

Developing a Volunteer Air Monitoring Program for Diesel Exhaust Particulate Matter

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Abstract

A recent study showed that several relatively rural Pennsylvania counties ranked among the top ten areas nationwide for air pollution residents were understandably worried. In Carlisle, Pennsylvania, in Cumberland County, residents were concerned about the high concentrations of air pollution from the many large diesel truck depots and truck stops in the area. Diesel exhaust contains high concentrations of particulate matter, which is harmful to human health. Furthermore, this pollution tends to concentrate in areas with heavy truck traffic. Because diesel exhaust pollution is concentrated in only a small area, it may not be detected by ambient air monitoring stations. This concerned a local environmental group, the Central Pennsylvania Clean Air Board, and they have begun work to establish an air monitoring program in areas with heavy truck traffic. This report outlines two strategies for volunteer air monitoring: the “bucket brigade” monitoring program and the use of a continuous air monitoring machine. Both could be used in the development of a volunteer monitoring program, which would both empower and educate community members about their local air quality.

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Introduction

After several counties in Pennsylvania were listed in the top ten areas nationwide for high levels of particulate matter, residents began to express concern over their local air quality (PennEnvironment 2006). A group of concerned citizens, physicians, and religious leaders in Carlisle Pennsylvania decided to form a citizen's group to raise awareness about the problems of air pollution (Blymire 2005). This group, the Clean Air Board of Central Pennsylvania (CAB), drafted a resolution supporting clean air initiatives in Cumberland County signed by local religious leaders. A pollutant of particular concern in this resolution was particulate matter, especially from diesel engines.

An area of Middlesex Township known as the "Miracle Mile" contains a mile-long stretch of Route 11 connecting the major thruways of Interstates 76 and 81 (Figure 1).



Figure 1. A map of Middlesex Township showing the intersections of Rt. 81 (blue), Rt. 11 (red), and Rt. 76 (green) (Pennsylvania Department of Transportation 2004).

This creates a hotspot of diesel truck traffic, concentrating the pollution from many heavy-duty diesel engines in a small area. A study of toll booth workers in Taiwan found that ambient air particulate concentration was much higher in the truck and bus lanes than in lanes marked for cars only. During an average eight-hour shift workers were exposed to levels of particulate matter much greater than the legal limit (Lai *et al.* 2004). Heavy truck traffic in this area contributes to air pollution problems in Cumberland County, and many residents are concerned about the health effects of particulate matter pollution from diesel engines (Joyce 2006). In a paid advertisement in a local Cumberland County newspaper, more than 100 area physicians signed a letter citing truck traffic as a contributor to poor air quality, emphasizing that “fine particle pollution from diesel exhaust is...astronomical along the ‘Miracle Mile’ in Middlesex Township” (Blymire 2005). In addition, these high concentrations of large diesel trucks in a small area can contribute to traffic congestion. More cars idling in traffic jams only further increases the ambient concentrations of exhaust gases, exacerbating the original problem of diesel exhaust pollution.

In 2004 the PennEnvironment Research and Policy Center, a nonprofit environmental research and education organization affiliated with the Public Interest Research Group, conducted a study to analyze data from the U.S. Environmental Protection Agency (EPA) on chronic particulate matter air pollution in communities and states across the country (PennEnvironment 2006). Many of the areas were not in attainment of EPA’s clean air standards for fine particulate matter pollution. Among the top ten worst airsheds for chronic particulate matter in mid-sized urban areas were four counties in central Pennsylvania: Lancaster (5th), York-Hanover (6th), Harrisburg-Carlisle

(9th), and Reading (10th). Furthermore, two other Pennsylvania cities, Philadelphia and Pittsburgh, ranked in the top 20 worst areas for large urban centers. Overall, Pennsylvania was ranked second overall among states for the highest chronic particulate matter pollution, and California was ranked first (PennEnvironment 2006).

Particulate matter pollution in Pennsylvania is produced by two major sources: coal-fired power plants and diesel engines (PennEnvironment 2006). Particulate matter that is smaller than 2.5 micrograms in size (PM_{2.5}) is especially dangerous to human health because it is small enough to penetrate lung tissues when inhaled and directly enter the bloodstream. Particulate matter formed by burning coal or diesel fuel contains heavy metals, which were present in the fuel before it was burned. Airborne particulates may also pick up heavy metals such as iron, lead, or copper from industry or vehicles (Fang *et al.* 2005). Ultrafine particulate matter has a high ratio of surface area to mass, because of its small size, and this maximizes the amount of toxic pollutants that can accumulate on the particle surface (Lai *et al.* 2004). When ultrafine particles enter the lungs and bloodstream, they carry these harmful metals into the body (Fang *et al.* 2005). However, there have been few studies on the health effects of long-term exposure to elevated levels of particulate matter from diesel engines. Furthermore, measuring the direct long-term exposure of people who work in areas of high PM_{2.5} is expensive and time-consuming.

Pennsylvania now requires all heavy-duty trucks, beginning with the 2005 model year, to meet California Air Resource Board (CARB) standards for emissions (Pennsylvania Department of Environmental Protection 2002). Before this regulation, the majority of diesel engines were fitted with diesel emissions control devices that were designed to turn off automatically during highway driving, allowing high concentrations

of pollutants to escape (Pennsylvania Department of Environmental Protection 2004). Federal regulations have also been enacted to require heavy-duty diesel engines to meet CARB standards, but these will not take effect until the 2007 model year. Diesel exhaust contains sulfur oxides (SO_x) and nitrogen oxides (NO_x), which are precursors to acid rain, but these regulations will mainly control emissions of NO_x from heavy-duty diesel vehicles. Emissions of particulate matter continue to be a concern (PennEnvironment 2006).

Establishing a Volunteer Monitoring Program

Creating a reliable and accurate volunteer monitoring program requires a dedicated group of trained volunteer monitors who are correctly trained in monitoring protocols. Training these volunteers properly requires time and effort. But providing adequate training sessions is worthwhile because it will lead to more accurate scientific data in the long term. The ideal volunteer monitor lives in the sample area, has a personal interest in the success of the monitoring program, and has the free time necessary to collect data on a regular basis (Hobson and Fishman 1998).

The “Bucket Brigade” Sampling Method

Discrete, one-time air samples have the advantage of being easy to use and relatively inexpensive to collect and test. Community groups nationwide have established a “bucket brigade” of air monitors using homemade air sampling devices (Figure 2). Residents concerned with air pollution, especially around industrial facilities, were initially forced to accept the information on pollution releases that was provided by

the local industries. After several people became ill after a chemical release at a petroleum refinery in California, attorney Edward Masry funded the development of a low-cost, easily used air sampling device (Global Community Monitor). This device can be assembled using a five gallon bucket and other common materials.



Figure 2. A sampler from the Louisiana Bucket Brigade takes an air sample near an oil refinery (Louisiana Bucket Brigade 2003).

Volunteers assemble the buckets and are trained how to use them, as well as how to fill out site data sheets and a chain of custody form, which records who handles the sample as it travels to the lab for analysis (Hobson and Fishman 1998). Before an air sample is taken, a blank sample must be collected using pure nitrogen gas instead of air. This sample is then sent to a laboratory for analysis, and any contaminants can be attributed to the plastic in the bag (Hobson and Fishman 1998). A small vacuum pump inside the bucket fills a non-reactive Tedlar bag with the air sample, and it takes about three minutes to collect one sample (Global Community Monitor 2006). Tests conducted by the U.S. Environmental Protection Agency (EPA) confirm that results from the bucket samples are comparable to those obtained by more sophisticated instruments (Nijhuis 2003). Sampling is usually done on an as needed basis, usually when residents see evidence of a pollution release, hear an explosion, or if they notice unusual smells in the area (Louisiana Bucket Brigade (2003).

The bucket brigade has been tremendously successful in helping community groups collect data on industrial pollution in their area (Nijhuis 2003, O'Rourke and Macey 2003). In November of 2005, the Community Labor Refinery Tracking Committee (CLRTC), a Philadelphia-based citizen group led by Joanne Rossi and dedicated to monitoring emissions from petroleum refineries, recently won a landmark lawsuit against Sunoco, Inc. over violations at its Philadelphia Refinery (Brubaker 2005). The information gathered by the bucket samplers enabled CLRTC to educate local residents, and the group plans to use some of the money earned in the settlement to purchase new air monitoring equipment.

The buckets do not require a great deal of training or technical expertise to operate, and are easily transported from site to site. Building the monitoring device also gives volunteers a sense of responsibility and ownership in the data collection process. Using the bucket brigade technology increases public participation and involvement in local environmental issues. Volunteers are able to create a "community environmental policing" strategy, similar to a neighborhood watch system, to monitor industrial pollution in their area (O'Rourke and Macey 2003). One of the greatest advantages of using a bucket brigade style monitoring system is "the power it gives communities...they own the technology and the data produced, they cannot be silenced" (Soeker quoted in Nijhuis 2003).

Ambient Air Sampling

Another method of air sampling is to take continuous samples of ambient air pollutant concentrations over longer periods of time. This is advantageous for bulk pollutants that are constantly in the air.

Continuous sampling is able to detect long-term patterns in air pollution concentrations, as well as identify particular pollutants of concern in an area. However, the tools to collect an ambient air sample are expensive, and require a certain amount of technical expertise and training to operate. One

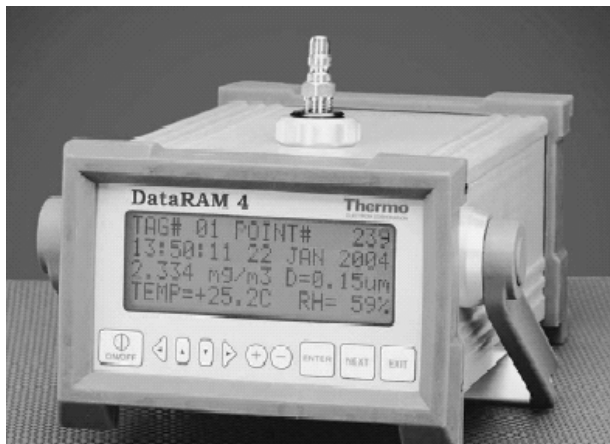


Figure 3. A DataRAM 4™ portable particulate monitor, manufactured by Thermo Electron Corporation (Thermo Electron Corporation 2004).

device for measuring ambient particulate matter concentrations is the DataRAM 4 (Figure 3), manufactured by Thermo Electron Corporation. This monitoring device runs on a rechargeable battery, and collects air samples using a built-in air pump. Because it runs on batteries, it can be used in any area outdoors, and can even be left in place for several hours of continuous monitoring (Figure 4). Particle size separators then fractionate the sample, and it can detect concentrations of particulate matter from 0.08 to 10 μm in size (Thermo Electron Corporation 2004). The DataRAM 4 monitors continuously, and displays new results every few seconds. Its data logging software is compatible with widely available analysis software, like Microsoft Excel, making it easy for volunteer monitors to record and share data.

The DataRAM 4 is much more expensive than the sampling bucket, but the data collected over a long period of continuous monitoring may be worth the cost. Unlike the bucket, where air samples must be sent to a lab for analysis, with this method volunteers obtain real-time results and trends. This allows volunteers to make meaningful



Figure 4. Air monitors take air samples using the DataRAM 4 (Louisiana Bucket Brigade 2003).

connections between their data and the conditions of the sampling site during the sampling period. Volunteer monitors can use computer software to analyze and describe trends in the data, which in turn creates a more educated and engaged group of volunteers. Finally, a continuous monitoring system may be better suited to collecting particulate air samples along highways and near truck stops, where levels of particulate matter may vary over the course of one day. At an industrial facility pollution releases are unpredictable, while traffic volume follows a fairly predictable daily pattern (Lai *et al.* 2004).

Data Collection

In Pennsylvania, as in all states, air quality is monitored from fixed ambient air sampling stations. Beginning in 1998, the U.S. Environmental Protection Agency mandated that air monitoring stations be established in all metropolitan areas with more than 500,000 people, and that all states had to establish at least two additional air monitoring stations elsewhere in the state (US Environmental Protection Agency 1997).

Additionally, special purpose monitors were established to monitor areas with high concentrations of fine particulate matter (PM_{2.5}). The location and sampling range of each station is limited, and detailed information is not always available to the public (O'Rourke and Macey 2003). The creation of pollution "hot spots" in areas where many diesel vehicles are concentrated is of particular concern in developing a community monitoring program.

Samples should ideally be taken at the same time of day at each site, as factors like traffic patterns and wind speed can affect the ambient air concentrations of air pollution. If using a continuous monitoring device, the monitor may wish to leave the device in place for a full 24 hour period, or only during the day. Since the bucket brigade sampling method collects only a discrete three minute sample, it is especially important to sample at the same time each day to ensure consistent results. When collecting a sample, even a brief one, volunteers should be sure to turn off their cars to avoid contaminating the sample with high concentrations of exhaust gas. Sampling should also be conducted away from sewer openings, cigarette smoke, and other potential sources of contamination (O'Rourke and Macey 2003). A data sheet is then filled out with the time of day, weather conditions, and other comments that the monitor may find relevant. Bucket samples will also need an additional chain of custody form to be sent to the lab along with the air sample (O'Rourke and Macey 2003).

CAB has suggested several sites as possible areas to sample in order to collect more detailed data on particulate matter pollution in Cumberland County. Air quality data would be collected in front of a recently built hospital on Rt. 81, as well as near an exit ramp on Rt. 81 and at a site along the Miracle Mile. The data from all of these sites

would be used to develop a better picture of pollution along the major highways in the area. Volunteer monitors may also be able to collect data at local schools, especially before and after school when large numbers of buses idle in front of the school. Collection of air samples may be conducted using one of two strategies: either one time, discrete air samples or via a continuous monitoring device. Each approach has its advantages and disadvantages, and the final choice of approach will depend largely on the amount of time devoted to volunteer training and sample collection.

Discussion

Because particulate matter air pollution is so dangerous to human health, air samples should be taken at several sites in the Carlisle area in order to form an accurate picture of air quality. The Clean Air Board has already identified several sites for prospective monitoring. Air samples should be taken along the “Miracle Mile” in Middlesex Township to try to assess what impact the heavy truck traffic may be having on local ambient air quality. CAB has also suggested that samples be collected at local elementary schools in an effort to quantify the levels of particulate matter pollution from idling school buses. In both of these cases it may be more appropriate to use a bucket brigade grab sample technique to collect a discrete, three-minute air sample. Because the greatest concentrations of air pollution may occur only at certain times of the day, for instance at the end of the school day, long-term sampling of air pollution may not be needed. However, traffic at truck stops may follow a continuous 24 hour a day pattern, and further research is needed to determine the best times to obtain samples in these areas.

Volunteer monitoring using the bucket brigade method is unlikely to yield the quantity, or quality, of data that could be obtained using a portable air sampler or a fixed ambient air monitoring device, but the results of the buckets are important in other ways. The bucket sampling technique is empowering for community volunteer monitors. Unlike water pollution, air pollution is often invisible and so it can be difficult to generate support for a problem that the public cannot see. Being able to build the sampling device, collect a sample, measure the concentrations of pollutants, and analyze the results is a powerful experience. Publicizing the results could also help to make more Carlisle residents aware of the problems of air pollution. The results of one such bucket brigade sampling program could help to promote the growing grassroots air pollution “community environmental policing” strategy (O’Rourke and Macey 2003).

Conclusion

Air pollution, specifically particulate matter, from heavy-duty diesel engines poses a significant health threat. Particulate matter is dangerous because once it is inhaled it is small enough to penetrate the bloodstream, transporting metals and other toxins into the body. Pollution from diesel engines is different from other forms of air pollution in that it tends to be concentrated in areas with heavy diesel vehicle traffic. While existing air quality monitors may sample the ambient air, they may fail to detect localized concentrations of dangerous air pollutants. This puts communities with large trucking industries, like Carlisle, at a significant risk of health problems associated with particulate matter pollution. A volunteer air quality monitoring program would give local

residents a more accurate picture of air quality in Cumberland County, as well as publicize the problems of particulate matter pollution.

Volunteer monitoring is an empowering way for community members to learn about their air quality, while providing information needed to work for improved air quality. CAB has already been very successful in mobilizing community support for cleaner air, and accomplishing their goals of reducing air pollution and raising community awareness. In April 2006, DEP announced that it will implement a one year study of air quality in the Carlisle area, and will provide up to \$75,000 to measure and analyze air samples. Data from the DEP monitors will then be used to determine whether further action is needed to reduce particulate matter pollution in the Carlisle area. The monitoring will most likely take place in a residential area, where people are most affected by long-term exposure to air pollution (Farr 2006).

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Outline of Data Monitoring Plan

Rationale:

According to the U.S. Clean Air Act and subsequent amendments, states are required to establish monitoring stations in urban areas and air pollution “hotspots” in order to monitor ambient air quality. Ozone and particulate matter, two important pollutants in urban areas, must be monitored at stations in all urban areas with more than 500,000 people (US Environmental Protection Agency 1997). The Carlisle area has become an area of high concentrations of particulate matter air pollution from coal fired power plants and especially the diesel engines used in the large central Pennsylvania trucking industry (Joyce 2006). Local community groups, including the Clean Air Board of Central Pennsylvania (CAB) are now trying to address the issue of harmful particulate matter pollution in Cumberland County, and are pressing for stricter monitoring and regulation of diesel engines. Particulate matter is released in diesel engine exhaust, and inhaling these fine particles can cause respiratory problems, especially in sensitive individuals or children. Ultrafine particles, those less than 0.1 micrograms, are the most hazardous to human health, as they are small enough to penetrate lung tissues and enter the bloodstream (Fang *et al.* 2005). In the Carlisle area, the abundance of diesel trucking companies means that pollution from diesel engines is concentrated in a small area, creating more hazardous conditions for local residents.

An air quality monitoring program is recommended, both to test for high levels of particulate matter pollution and to establish baseline data before any future truck warehouses area constructed. This project will create an outline plan for any future air monitoring program that may be established in the Carlisle area. It will address training of volunteer monitors, data collection goals and protocol, and site selection. In addition, this project will elaborate on the environmental and human health effects of diesel exhaust particulate matter. Implementation of a volunteer monitoring program would be an excellent project for CAB, which already has a strong and active base of community members. Organized as a joint effort between community activists, faith groups, and concerned citizens, CAB already has clear goals regarding pollution reduction in the Carlisle area. In the future this project may serve as a model for establishing a community-based air quality monitoring program,

Project Outline

A. Establishing a Volunteer Monitoring Program

1. Training and recruitment of volunteer monitors
2. Seeking professional help or consultation
3. Locations of EPA certified air sample testing laboratories

B. Data Collection

1. Pollutants of concern in the Carlisle area
2. Continuous monitoring of air quality, advantages and disadvantages
3. “Bucket Brigade” and grab sample techniques – advantages and disadvantages
4. Establishing a monitoring schedule at each site – how often, what time of day
5. Protocol for air sample collection

C. Choosing Sampling Sites

1. Overview of the five prospective sampling sites
2. Some criteria for evaluating sampling sites
3. Establishing baseline data in case of future construction
4. Ideas for future monitoring projects

D. Appendix – Environmental and Human Health Effects of Diesel Exhaust

1. Particulate Matter – specifically $PM_{2.5}$
2. Sulfur Oxides (SO_x) and their role in acid precipitation
3. Nitrous Oxides (NO_x) and acid precipitation
4. Other environmental concerns – stormwater runoff, traffic congestion