Instructor's Manual
Module 5: *Air Pollution Emissions 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:
   • Classify emission types
   • Identify emissions from major sources
   • Understand emissions of key pollutants in the Mid-Atlantic U.S.
   • Become familiar with ways to estimate emissions
   • Learn about key resources to find emission data

D. Instructor preparation:
Go to the course web site and download all relevant materials for Module 5:
      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 5 Instructor's Slides* to follow along.

Sub-Module 1: Introduction (Slides 1-6)
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 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 a photograph. In this, maybe the students will be wondering what might be going on to create the black plume.

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. Maybe a rhetorical question is appropriate, for example: is 17 out of 100 good/bad?

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 if needed.

Sub-Module 2: Emission Classification (Slides 6-28)
The primary purpose of this sub-module is to address the first, second and third course objective, namely identifying and classifying emissions relevant to the Mid-Atlantic.

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 "emissions". From there, the student groups simply connect concepts to this central concept. For example one related concept might be "industry", and then connected to industry, might be "production schedule" and "feedstock materials". For example:
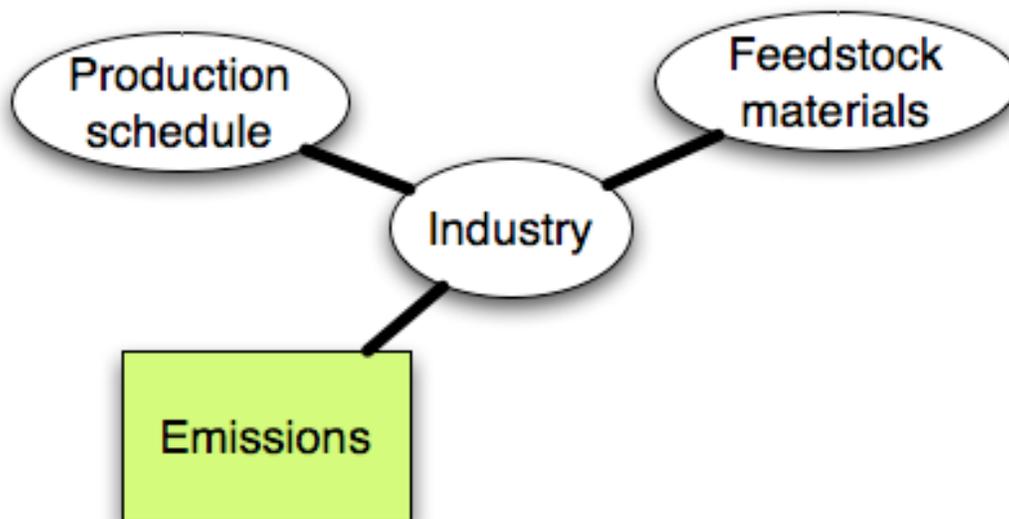
There are no right or wrong ways to do this. If possible provide some large sheets of paper and markers so the students can share their work. If such paper is not available, blackboards, or transparencies work. Be careful, you can easily eat up a lot of time on this activity. Tell the students they have five minutes to work on this. This activity also helps the class reach a higher comfort level.

Slide 7 –Examples of emission rate units (for industrial sources) are kg/day, lb/hr or something similarly appropriate. The important points on this slide are the factors influencing emission variability, and the factors that influence emission sources. Make sure to stress these as complicating factors; no two locations have identical emissions because of these factors.

Slide 8 – Because there are so many different types of emission sources, people try to organize them by categories. A few ways are introduced in this slide and explained in further detail next.

Slide 9 – Emissions by **pollutant type** is the first categorization presented. Refer to Module 2 for more information on pollutants.

Slide 10 – This example illustrates the accounting effort required at the state level. The totals, summations from many sources in the state, add up to large numbers. Based on these totals, ask the students if it means that North Carolina has more severe air quality issues from criteria pollutants (since the total is six times larger than for HAPs).

Slide 11 – Emissions by **source type** is covered next. Here the distinction is whether the source is moving or not (mobile or stationary). Within each type, there are sub-types (point and area, for example). Hence, the language to more completely describe a source could be "a stationary point emission", or "a mobile non-road emission".

Slide 12 – This activity is meant to have the students pause and process the learning to date. In groups they should be able to come with examples for each type of source. Ask student groups for their ideas and consider making a master list of ideas on a blackboard, or a blank Powerpoint slide.

Slide 13 – This slide reiterates emissions by source type in a visual way. It also provides a few examples that may be similar or different than the ideas shared in the previous activity.

Slide 14 – There is much information on this graph; walk the students through it slowly. Explain the axes. Note how the mix of source types varies (%) with each pollutant, as does the total emission rates (tons/yr). Which emissions are problems? Is there one solution that works for all? Good questions to ask the students and generate a mix of opinion. Discourse can be a great motivator for learning.

Slide 15 – This is a great example comparing emissions of sulfur dioxide in neighboring states. Why are the emissions so much different among these states? Ask the students. Population, source of power generation, and industrial sources are key factors.

Slide 16 – One way to begin investigating the explanation of the differences among states would be to examine emissions at the county level. Via this map, some insight might be gained about probable sources of sulfur dioxide. Why does Pennsylvania have several counties in the highest emission rate category (dark blue)? Coal-fired power plants? Steel manufacturing? Additional information is needed.

Slide 17 – A depiction of some of the temporal trends for sulfur dioxide emissions. In this case these are emissions from power generating facilities. The yellow states reduced emission between 1999 and 1990, the white states did not. Ask the students why that might be. Most of the reductions were due to acid rain abatement programs started in the early 1990s.

Slide 18– A second example to show the emission differences between two pollutants (sulfur dioxide versus volatile organic compounds). The state comparison chart for VOCs is very different from the SO2 chart. Ask the students how? Some possible observations: a different state has the highest emission rate and point sources play a much smaller role. Natural area sources are mentioned; certain trees release VOCs, and collectively these emissions can rival anthropogenic (human-made) emissions.

Slide 19 – Depicts the VOC emissions on the county level. Ask the students for observations. It is clear that urbanization seems to be correlated to VOC emissions. Why is it the case for VOCs and not for SO2? This is the effect of area sources versus point sources.

Slide 20 – This activity gets the students thinking about differences in specific sources, in this case, specific area sources. One NH_3 source that North Carolina has is confined animal feeding operations (CAFOs) a notorious source of NH_3 (particularly from poultry

operations). Have the students work alone if you are short for time, of in groups if you have ample time or are concerned about participation (groups tend to be more willing to volunteer their work).

Slide 21 – Another example, a different pollutant. NOx has a larger dependence on mobile sources (the air used in fuel combustion produces NOx) and virtually no dependence on area sources. Point sources tend to be power generation.

Slide 22 – A clear connection of urbanization and mobile emissions is depicted in this map. All the commuting has air quality consequences.

Slide 23 – The temporal trends in NOx emissions in the Mid-Atlantic states are depicted in this map from the EPA. States in yellow have reduced their emissions over the 1990s, states in white have not. NOx emissions are tied to fuel use, both in power generation and vehicle use. Does that explain why certain states are struggling? Ask the students to see what they think. The reduction in NOx were initially motivated by acid rain abatement, but more recently regional ozone abatement has provided extra incentive.

Slide 24 – This activity requires the students to think about why these county-level maps have certain patterns. Here, simply point out that the red colors are higher emission rates (the numbers are not so important). The point sources have no real pattern. Large point sources of NOx are likely power generating plants, and those are located where convenient. The mobile source emissions have a clearer pattern – clustering of high emissions around major metropolitan areas due to traffic levels (Charlotte for example).

Slide 25 – This slide connects the emission type with computer models that are commonly used. All of these PC-based models are freely available from the U.S. EPA, however there are more user-friendly implementations for sale from various vendors. These models are generally used to estimate the air pollutant concentrations in the atmosphere around the emission source(s). Such simulations can be used to look at impacts from changes in the emission levels, among other purposes.

Slide 26 – A few more ways to describe emissions. The point sources in the previous graphs are all granted emission permits by the state. There are emissions that don't follow this scripted path. Fugitive emissions are those that escape from their source. Accidental releases are often substantial in some (poorly run) facilities, and for some pollutants natural sources can be significant. Particulate matter (PM10 in particular) can have major fugitive sources. Accidental and natural emissions are common for many VOCs.

Slide 27 – This graph depicts shows some of the specific sources of PM2.5 for the country. Some are fugitive emissions; ask the students to identify which ones. In this case, traffic over paved and unpaved roads degrades some of the road surface and wind can transport this material off the road. Some of the industrial process emissions may be fugitive. The miscellaneous sources include non-road gasoline- and diesel-powered construction, industrial, lawn and garden, farm, light-commercial, logging vehicles and other non-road sources; soil sources, agriculture and forestry, cooling towers, non-

transportation-related fugitive dust, wildfires, managed burning, and other fugitive dust and combustion that could not accurately be allocated to specific source categories.

Slide 28 – This activity is meant to get the student to integrate what they have learned to what they know from professional and personal experiences. There are no right answers, but clearly population in the Mid-Atlantic will go up in the coming decade; how will that impact any of the sources? Their emissions? Air quality? Even for a very population-dependent pollutant, say NO_x (from automobile traffic) it is not completely clear what influence related factors might have on NO_x emissions from transportation sources, for example: the influence of consumer choices on car type, technological changes in car designs, and economic pressures from fuel prices. Bring these kinds of factors up. This one example highlights the tremendous challenges in forecasting emissions, and subsequently air pollution levels.

Sub-Module 3: Emission Estimation (Slides 29-38)
The primary purpose of this sub-module is to address the fourth and fifth course objective, namely estimating emissions and finding key data resources.

Slide 29 – This slide introduces some ways to estimate the amount (rate) of emissions. The decision is essentially one between measuring or modeling the emissions. The EPA TTN is the Technology Transfer Network, a web site where, among other resources, emission models can be downloaded. This can be found at the first or fourth resource listed on Slide 40 "Further Learning".

Slide 30 – Details of the mass balance method. This is a mathematical way to account for the materials used by an industry (or other source), some of which can become pollution (instead of, say, product) and might be designate as mass moving out of the system (the plant facility, for example).

Slide 31 – A simple numeric example to make the mass balance concept a little more tangible.

Slide 32 – Process modeling is used when the model, time, and talent exist. These models generally try to describe (with mathematics and implemented on computers) how a specific industrial process functions. As such, many of these models have very specific purposes, unlike the mass balance approach which can be applied to very different types of systems.

Slide 33 – MOBILE6 is mentioned here (and can be downloaded at the TTN). Used to estimate emissions from vehicles, these calculations can then be used in other models to estimate air pollution in near-roadway environments, or urban areas. The model has several variables which attempt to replicate the range of vehicle conditions, all influencing emissions of exhaust pollutants.

Slide 34 – Emission factor modeling is a compromise approach. Modeling to permit predictive capabilities, but simple to use. The disadvantages are from the simplification.

The emission factors used are at best average values, at worst they can be very different than actual conditions at the site of interest. The emission factors are found in the AP-42 document produced by EPA (and noted on Slide 40).

Slide 35 – This example clarifies the emission factor model approach. If the lime manufacturing facility had some type of air emissions control device (likely) then the emissions would be altered by the average control efficiency. For example, if there was a baghouse with 90% capture efficiency the resulting emissions would be 10% of that presented. So if there was 2000 kg/day of lime being processed,

$$E = 2000 \text{ kg/day x } 22 \text{ kg PM10/1000 kg lime x } (1 - 0.9) = 4.4 \text{ kg/day PM10}$$

Slide 36 – TANKS is a PC software package to estimate the emissions from storage tanks. The model is based on AP-42 but has a nice user-interface to make the calculations easy to perform. The software is available at the TTN (see the fourth resource on Slide 40).

Slide 37 – This activity forces the students to question each of the emission estimation methods. Possible errors are many (human error is possible for all), but could include:

• sampling errors (wrong place or time) for the first method,
• incomplete mass balance construction (not accounting for all the sources, for example) is a possible error for the second method,
• incomplete knowledge of the system (complex models sometimes need more information than is available for the source be modeled) for the third method, and
• using model parameter values that are not accurate (as mentioned, the emission factors are average values at best).

Slide 38 – This slide highlights the best source of emission data available. The AirData web tool allows searching by geographic region and pollutant. One major disadvantage is that the most recent data is a few years old. Another limitation is that no fugitive (or accidental) emissions are estimated and reported, so they are not available here.

Sub-Module 4: Conclusion (Slides 39-42)
These slides provide a meaningful ending to the learning. Don't underestimate their importance.

Slide 39 – 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.) line*, but this does depend on the type of problem being studied. Roadway
       systems (more specifically the traffic on the roadway) are modeled as a system of
       lines when interest is focused on the impacts in the near-roadway environment. If
       the concern was focused on simply quantifying the total emissions in each

category of sources, then vehicles might be considered as some kind of area source, as their exact location would not matter.

2.) AP-42 guides the use of *b.) emission factor modeling*
3.) The biggest source of NOx in North Carolina is *a.) vehicles* (as of 2002, see Slide 21)

Slide 40 – 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. There are several emission-related resources (reading, data, models, etc.) at the first resource. Emission data can be found at the second, third, and sixth sites (the Scorecard site is a simple-to-use one of interest to lay audiences, or friends and family). Various modeling tools are available at the fourth site. AP-42 emission factors are at the fifth site. The seventh resource, the MARAMA Guide, has additional perspective on the subjects covered in this module and makes a great reading companion to this course.

Slide 41 – 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 the most important thing about emissions. This activity could take some time, so set time limits up front.

Slide 42 –Thank the class for coming and for their participation! This is a simple yet powerful way to end the class.