A Teaching Module on Ozone as an Air Pollutant and its Effects on Plants

Since many universities and colleges offer limited environmental courses designed to educate students about air pollution during the summer (the height of the “bad” air quality season in the US) and because there are no known programs that teach air pollution effects on vegetation in an interactive manner, we developed a teaching module using ozone as the example air pollutant (and its effects on plants). This module is available for download on the web and can be inserted into preexisting courses, serve as a foundation for mini-courses, or sections of it used as individual lectures or exercises. Within the module is a unique exercise where students compare time-lapse photographs, illustrating the onset of ozone injury on plants recorded during a summer, with the ozone data collected during symptom development. This allows the students to relate the severity of the ozone-induced symptoms with the ambient ozone levels.

Ground Level Ozone as an Air Pollutant
Ground level or tropospheric ozone is a major air pollutant in many industrial areas around the world affecting the human health, environment, and the economies of many countries. Ozone is one of the criteria pollutants designated by the Clean Air Act of 1970 to be monitored across the US to determine the safety of the air for human and ecosystem health. The ozone season, when the highest ozone levels occur and cause the greatest amount of concern to human health and vegetation injury, is typically mid-April through late October in much of the US. Human health problems associated with ozone pollution include coughing, congestion, chest pain, and throat irritation; and ozone can worsen respiratory diseases such as asthma, bronchitis, and emphysema. Elevated levels of ozone often experienced during the ozone season can cause damage to trees, agricultural crops, and other vegetation. Symptoms of plant injury due to ozone include leaf stipple, chlorotic mottle, tip burn, late season leaf yellowing, premature defoliation, and decreased crop yields.

Development of the Ozone Damage on Plants Exercise
Since plant damage from ozone in the landscape occurs during the summer when most agricultural and environmental courses are not being taught, we developed an exercise (entitled Environmental Crime Scene Investigation) using time-lapse photographs of the onset and development of ozone-induced injury on plants. We also supplied the recorded ozone levels during the time when the photographs were taken. This allowed the students during their regular semester courses to establish relationships between leaf injury and ambient ozone levels.

Photographs of ozone-induced leaf injury were taken for five ozone-sensitive forest and agricultural species located at the Air Quality Learning and Demonstration Center (located on the Penn State campus) during a recent ozone season. The plant species photographed (common milkweed, black cherry, yellow poplar, Chambourcin grapes, and tobacco) had been previously shown to be sensitive to summer ambient levels of ozone in central Pennsylvania. A Pennsylvania Department of Environmental Protection air quality monitoring station, located at the Learning Center, collected weather data (temperature, wind speed and direction, solar radiation, relative humidity, precipitation, soil moisture, and visibility) on a daily basis and monitored air pollution concentrations for nitrogen dioxide (NO_2), nitrogen oxides (NO_x), carbon dioxide (CO_2), carbon monoxide (CO), particulate matter (PM_{10} and $PM_{2.5}$), and ozone (O_3). The air pollution data are collected as mandated by the Clean Air Acts and are reviewed the by US Environmental Protection Agency.

After analyzing the photographs for onset and development of visible ozone injury on the leaves (Figure 1), the air pollution data (Figure 2) were examined to determine if high levels of ozone pollution were present immediately prior to the dates when symptoms occurred, or if the injury was the related to low chronic concentration over an extended period of time. Since other environmental factors can have an effect on how much or when symptoms occur, select weather data were also evaluated.

The Development of the Ozone Teaching Module

A larger more comprehensive ozone teaching module that incorporated the in class activity was then developed. The purpose of the module was to educate students regarding ground level ozone pollution. The length of the ozone module is approximately three hours; however it includes several individual portions that could be taught as smaller segments. The contents of the module include an overview; two power point presentations, both containing 38 slides; a homework assignment; an in-class activity; a quiz to test the students before and after completing the module; and an answer key for both the in class activity and quiz.

The first power point presentation in this module provides an overview of ground-level ozone, how the pollutant is formed and transported, and the importance of ozone to human and environmental health. The second power point presentation focuses on how ozone pollution affects vegetation. Both power point presentations contain several photographs, charts, animations, graphs and activities as to keep the students engaged and cater to all learning type techniques. For the benefit of the educators who use the module, important information and suggestions to assist in presenting the information are written in the notes section under each slide in the power point presentations.

The next section of the module is the in class exercise that was developed utilizing the photographs and real-time weather and air pollution data. The purpose of this activity is to allow the students to use the knowledge that they gained during the power point presentations to better understand the environmental impacts of ozone pollution. By the end of this exercise the students should be able to determine the connection between the plant injury and ozone levels when shown photographs and weather and air pollution data. The format of the module exercise is a word document so new sets of photographs and weather data can be easily inserted to maintain the module updated with current information.

Testing the Module

After the module was developed, it was presented to students (n=16) in the Agricultural and Extension Education (AEE) 313 course at Penn State University. The students in this course were pre-service student teachers about to begin their student teaching term. A 15 question, multiple-choice quiz was used to determine the individuals' knowledge on the subject matter prior to being presented the information in the teaching module. Following the quiz, the class was presented with the first power point presentation, followed by a short break, the second power point presentation, and then the in-class activity, during which the students were allowed to work in groups. At the completion of the activity, answers were discussed as a class and any last-minute questions were answered. To test the effectiveness of the module and for statistical purposes, the students were given a post-module quiz that was identical to the pre-module quiz. A paired t-test was conducted on pre- and post-module quiz results to determine the effectiveness of the teaching module.

The results of the paired t-test indicated that the confidence interval {95% CI for mean difference: (-7.60444, -5.27056)} for the mean difference between the two quizzes did not include zero, which suggests a difference between them. The small p-value (p=0.000) further suggests that the data are inconsistent with the Null Hypothesis (The mean difference between the two quizzes will be equal to zero), which means that there is a difference between the mean values for the two quizzes. Specifically, participants did better on the post-quiz (mean = 13.06) than on the pre-quiz (mean = 6.63). Thirteen out of the 16 participants received over 80% on the post-quiz, whereas none of the sixteen participants received over 80% on the pre-quiz.

Several of the AEE 313 students who were presented with the module, expressed interest in using it during their student teaching term and feedback was received from three of these individuals. One student teacher used the module in a plant science class containing 23 students. Feedback from this teacher was "…the students did enjoy it and found the information surprising and interesting…they really thought it was neat that they could check the ozone level in their area and see surrounding areas". The second teacher who provided feedback was using the module in his/her greenhouse class, consisting of 28 students. Unfortunately, due to the structure of the class the student teacher was not able to present the module all at one time but instead in 15-minute increments. Therefore, this individual could not provide much detail on the students' reaction to the module. The third individual who provided feedback

taught the module during a plant physiology portion of their class, which contained eight students. This student teacher said about the module, "…it not only tied everything I taught in the unit together, it allowed students to learn about the effect of ozone on these plant processes. The students really enjoyed the links to the internet and all the graphics". However, this teacher also mentioned that the students didn't do very well on the quiz, which she found confusing, considering the students interest in the subject matter. Although some feedback was negative, the majority was positive and provided further evidence that the ozone module can be successfully incorporated into high school curricula.

Availability of Teaching Module onto the Internet

The module is available for download at various public websites including the Pennsylvania Department of Environmental Protection (http://www.portal.state.pa.us/portal/server.pt/community/curriculum_class_activities/13906) and Penn State University (http://www.personal.psu.edu/drd10/Ozone_Learning_module/Ozone_Pollution_Teaching_Module.html). It is envisioned that the module could also be used as an outreach tool for public and private institutions.

Submitted by:

Sabrina Chrzanowski Haydt, Donald D. Davis, Tracy Hoover, and Dennis R. Decoteau (drd10@psu.edu)
Departments of Horticulture, Plant Pathology, and Agricultural and Extension Education and the Penn State Institutes of the Environment and Energy
Penn State University