NO_2 and VOC's in urban environments, ozone levels may be extremely high in urban areas. However, high ozone levels are not limited to cities and Ozone Action Days may be declared. Ozone Action Days are observed at certain times during the summer months when the weather conditions (such as heat, humidity, air stagnation) run the risk of causing health problems. Ozone can quickly travel to rural areas, maybe hundreds of miles away, by being blown by natural winds. This is apparent in many rural areas of the country and is evident right here in southern Indiana. The U.S. Environmental Protection Agency (EPA) has established 80 ppb of ozone exposure over eight hours as the National Ambient Air Quality Standard. While the ozone levels in Bloomington during the month of August did not consistently average a concentration over this 80 ppb mark, the readings did hit this mark on regularity.

This reports intention is to display and describe the ozone concentration levels in Bloomington in the month of August. By use of plots and graphs, looking at precipitation, temperature, ozone concentration throughout the day, and number of days spent at air quality index values throughout the month, conclusions about Bloomington ozone levels can be made.

Figure 1 below shows that the ozone levels typically reached the National Ambient Air Quality Standard around 11:30am and dipped back under the standard around 4:30pm – roughly five hours at or above the standard. As seen in the graph, the lowest ozone concentration seems to occur in the early morning around 4-6AM while the levels of highest ozone concentration are seen from 12-4PM. Since mornings are cloudier, colder, and less sunny than other parts of the day, sunlight isn't able to enter the lower atmosphere as frequently to create reactions leading to the formation of ozone. Around noon, direct sunlight and lower UV wavelengths enter through the clouds at a higher rate causing the ozone concentration in the lower atmosphere to rise drastically.

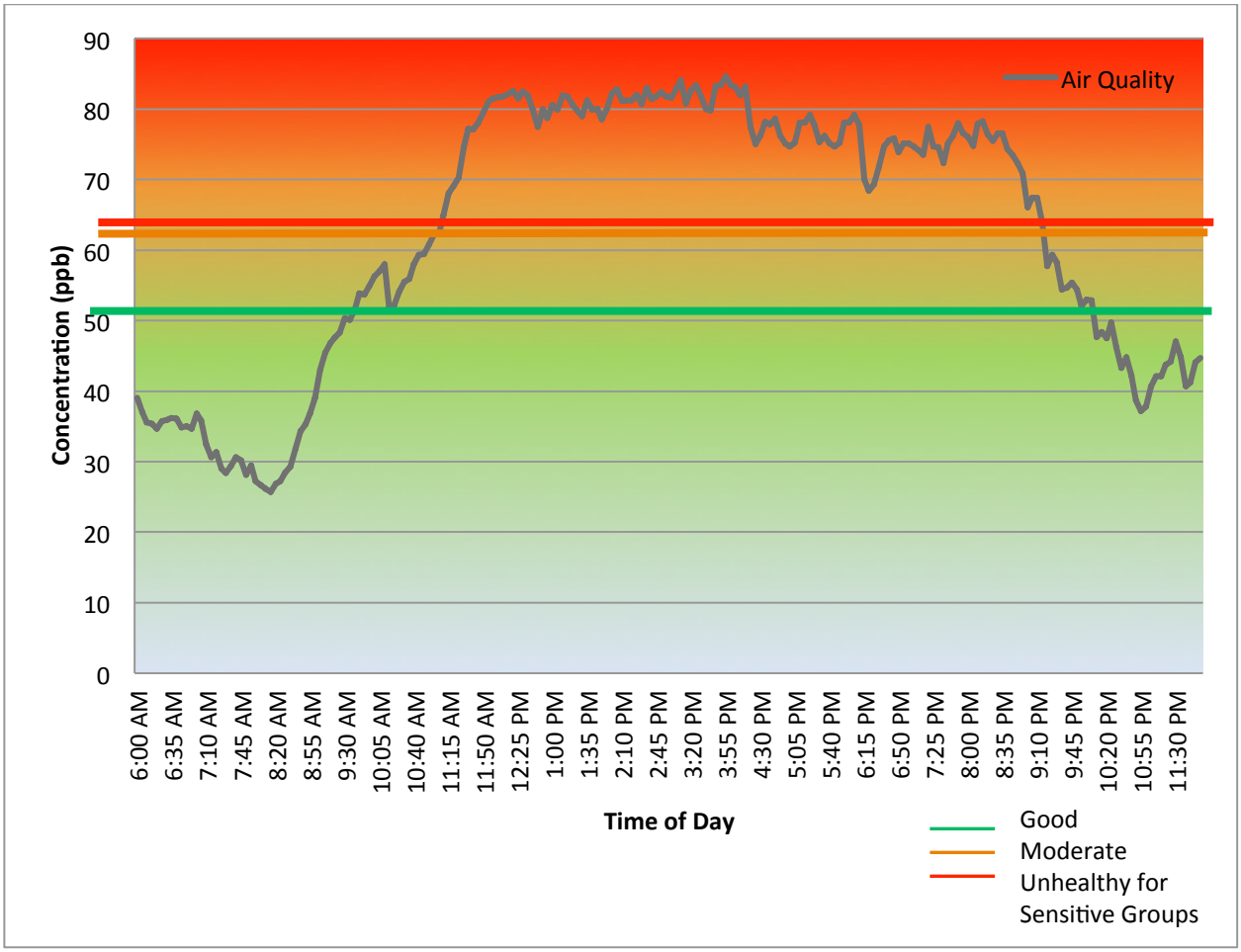


Figure 1: Time Profile for Ozone on a Hot, Sunny Day. The green zone indicates "Good" air quality and falls within the range of 0-59ppb over an 8 hour average. The orange zone indicates "Moderate" air quality and falls within the range of 60-74ppb. Red represents "Unhealthy for sensitive" groups and falls within the range of 76-95ppb.

The ozone concentrations measured in August may be relatively high compared to other months of the year in Bloomington. Summer months allow higher temperatures and more sunlight, which is a piece of the recipe for an increase in ozone pollution. In addition, fuels are known to volatilize faster in warmer conditions, therefore more VOC's will be present in the atmosphere. And lastly, hotter temperatures cause engines to run leaner, emitting slightly more NO_x into the air. The typically warm month of August allowed us to analyze a correlation between ozone concentrations and temperature as shown in Figure 2 below.

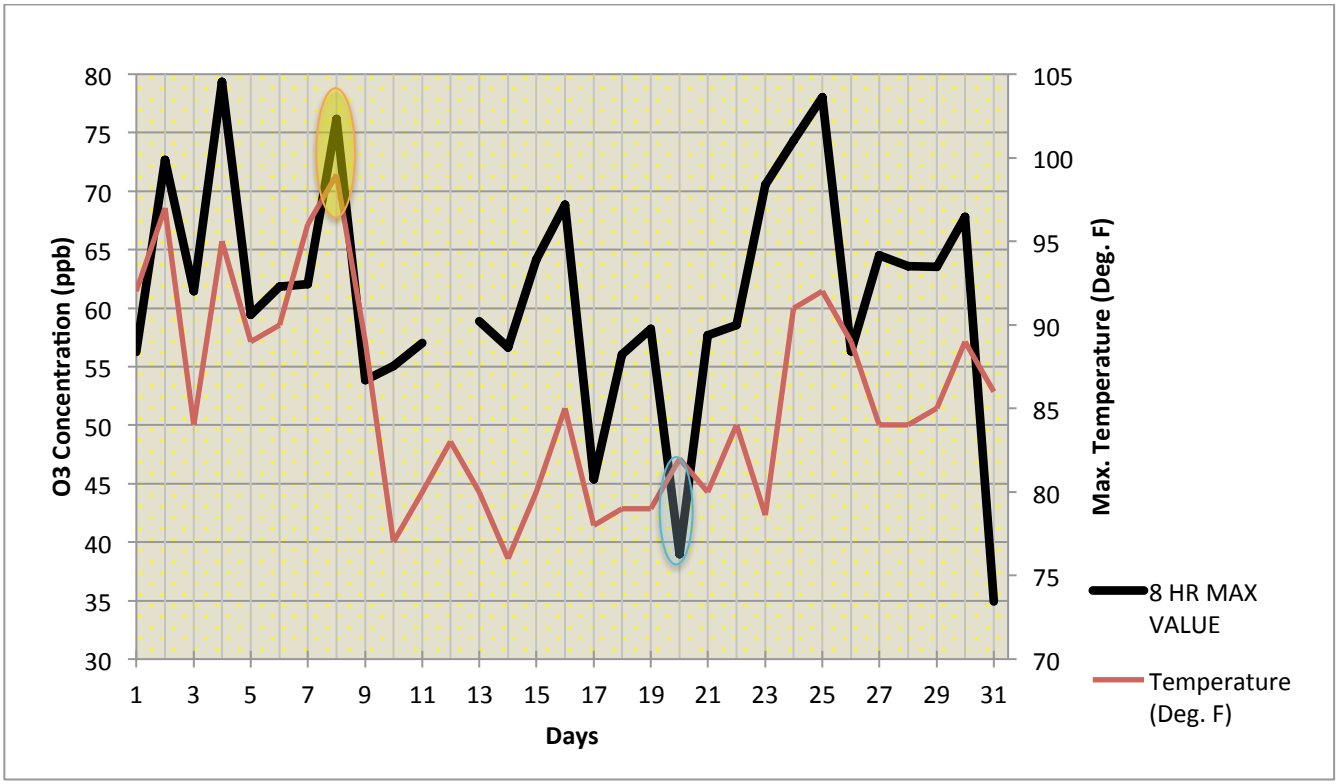


Figure 2: Relationship Between Max Temperature and 8-Hour Ozone Levels. A definite correlation with high temperatures and high ozone levels can be seen during August. A high temp./ozone correlation can be seen clearly indicated by the yellow oval, and a low temp./ozone correlation can be seen clearly by the blue oval.

Figure 3 below demonstrates the correlation between high temperatures and ozone levels. Although this plot shows a rather low R^2 value, there is a vividly apparent relationship between temperature and ozone levels that can be seen in Figure 2. The reason for a low R^2 value could be from a variety of other factors, such as cloud cover, precipitation, traffic levels, and blowing winds from neighboring urban areas.

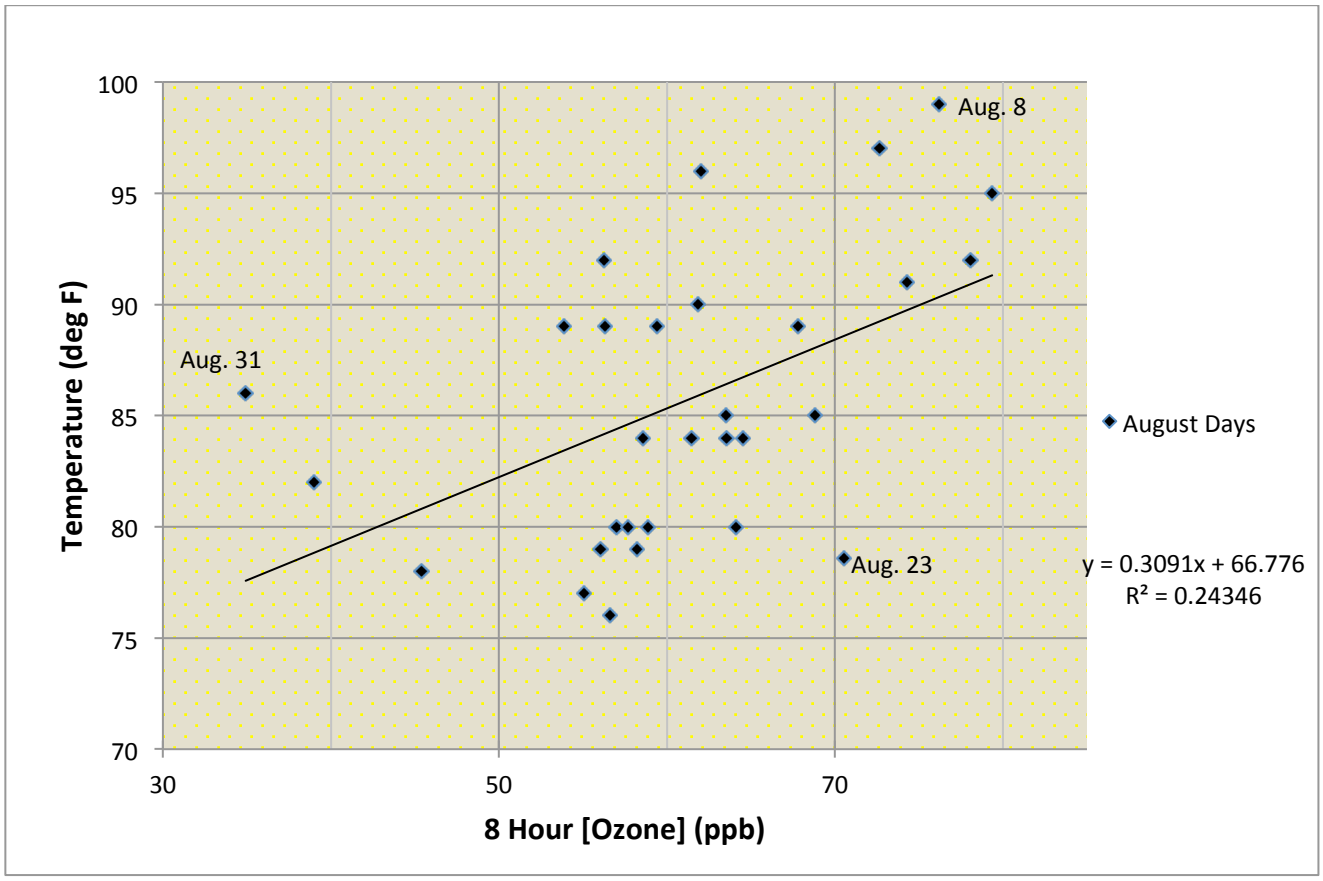


Figure 3: Correlation Between Maximum Temperature and Ozone Levels. Each data point represents an August day in Bloomington. By plotting Temperatuer versus [Ozone], a correlation between the two could be made. From this graph, a weak positive correlation is shown, although temperature is not the only factor in ozone pollution.

There is also a significant (although less significant) correlation between rainfall and ozone levels as shown in Figure 4 below. The graph suggests the more rainfall, the lower the ozone concentration the day of and even the day after the rainfall. A simple hypothesis for this correlation is that rainfall is brought on by cloudy skies. The more cloud cover there is in the sky, the less sunlight there is to reach Earth's surface. Therefore, lower sunlight levels lead to less intense production of ozone.

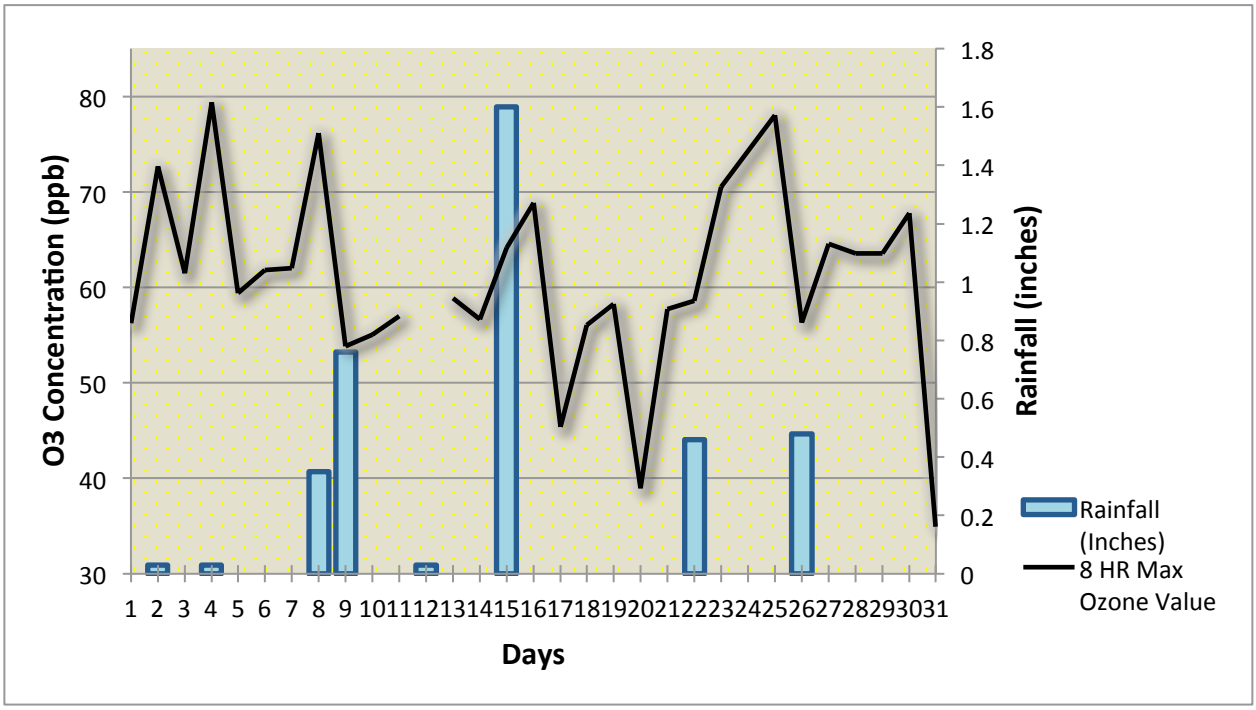


Figure 4- Rainfall's Effect on [O3] in August: An analysis of the relationship between rainfall and 8-hour ozone levels. As illustrated, lower levels of ozone can occur on days where precipitation is prevalent, although other factors, such as temperature, may be at play.

When considering Figure 5 below, it can be seen that ozone levels in Bloomington in general are fairly safe. Only during four days of the month of August are ozone levels over an 8 hour period actually considered unsafe to sensitive people. This may affect people such as those with respiratory conditions like asthma and emphysema. However, the graph also shows that the majority of the days during August had ozone levels which were safe according to EPA standards.

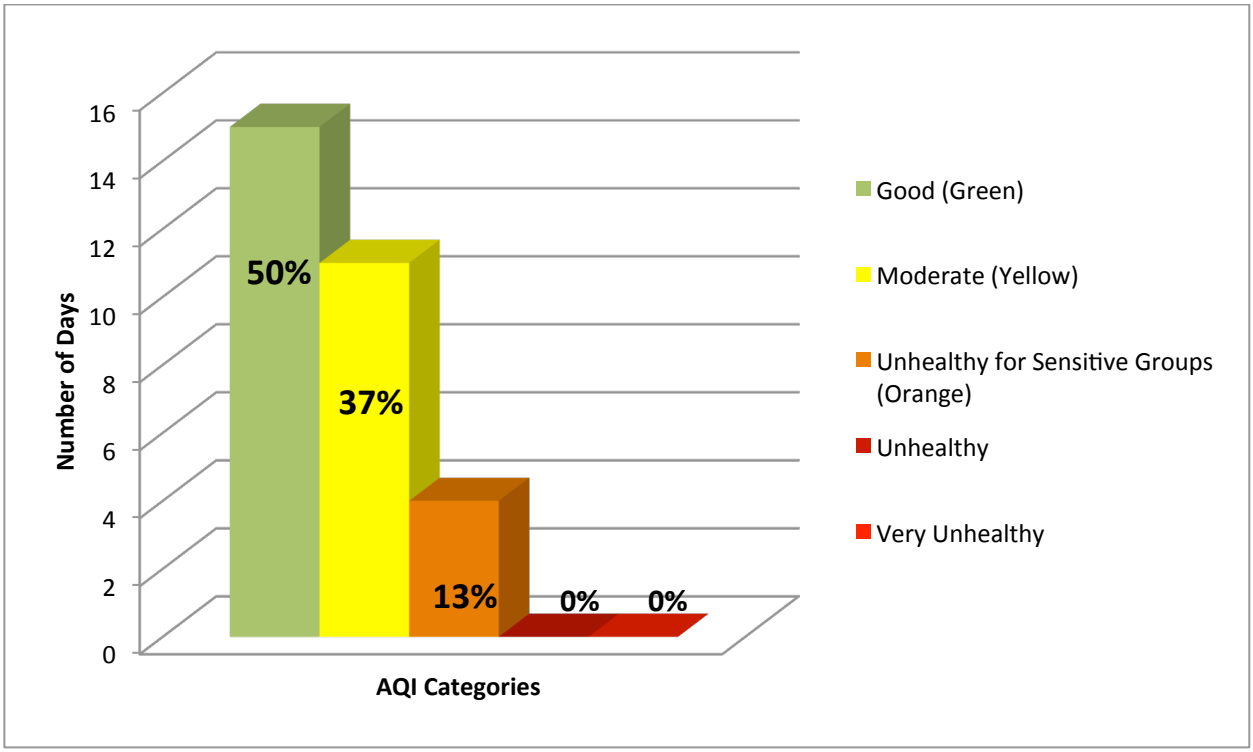


Figure 5 - Number of Days at Various Air Quality Index Categories: An analysis of the Air Quality and Health Concerns by Local Residents.

Recommendations for Bloomington Citizens

Given that August is the hottest month of the year, ozone can be seen at especially high levels. Although only three days during August had ozone levels which can be considered unsafe, those unsafe levels do have health effects which might be avoidable. Knowing that one of the biggest causes of ozone pollution is tailpipe emissions from automobile traffic, we as a city of Bloomington should find ways to cut down on automobile traffic. For example, a simple three mile trip from the east to the west side of Bloomington involves a significant amount of construction and traffic. This traffic leads to not only more time spent in the car, but also more tailpipe emissions from our cars. Sharing rides is an easy way to cut down on traffic and therefore fuel emissions.

A hot topic in Bloomington right now is the possibility of the extension of I-69 from Indianapolis through Bloomington. If the extension of I-69 did happen it can be inferred that the increase in commercial traffic would have a negative effect on our ozone levels. To ensure

ozone levels in Bloomington remain at relatively healthy levels, our citizens can take further certain precautionary measures. We can limit engine idling, refuel our automobiles after dusk, call ahead for directions, conserve electricity, and use household garden and workshop chemicals in ways which keep evaporation to a minimum.

Work Cited

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