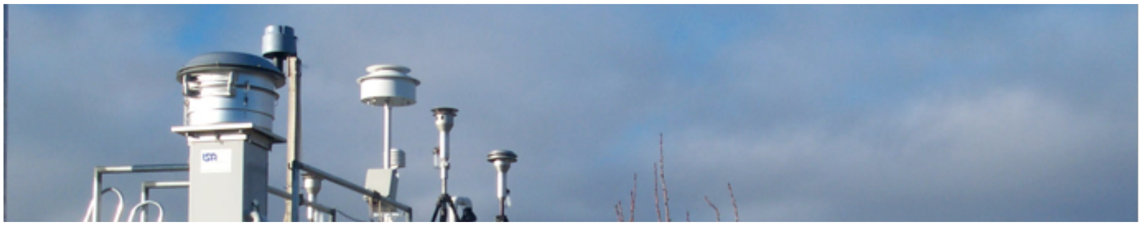


Instructor's Manual

Module 4: *Measuring Air Pollution in the Mid-Atlantic United States*

A. Typical class length:
45-60 minutes

B. Target students:
Entry-level state employees

C. Module objectives:
The goals of this module are to have the students:
- Learn some ways to measure key pollutants in emissions and ambient air
- Understand the trade-offs in monitoring site selection
- Be familiar with ways to monitor air quality remotely
- Be able to use a few data analysis methods

D. Instructor preparation:
Go to the course web site and download all relevant materials for Module 4:
Instructor's Slides (Powerpoint)
Student Handouts (PDF)
Instructor's Manual Overview (PDF)

http://bigmac.cee.mtu.edu/marama/Modules/Modules.html

Review all the materials, make any changes you feel are necessary for your version of the course, master the material, then deliver your class!

E. Understand the sub-module objectives
Each course module is constructed of a series of sub-modules based on modern learning theory. The sub-module typically focuses on a narrow aspect of the module topic. The module can be viewed as the collection of several discrete topics presented in a fashion more appropriate for the range of learning styles among students in your class. Most sub-modules are constructed around a *motivation-theory-application-analysis* learning cycle. While it is good practice to have this cycle for each sub-module, it is acceptable to have a portion of the sub-modules that do not have all four components of the cycle. In general though, it is poor practice to have only the theory sections, as this will likely achieve the low-retention rates found in lecture-based learning environments. The rest of this manual

provides tips and insight into specific slides. Please refer to the *Module 4 Instructor's Slides* to follow along.

Sub-Module 1: Introduction (Slides 1-5)
The primary purpose of these slides is to engage the student almost immediately upon entering the classroom. Educational research suggests that in a typical class, the first ten minutes is lost on most students as they are disconnecting from what they were previously doing. A suggested approach for this phase of the module is:

Slide 1 – Have this slide projecting before the students enter the classroom. Each module starts with a photograph connected to the content. Most students will subconsciously begin thinking about the course material when looking at the photograph. In this, maybe the students will be wondering why these instruments are in a suburban neighborhood.

Slide 2 – Introduce the topic. This will make sure everybody in the room belongs in the class.

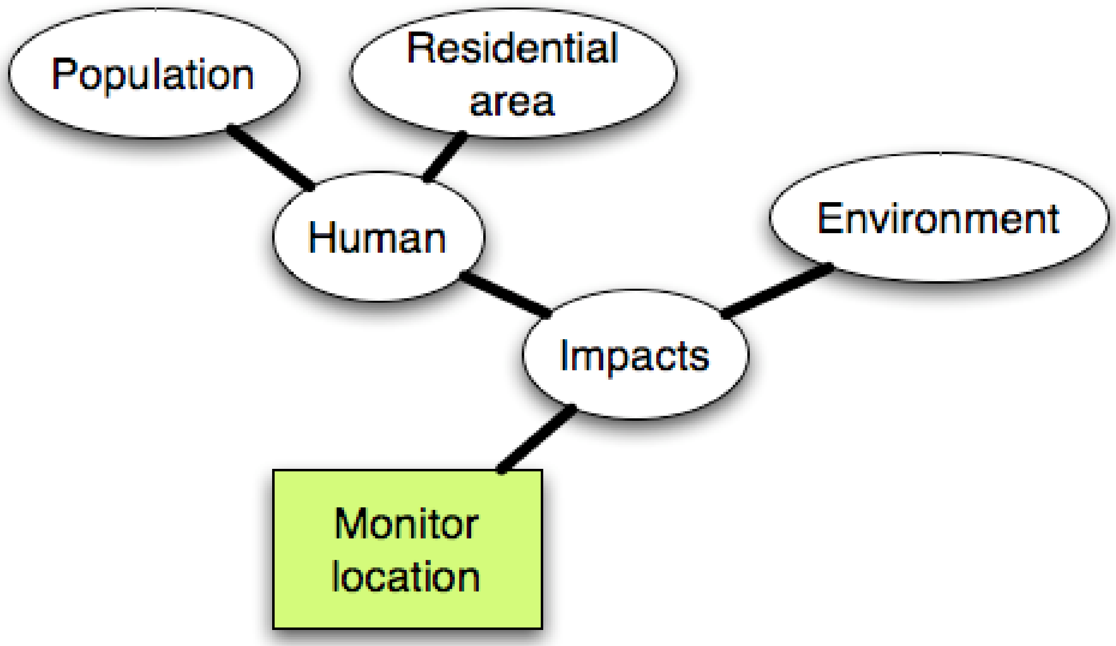
Slide 3 – This slide serves as the initial motivation. Feel free to substitute a similar compelling fact, observation, or finding from your own experiences. This slide should be put up long enough for the students to review, and perhaps some short comment from you. In this case, a reasonable comment is that there is a lot of measuring going on. Is it too much? Not enough?

Slide 4 – All modules have a preliminary quiz. The purpose of the preliminary quiz is two-fold: (1) it gets the students thinking more about the subject, and (2) gives you a comparative benchmark at the post-module quiz. Feel free to substitute questions with some of your own, but bear in mind that the total time expended here should be about two minutes. Simply have the students circle the answers on their copies of the student handouts, or produce a handout quiz if you want to tally the results. One way to engage the class as a whole is simply to ask for a show of hands for each answer. The solutions to this quiz can be found in the post-course quiz slide below.

Slide 5 – The course goals slide is a good one to emphasize. Tell the students clearly what they will learn by the end of the class. If you add to, or delete, any material modify the course goals as needed.

Sub-Module 2: Monitoring (Slides 6-15)
The primary purpose of this sub-module is to begin to address the first and third course objective, namely identifying key pollutants to monitor and being aware of some of the methods available.

Slide 6 – There is no better way to assess what the current state of knowledge among students than concept mapping. The technique is simple: in the middle of the page write the key concept and put a box around it. In this case it might be "monitor location". From there, the student groups simply connect concepts to this central concept. For example one related concept might be "impacts", and then connected to impacts, might be "human" and "environment". To human, perhaps "population" and "residential area" are important for a particular type of human health impact, and are thus connected.



There are no right or wrong ways to do this. The connections can be made in any way that makes sense to the group (each person will have a unique way of making these diagrams, so the group process usually takes longer). If possible provide some large sheets of paper and markers so the students can share their work. If such paper is not available, blackboards, or transparencies work. Be careful, you can easily eat up a lot of time on this activity. Tell the students they have five minutes to work on this. This activity also helps the class reach a higher comfort level.

Slide 7 – Presents some of the major criteria that must be resolved prior to reaching a conclusion regarding how, when and where to monitor a pollutant. Compromises will generally be made between these features.

Slide 8 – This slide presents the main pollutants that are routinely measured. Criteria pollutant ambient air concentrations are regularly measured (usually every hour, with the exception of lead). Criteria pollutant emissions are routinely measured (except lead and ozone, the latter having no emissions). Additionally, VOCs an NH_3 are measured as they directly influence the ambient concentrations of two criteria pollutants, ozone and fine particulate, respectively.

Slide 9 – An introduction to the general needs of modern air pollution monitoring are presented. Note the features on measurement acquisition: modern reporting and information availability (nearly real-time measurements are available to the public via regulatory agency web sites in most states). A critical point is that while there are many ways to measure most pollutants, only a subset have been certified as acceptable ways by the U.S. EPA.

Slides 10-11 – These slides provide examples of technology to measure two important pollutants to the Mid-Atlantic, particulate matter and ozone. The Tapered Element Oscillating Microbalance (TEOM) estimates particulate concentration by measuring the change in behavior of an oscillating particle impactor plate. The ozone analyzer is designed around the behavior of ozone to absorb ultraviolet radiation (recall how the ozone layer protects the Earth). The more ozone, the greater the absorption of uv-light. Common features between the two include data storage (often a couple month's worth), and transmission of the data.

Slide 12 – This slide introduces the differences in measuring pollutants in source emission air (versus the ambient atmosphere). These measurements are usually performed in the tall stacks seen at factories and power plants.

Slide 13 – Remote monitoring techniques are growing in use and effectiveness. Remote sensing is particularly good when massive areas must be monitored, or when environments are too extreme (temperature, for example) for in situ monitoring. Satellite-based measurement of pollutants in the near-surface atmosphere are confounded by the mix of pollutants found in the atmosphere (including clouds).

Slide 14 – An example of one instrument MOPITT on one satellite in this case measuring carbon monoxide. This demonstrates the spatial coverage and resolution of some such instruments.

Slide 15 – An example of the type of pollutants continuously monitored from stack sources.

Sub-Module 3: Location (Slides 16-23)
The goal of this sub-module is to examine the decision-making process of siting an air quality monitor.

Slides 16-17 – A network of monitoring sites is generally planned, but at some point specific locations must be selected. This slide covers some of the criteria used in the selection process. Ask your students if they can think of any others.

Slide 18 – This slide is a series of photos taken around the perimeter of a monitoring site. Explain the photos to the students as their notes are likely to be small and black-and-white, and they may not be able to see all the details on the projected version. The top photo is looking north past the site, for example. By looking around the site this way, students should draw some conclusions about where the site was place (in the middle of a clearing), and potential purposes (air pollutant exposure of children). Why might this high school site have been chosen? Ask the students.

Slide 19 – Another example to show the placement of a monitoring station. What might be the purpose of this site?

Slide 20 – A rooftop monitoring site. What trade-offs exist for such a placement?

Slide 21 – A monitoring site in an urban setting.

Slides 22-23 – The first slide shows the regional big picture. Each dot is the location where at least one criteria pollutant ambient air monitoring site is located. A natural question to ask is: why these locations? See Slide 23. Follow-up questions might be: Is this too many sites? Too few? What is lost by choosing these locations over others?

Sub-Module 4: Data Analysis (Slides 24-35)
The goal of this sub-module is to address the last objective of the course module, learning a few data analysis methods.

Slide 24 – Provides some reasons for computing and using statistics of air pollution measurements.

Slide 25 – QA/QC efforts are ways to ensure confidence in the air pollution measurements.

Slide 26 – This slide presents an example quality control strategy. Such strategies are commonly comprised of the components in the left column, however each specific strategy meets the components with a unique combination of solutions. Deciding on which solution best satisfies each component is the challenge, however several of the QC components are fixed properties of a particular monitoring instrument.

Slide 27 – Tread more slowly here, some (simple) mathematics coming next.

Slide 28 – Identification of outliers is connected to the quality assessment of the data. It is important outliers be identified if meaningful statistics and conclusions are to be constructed from the data.

Slide 29 – This slide introduces one easy method for determining whether measurements are outliers. The t* value that is calculated (after the average and standard deviation are estimated) is compared to the value $t_{\nu,\alpha}$ which is looked up in statistics tables for "t-statistics" (usually in the appendices of most statistics books). The term n is the degrees of freedom (typically the one less than the number of datapoints), and α is the confidence limit (how certain you are of the results, in this case the decision that the datapoint is or is not an outlier).

Slide 30 – This is a simple example of the Barnett-Lewis method. The $t_{\nu,\alpha}$ value is looked up, the t* value is calculated from the data. Note that a 95% confidence limit translates to an α value of 0.05 (=1-0.95=0.05).

Slided 31-32 – Introduces some reasons to smooth data, and one way to do so (moving average). The equation on Slide 32 is a simple sum, but may look confusing due to the summation limits and subscripts. The parameter *t* is the point in the data (for air quality data, *t* is often time), *k* is the period over which the average is being determined, *j* is first datapoint in the series of data being summed, and *y* is simply a representation for the data. For example we might have a short data set like below:

Measurement	**Ozone concentration (ppm)**
1	0.12
2	0.15
3	0.14
4	0.10
5	0.11
6	0.13
7	0.08
8	0.07

Let's say each of these measurements is a daily average, and we want to compute a 3-day moving average (k=3). We need three days of data before we can compute an average, so it would not be until the third measurement (t=3) that we are in such a position. Here is what the math would look like:

$$\bar{y}_3(3) = \frac{1}{3}\sum_{j=3-3+1}^{3} y_j$$

Taken a step further:

$$\bar{y}_3(3) = \frac{1}{3}(y_1 + y_2 + y_3)$$

And putting in the ozone measurements:

$$\bar{y}_3(3) = \frac{1}{3}(0.12 + 0.15 + 0.14) = 0.137 \text{ ppm}$$

For the next available measurement (t=4), the math would go:

$$\bar{y}_4(3) = \frac{1}{3}\sum_{j=4-3+1}^{4} y_j$$

$$\bar{y}_4(3) = \frac{1}{3}(y_2 + y_3 + y_4)$$

$$\bar{y}_4(3) = \frac{1}{3}(0.15 + 0.14 + 0.10) = 0.130 \text{ ppm}$$

Filling out the table would produce the following:

Measurement	Ozone concentration (ppm)	Moving average (ppm)
1	0.12	Not possible
2	0.15	Not possible
3	0.14	0.137
4	0.10	0.130
5	0.11	0.117
6	0.13	0.113
7	0.08	0.107
8	0.07	0.093

Note: the moving average is easily computed with a spreadsheet.

Slide 33 – This example illustrates one use of smoothing data. The yearly changes in ozone may be due to many reasons (unusual weather, for one). From a performance perspective, it might be unwise to base the evaluation of an area's air quality on data from one year. Three-year moving averages (or any period longer than one year) would be one way to reduce the effects of annual variability. This would give a better view of whether changes in annual concentrations are trending or not.

Slide 34 – This question will be challenging, as it will require a pretty good understanding of the moving average. In that light, use it also as an assessment method to determine whether the students are confused or not.

Slide 35 – A suggestion of one use for the moving average. Perhaps the "signal" of interest is not the moving average, but rather the deviation of the annual data from the longer term trend. In this graph the annual averages are subtracted from the three-year moving average. Negative values suggest that that year's average was below the trend. And that information could be used to identify reasons why the ozone levels were lower than typical. This example is one that shows a powerful use for statistical analysis methods: they help us data sleuth, uncovering the messages within the measurements.

Sub-Module 5: Conclusion (Slides 36-39)
These slides provide a meaningful ending to the learning. Don't underestimate their importance.

Slide 36 – The post-quiz goes here. The students should only need 30-60 seconds. Collect their responses, if assessment is needed, else a show of hands with discussion is fine. The purpose of the post-quiz is simply to force retention of key points. The answers for this quiz are:

1.) *a., b. and c.*, should all be considered in siting an air quality monitor. A water supply is not needed for any conventional monitoring instruments.
2.) A TEOM continuously measures the ambient concentration of *d.) fine particles*
3.) The closest answer (117 total) is *d.) 100*.

Slide 37 – This slide has some resources for the students to learn more on their own. Add to it, as relevant. Encourage additional learning with references that you know to be particularly helpful. The AirData site provides public access to air quality data in the U.S. Measurement method guidelines are provided in the second, third, and fourth sources. The MARAMA Guide has additional perspective on the topics introduced in this module.

Slide 38 – The moment to reflect is an important pause before concluding the class. It helps the student sort and summarize what they have learned, and if desired can be a good summative assessment for your efforts. For example, as an assessment tool, simply ask the students to write their response to the question on a scrap of paper and leave it behind following the class. Read through the responses to adjust any future offerings of the class. It will be extremely illuminating to learn what the class mentions as most important lesson? Again, this activity could take some time, so set time limits up front.

Slide 39 –Thank the class for coming and for their participation! This is a simple yet powerful way to end the class.