Cascades to Coast GK12 Curriculum

What is in our air?
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Learning goals:
Upon completion of this curriculum, students will:

i. understand the key concepts about air, air pollution, and the health impacts of air pollution;
ii. develop a habit of observation and inquiry;
iii. participate in a student-directed, authentic inquiry project in air quality.

Objectives:

• Understand the properties of air and how they are measured.
• Describe how human activities are changing the composition & properties of air.
• Understand the sources and sinks of the criteria pollutant, nitrogen dioxide (NO2) in the urban environment
• Describe the influence of NO2 on human health.
• Design and carry out an inquiry on NO2 in their environment.
• Communicate scientific findings of their NO2 inquiry using PowerPoint, posters and oral presentations.

Target Grade:
7th grade

State Standards:

❖ 6.1P.1
Describe physical and chemical properties of matter and how they can be measured.

❖ 7.2E.3
Evaluate natural processes and human activities that affect global environmental change and suggest and evaluate possible solutions to problems.

❖ 8.2P.1
Compare and contrast physical and chemical changes and describe how the law of conservation of mass applies to these changes.

❖ 8.2P.2
Explain how energy is transferred, transformed and conserved.
Activity Summary:
We describe a curriculum designed and implemented to enable 7th grade students to understand the basic ideas about air, air pollution, and scientific inquiry. The curriculum was implemented over the course of a year as three 6-7 week units: background information, scaffolded inquiry and student-directed inquiry. Each unit consisted of about 6-8 contact hours. The entire curriculum could also be covered in a 6-week period.

UNIT 1
Background: Concepts about Air:
We identified five key concepts that students had to learn about air and air pollution:
- What is air?
- Physical properties of air
- Composition of air
- Understanding parts per million and parts per billion
- Nitrogen dioxide – sources, sinks and health effects.
Each concept was introduced through a hands-on activity. The habits of inquiry and observation were encouraged by asking students to hypothesize what would happen in the activity and what observations would support or disprove their hypothesis.
After the key concepts were introduced, one period was dedicated for students to reflect on what they had learned and to develop questions. While this activity empowered students to sharpen their curiosity, it also provided us with an opportunity to address students’ misconceptions.

Week 1: 1 period: What is air?
Week 2: 1 period: Physical properties of air: Pressure
Week 3: 1 period: Composition of air
Week 4: 1 period: Understanding parts per million and parts per billion
Week 5: 1 period: Nitrogen dioxide – sources, sinks and health effects
Week 6: 1 period: Ask-a-Scientist (questions and debrief)

UNIT 2
Scaffolded Inquiry:
We introduced a scaffolded inquiry activity to prepare the students for the final student-directed air quality inquiry project. In this first inquiry, the students were given the research question: where will NO2 levels be the highest – the front of the school along a major street, the back of the school (where there is a community garden), or inside the classroom?

Week 1: 1 period: Review procedure and data sheet for scaffolded inquiry.
Week 1: 2 periods: Assemble NO2 samplers, deploy samplers, fill in data sheets.
Week 3: 1 period: Pick up samplers, fill in data sheets. Review and note any observations that would affect NO2 readings (sampler was on the ground; spider in sampler; etc.).
Week 4: 2-4 periods: Review results; discuss implications.
Week 5-6: (as needed): Work on posters.
Week 7: 2 periods: Student presentations of results.

UNIT 3
Student-directed Inquiry:
In the student directed inquiry project, the research goal and protocol were developed by the students themselves. Since communicating one’s science is an important part of the scientific process, students
presented their results after both the scaffolded and student-directed inquiry projects in either poster or slide (PowerPoint or PREZI) format, both in the classroom and at the GK12 conference.

Week 1: 2-4 periods: Develop goals, methods and observation sheet with students.
Week 2: 1 period: Assemble and deploy NO2 sampling tubes. Make sure all students have a log book/observation sheet and understand the observation protocols!
Week 4: 0.5 period: Pick up NO2 samplers.
Week 5: (as needed): Discuss results, have students do research to better understand the results.
Week 6: (as needed): Work on presentations.
Week 7: Students present their results.

Activity Plans

UNIT 1

Background: Concepts about Air

Key learning goal:
At the end of the unit, students will have developed a better understanding of the basic concepts related to air and air pollution. They will be able to develop a hypothesis (what they expect to happen based on prior knowledge), hone their observational skills, and be able to reason whether their observations support their hypothesis or not.

We had identified 5 key concepts to teach students about air and air pollution:
- What is air?
- Physical properties of air: Pressure
- Composition of air
- Understanding parts per million and parts per billion
- Nitrogen dioxide – sources, sinks and health effects

Each of these concepts was introduced in a 1-period class (typically). Each period used the same format: a review of existing student knowledge, introduction of the new concept building on students' existing knowledge, solidifying the new concept through a hands-on activity or demo, and further reinforcing retention of the new concept through a debriefing discussion and note-taking.

1. Review
   The first several minutes were used to review what was learned in the previous class.

2. Introduction of the new concept
   The new concept was introduced, typically by asking the students how they would explain a phenomenon within their experience. For example, to introduce the concept of air, we asked the students how they knew there was air around us. To introduce the concept of the physical properties of air, we asked the students how they would describe air to a friend on a different planet.

3. Hands on activity or demo to demonstrate concept
   Following the introduction of the concept, we either had a demo or a hands-on activity based on the concept.
   This section was used to introduce the students to and reinforce their practice of the scientific method. The students hypothesized on the outcome of the demo/activity based on their existing knowledge. They were required to make observations and fill out a data sheet during the demo/activity. They worked in small groups to determine whether the observations supported their hypothesis or not.

4. Wrap-up
Finally, we debriefed as a group and summarized what we had learned about the concept.

Ask-a-Scientist
We used the last period in this unit for students ask the fellow any unanswered questions they had about air. Each student was given an index card, with the expectation that each student would write down at least one question. The remainder of the class was a free-flowing discussion that resulted in a lot of great questions.
This period served two useful purposes. First, it gave us (the teacher and the fellow) an opportunity to observe what the students had learned and to correct any misconceptions. Second, it gave the students a chance to review and integrate their knowledge about air and air pollution.

See Appendix I for detailed lesson plans for:
- What is air?
- Physical properties of air: Pressure
- A sampling of questions about air from students; and some answers.

Extensions
- Properties of air – temperature, relative humidity
- Wind
- Chemical properties of air
- Pollutants – ozone, PM2.5

Assessment Questions
- Review and wrap-up, data sheets and science notebook were used for formative assessment.

UNIT 2
Scaffolded Inquiry: What are the Nitrogen Dioxide(NO2) levels around the school?

Key learning goal:
At the end of the unit, students will have a better understanding of the air pollutant nitrogen dioxide – its sources, its sinks and its effects on human health. They will get a hands-on opportunity to follow the scientific method, as well as to practice communicating their science.

1. Prior to Week 1 (for fellow and teacher)
   a. Prepare map of classroom (using PowerPoint) and vicinity of school (using Google Earth).
   b. Walk the area identifying spots where students can safely place NO2 samplers.
   c. Prepare sampler materials (see Appendix II materials needed and procedures for preparing TEA solution and analyzing the NO2 passive samplers).
   d. Divide students into groups and work out the logistics of how many samplers each group will place and where.
   e. Prepare datasheet.
   f. Prepare packet for each group:
      i. Instructions for assembling and labeling tubes.
      ii. Indoor & outdoor map, with marked with the sampler sites for each group.
      iii. Datasheet for noting time of deployment.

2. Week 1: 1 period: Introduce experiment
a. Review experiment.
b. Have each group write down their hypothesis.

3. Week 1: 1 period: Review procedure and data sheet
   a. Do a dry run through the deployment procedure.
   b. Make any changes needed to datasheets and procedures.

4. Week 1: 2 periods: assemble NO2 samplers, deploy them, fill in data sheets
   a. Assemble NO2 samplers.
   b. Place samplers indoors and outdoors.
   c. Note timings of deployment.
   d. If possible, co-locate 2-3 samplers with a NO2 monitor. We co-located 2 samplers at the Portland DEQ air monitoring station to serve as an experimental control.

5. Weeks 2-3: Samplers accumulating NO2
   a. Samplers need to be deployed for about 2 weeks.
   b. Students should monitor the samplers (especially if any are in busy places such as the playground).
   c. Students may optionally want to track weather conditions and wind directions during the two weeks samplers are in the field.

6. Week 3: 1 period: Pick up samplers
   a. Pick up samplers
   b. Note time of picking up samplers. Students should additionally note any relevant observations of the samplers (spider in the sampler; thrown on the ground, missing, etc.).
   c. Retrieve DEQ controls, if any.

7. Week 3/4 (fellow): Analyze samplers, retrieve wind and weather data
   a. Analyze the samplers.
   b. Retrieve wind and weather data.
   c. Map the data.

8. Week 4: Discuss results
   a. Hand back to each group of students the NO2 levels for their samplers.
   b. Show students the NO2 map for indoors and outdoors.
   c. Discuss results, implications.

9. Week 5-6: (as needed): Research & presentation preparation
   a. Students do background research.
   b. Work on posters.

10. Week 7: 2 periods: Students communicate their science
    a. Students present the results of the scientific inquiry both as posters and oral presentations.

See Appendix I for NO2 samplers assembling instructions (for students), maps given to students for placing their tubes, and maps showing the measured NO2 levels.

Assessment Questions
Posters and oral presentations

UNIT 3
Student-directed Inquiry:

Key learning goal:
At the end of the unit, students will have designed a scientific inquiry to answer a question about NO2 levels that is of interest to them.

1. **Week 1: 1 period: What is the question?**
   a. Review NO2 information, especially air pollutant standards and impact of air pollutants on human health.
   b. Prompt the students: if they had access to a reasonably large number of NO2 tubes, what would they want to measure?
   c. Settle on one question. If necessary, take a vote.
      In our class, students pretty quickly concurred that they wanted to measure NO2 around their homes.
   d. Discuss why the question is important to students, what do they expect to find and why. Encourage students to summarize the discussion and write it up in their science notebooks.

2. **Week 1: 2 periods: How can we answer the question?**
   a. Work with the students to decide on:
      i. How many samplers?
      ii. Where will the samplers be placed?
      iii. What other variables need to be observed?
      iv. What is the protocol for measuring the other variables?
   b. Form a hypothesis

3. **Week1/2 (for fellow and teacher): Getting sampler materials and preparing data sheets**
   a. Get materials together for assembling the required number of samplers.
   b. Prepare any maps that might be needed.
   c. Prepare inquiry packet:
      i. datasheet/observation booklet that students have designed.
      ii. Observation protocols.
      iii. Space for NO2 tube deployment & pick-up timings.

4. **Week 2: 1 period: Deploy samplers**
   a. Review observation protocols and datasheet.
   b. Deploy samplers.
   c. Co-locate 2-3 samplers with a calibrated NO2 monitor as experimental controls, if possible.

5. **Weeks 2-3: Samplers accumulating NO2**
   a. Samplers need to be deployed for about 2 weeks.
   b. Check in with students that they are monitoring the samplers and keeping up with their observation protocols (teacher).

6. **Week 3: 1 period: Pick up and analyze samplers**
   a. Students turn in samplers and completed datasheets.
   b. Analyze the samplers (fellow).
   c. Consolidate class datasheets.
   d. Prepare any relevant maps.
   e. Retrieve wind and weather data (if relevant).

7. **Week 4: Discuss results**
   a. Hand back to each group of students the NO2 levels for their samplers.
   b. Discuss results, implications.

8. **Week 5-6: (as needed): Research & presentation preparation**
   a. Students do background research.
   b. Work on PREZIs.

9. **Week 7: 2 periods: Students communicate their science**
   a. Student presentations of results.
See Appendix I for the question, data sheets, and protocols designed by the students.

**Assessment Questions**  
PREZIs (or PowerPoint) and the accompanying oral presentations

**Materials**  
See Appendix II

**Handouts and worksheets**  
See Appendix I

**Extensions**  
Students can extend their experiments for science fair projects.
Appendix I
Activity Plan

What is Air?

Key learning goal:
What is air? What state of matter is air in? Does air have mass? What are the physical properties of air?

1. Begin by prompting students with questions such as:
   - what is air?
   - how do they know there is air around us?

   The goal is to guide students to draw conclusions based on their own observations about air. Are there observations from their own experience that they can use to confirm that there is air around us? If students seem at a loss, show them a sheet of paper floating down or ask them what happens when they breathe out on a cold day.

   In my classroom, I prompted the students to describe how they could use their 5 senses to observe air – Can you see air? Can you hear air? Can you feel air? Can you smell air? Can you taste air?

   At the end of the discussion period summarize the discussion and have the students write it in their science notebooks.

2. What state of matter is air in?

   This is a chance to review the three states of matter, and may be get the students thinking about liquid air and solid air – and what that might mean for life on Earth.

   Wrap-up, and have students write in their notebooks.

3. Does air have mass?

   My class was divided on this – most students said air did not have mass, because if it did, we would be crushed. A few students said air had mass (without giving a very good reason for why they thought so). I prompted the students to describe how they would find out who was right.

4. What are the physical properties of air?

   Prompt the students to say how we describe things. Typically, we use color, shape, size, smell, name, etc. to identify things. How would we describe air? If students have studied temperature and pressure, these can be added to the list.

Related Concepts

Scientific Method

Materials

None

Handouts and worksheets

None

Extensions

Measuring the density of air

Assessment Questions

How do we know there is air around us?
How can we describe air?
Does air have mass? How would you measure it?
Activity Plan

Physical Properties of Air: Pressure

Key Learning goal:
At the end of the activity, students will have a better understanding of atmospheric pressure and how it affects us in everyday life.

1. Review the physical properties of air that have been covered so far (color, state of matter, does it have a shape?, Does air have mass? Density). Tell the students that they will be learning about another physical property of air.

2. Do the following demo
   (here is a link: http://www.youtube.com/watch?v=XfFdNNilAJs)
   a. Fill a plastic glass half to three-quarters full of water.
   b. Place a plastic lid on the glass.
   c. Holding the lid with one hand, slowly turn the glass over, so the open end of the glass is facing down.
   d. Ask the students what they expect to happen when you let go of the lid - ask them to support their answers.
   e. Remove your hand that is holding up the lid.
   f. The water does not fall.

3. Give the students a minute or two to think about it, and then ask them how they would explain their observations of the demo. Write the students' hypotheses on the board. Ask them how they might test their hypotheses. For example, one hypothesis might be that the lid stays on the glass due to suction and thus prevents the water from falling. A follow-up question would be what causes the suction? If water is causing the suction, what would happen when the amount of water in the glass was changed?

4. Let the students work in groups repeating the experiment and testing their hypothesis. Give the students about 20-30 minutes to explore what happens. Make sure they record their observations in a simple observation sheet.

5. Some things the students may explore to test or strengthen their hypothesis:
   a. Using different amounts of water in the glass
   b. Comparing what happens when hot and cold water are used
   c. Seeing what happens when the upside-down glass is squeezed
   d. Seeing what happens when the upside-down glass is shaken
   e. Using different materials for the lid (cardboard, paper, metal, wood…)
   f. Whatever else (that is safe) they would like to test. For example, some students added crumpled paper to the cups; others put in pencil stubs. Make sure the students tie back their "experiment" to their hypothesis.

6. After students have done the experiment, let the students discuss their observations in their groups to determine if their observations support their hypothesis.

7. Come together as a class, debrief. Explain to the students that air has a property called “atmospheric pressure”. It is atmospheric pressure that pushes up against the lid and keeps the water from spilling. Atmospheric pressure is about 15 pounds per square inch (psi). Air exerts this pressure everywhere – on the table, the floor, our heads…and that is why astronauts need to wear spacesuits.

Related Concepts:
Air has mass
Air is made up of molecules
Air is a gas
Materials:
- Plastic tubs (to catch water in case of spillage)
- Clear plastic glasses
- Yogurt container lids (preferably clear)
- Water
- Towels for mopping up

Handouts and worksheets:
(attached )

Extensions:
The soda can demo makes a good extension.
(Here is a link: http://www.youtube.com/watch?v=skhSfFz28g0 )
- Add about a tablespoon or two of water in an empty soda can.
- Place the soda can on a burner or hot plate till the water starts steaming.
- Count till 10 once the water starts steaming. Then, using tongs, turn the can into a bowl of cold water.
- Atmospheric pressure will crush the can.
   (Heating the can causes the water to vaporize. As the steam rises, it pushes the air out of the can. Dunking the can in the cold water converts the steam to water, reducing the pressure inside the can. The greater atmospheric pressure outside the can causes the can to implode).

Assessment Questions:
If doing the soda can extension, ask the students to write a one paragraph explanation of why the soda can in the soda can demo was crushed. The clarity of the explanation can provide an assessment of how well the student has understood the concept of atmospheric pressure. If not doing the extension, ask students to explain why astronauts wear spacesuits.
Date: ________________

Names: ______________________________________________________________________

______________________________________________________________________

1. What is your hypothesis?

2. Describe in words and draw a picture showing how you did the experiment.
3. Write down what you observed when you were doing the experiment.

4. Do your observations support your hypothesis? How would you explain your observations after doing the experiment?
Ask-a-Scientist : Sample Questions

1. How do humans filter out the NO2 from the air?
2. When you breathe air and breathe it out, how does it turn into carbon dioxide?
3. What all is in the air?
4. How do people measure air?
5. Will air ever run out on Earth?
6. How long can we live without air?
7. Does air pressure change around the world?
8. Can too much air kill you?
9. Is there a way to bring NO2 levels down?
10. What state has the cleanest air?
11. Will we ever be able to see air, because it is colorless?
12. How can we know if there is anything bad in the air?
13. Can air be liquid or solid?
14. How much air do you need to hear sound?
15. Can oxygen be bad for us?
1. How long has air been on the Earth?

Air, similar to what we know today, has probably been on Earth for only about 1.5 billion years. Oxygen did not appear in the Earth's atmosphere till about 2 billion years ago, and it took at least another 500 million years for the amount of oxygen in the air to reach the amount we see in the atmosphere today. Scientists think that the atmosphere we see today is probably the third atmosphere the Earth has had. The first atmosphere (about 4.5 billion years ago) was likely mostly hydrogen, and Earth lost it all in the heavy solar winds of that time. The Earth's second atmosphere was formed about 4.4 billion years ago by the release of gases by volcanoes and meteor strikes. It was mainly made up of CO2, N2, water vapor, ammonia and methane, and no oxygen. The second atmosphere was transformed into our current atmosphere by the action of cyanobacteria. Our current atmosphere still has a lot of nitrogen (78%), very little carbon dioxide (0.04%) and quite a bit of oxygen (21%).

2. If air is colorless, how do we know it is there?

Although we cannot see air, we can sense it using our sense of touch, smell and hearing. Also, using our sight, we get some clues that air exists as we see smoke rising, clouds floating and birds flying.

3. How do we know what air is made of?

It took scientists centuries and centuries to figure out what air is made of. More than 2000 years ago, the ancient Greeks thought that air was an element, not a mixture of gases. People believed the idea that air was an element for a very long time. It was only in the 1700s that experiments by famous chemists such as Lavoisier, Priestley, Cavendish and others showed that air is a mixture of gases. Priestley discovered oxygen in 1770s, and Cavendish showed that air is 21% oxygen. Daniel Rutherford discovered that nitrogen was a part of air in 1772. It was more than a hundred years later, in 1864, that William Ramsay discovered argon.

4. Can air have a chemical reaction?

Air is a mixture of many compounds like nitrogen, oxygen, argon, carbon dioxide, nitrogen dioxide, etc. Other than Argon (which is very chemically un-reactive), all compounds that make up air can and do take part in chemical reactions under the right conditions. For example, a forest fire is a chemical reaction between carbon in the forest and oxygen in the air. The nitrogen and oxygen in the air also react chemically when heat energy is supplied to form NO and NO2.

5. How does air stay in Earth, but not in space?

The reason why air stays on Earth, but not in space is the same reason why a ball thrown in the air comes back down to Earth and does not go off into space: gravity. All gases that make up the atmosphere, like the ball, have mass, and therefore "fall" towards the Earth because of gravity. However, all molecules in the air have some energy which depends on the temperature. Hydrogen molecules, which are the lightest, often get enough energy to escape Earth's gravity and go off into space. Planets with stronger gravity, like Jupiter, can hold on to even the hydrogen in their atmosphere. Small planets or moons may not have enough gravity to hold on to any gases.

6. Can air pressure and temperature change the sound of air?

The speed of sound does change with temperature: sound travels faster in warmer air. Temperature can change the pitch (or frequency) of the sound in musical instruments. In wind
instruments like the trumpet or flute, warmer air makes the sound slightly higher in pitch. Pressure does not change the speed of sound in the air.

7. Where does N₂ go after it enters our body?
The nitrogen that we breathe in is breathed out unchanged. Nitrogen is an important component of proteins, but humans cannot use the nitrogen in the air to make proteins. This is because the nitrogen bond in the nitrogen molecule is very strong and we cannot break it.

8. When Earth runs out of air, is there another planet with a similar context of air?
Scientists are very interested in finding an earth-like planet outside our solar system. Scientists have defined a "Goldilocks" zone - the orbital distance from a sun where the temperature is not too hot or too cold so that liquid water can exist. NASA scientists have found several planets in our galaxy that are in the Goldilocks zone, but we do not know what their atmospheres are made of - yet.

9. When you breathe air and breathe it out, how does it turn into carbon dioxide?
The air that we breathe in goes into our lungs. From the lungs, the arteries absorb the oxygen and carry it to the cells in the body. Each cell uses this oxygen to "burn" fuel - just like we burn wood - to generate energy. And, just like when we burn wood, burning the fuel in the cell uses up O₂ and produces CO₂. The carbon dioxide (and remaining oxygen) is collected by veins and taken back to the lungs, where it is breathed out. The air we breathe in has 21% O₂ and 0.04% CO₂. The air we breathe out has about 17% O₂ and 4% CO₂.

10. How many molecules are inside the human body?
There are approximately 1.22 x 10^27 molecules in a 12-year-old's body. Another way of saying this is that a 12-year-old has [(one billion) times (one billion) times (one billion)] molecules – which is a humongous number!
If we imagined that each molecule was the size of a small sphere with a diameter of 1 cm (like a ball bearing), then:
One billion molecules would fill 2 big classrooms.
If we began piling (one billion times one billion) of these 1 cm diameter-size molecules over the entire city of Portland, the pile would rise to the height of Mt. Hood! And if we wanted to pack (one billion times one billion times one billion) of theses 1 cm diameter size molecules, we would need two spheres – one the size of Earth, the other the size of the Moon (and we would still have a few molecules left over)!
It is a good thing molecules are much, much, much, smaller than 1 cm!
This is how I estimated the number of molecules in a 12-year-old's body: Let us say that the 12-year old weighs about 45 kg (about 100 lbs). To make the calculation simple, let us say that the body is made up of only water (actually the body is only 2/3 water). One mole of water is 18 g. So, 45 kg of water will be [ (45 x 1000) / 18 ] moles. Each mole has Avogadro's number (6 x 10^23) molecules. So 45 kg will have [ (45 x 1000 x 6 x 10^23 ) / 18] molecules = 1.5 x 10^27 molecules. Since the body is only 2/3 water, we can guesstimate that there will be 1 x 10^27 molecules of water + the molecules in the remaining 1/3 of the body. Since these molecules are heavier than water, there will be fewer than 0.5 x 10^27 of them – let us say 0.2 x 10^27. This leads us to guesstimate that an average 12-year-old has about 1.2 x 10^27 molecules in his/her body.
NO2 sampler assembly instructions for scaffolded inquiry

Names:__________________________________________________________________________________

Date:_____________________________________

Group #:__________________________

Procedure:

Each group will make 6 (3 pairs) of NO2 samplers according to the following steps:

1. Place 2 wire meshes in six red caps. The wire meshes should be flat and at the bottom of the cap. You may need to use a clean metal rod to tap them in.
2. Once 6 caps have meshes, place them in the tray and bring them to the teacher or the scientist to add TEA (triethanolamine) to the meshes in the 6 red caps.
3. Once the TEA solution is placed in the cap, put a tube in each cap. Push it till it reaches the bottom of the cap.
4. Label the samplers (on the caps with the meshes and TEA solution):
   - grp# i1 (so group 1 will label 1i1)
   - grp# i2 (so group 1 will label 1i2)
   - grp# f1
   - grp# f2
   - grp# b1
   - grp# b2
5. Place another empty cap loosely on the open end of each sampler.
6. First place the samplers labeled i1 & i2 inside the classroom, using zip ties and blue tape. The classroom map shows you where to place your tubes. Once the samplers are put up, remove the loose caps and note the time the caps were removed.
7. Next we will place the samplers labeled f1 and f2 in front of the school. The samplers in the front will be placed on either trees or poles along the front of the school. The school map shows where your tubes will be placed. Remove the caps that were loosely put on. Note the time you removed the caps.
8. Finally, samplers labeled b1 and b2 will be placed in the back of the school. The school map shows you where to place your group’s tubes. Remember to remove the loose caps. Remember to note the time you took off the caps!

Sampler uncapping time:

Inside:________________________
Outside front:_____________________
Outside back:_____________________

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Vestal K-8 7th grade science classroom NO₂ map
NO$_2$ (ppb) around Vestal K-8
Measured from 16th – 25th Nov 2011, using passive samplers
Student-directed inquiry

Research Question:
What are the NO2 levels inside and outside students' homes?

Hypotheses:
(1) NO2 levels inside students' houses will be less than outside, unless people use fireplaces during the sampling period.
(2) NO2 levels will be higher at student homes where people cook a lot, do not open windows, or there is a smoker in the house.
(3) Students who live close to freeways or major streets will have higher NO2 levels than students who live further away from busy streets.

Lickert scale for ranking indoor and outdoor NO2 levels at student homes:
Outdoor NO2:
- Distance from freeway
  5 - More than one freeway 1 block from house
  4 - One freeway 1 block from house
  3 - Freeway 2 blocks from house
  2 - Freeway 3 blocks from student house
  1 – Freeway more than 3 blocks from student house
- Distance from busy street
  5 - More than one busy street 1 block from house
  4 - One busy 1 block from house
  3 - Busy street 2 blocks from house
  2 - Busy street 3 blocks from student house
  1 – Busy street more than 3 blocks from student house
- Gas station nearby?
  (Students reasoned that a gas station would increase the idling, and hence increase NO2 emissions)
  3 - More than one gas station within a block of house
  2 - One gas station within a block of the house
  1 - One gas station within 2 blocks of the house

Indoor NO2:
- Gas or electric cooking range?
  2 – Gas cooking range
  1 – Electric cooking range
- Cooking time
  5 – 1.5 hours cooking daily, on average
  4 – one hour of cooking daily, on average
  3 – 45 mins of cooking daily, on average
  2 – 30 mins of cooking daily, on average
  1 – 15 mins of cooking daily, on average
- Ventilation during cooking
  5 – almost always
4  – most of the times  
3  – sometimes  
2  – rarely  
1  – almost never

- **Open windows?**  
  5  – almost always  
  4  – most of the times  
  3  – sometimes  
  2  – rarely  
  1  – almost never

- **Fire in fireplace?**  
  5  – always  
  3  – sometimes  
  1  – rarely

- **Indoor smoking**  
  5  – always  
  3  – sometimes  
  1  – rarely

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NO2 levels inside students homes
Appendix II
Passive Nitrogen Dioxide Sampler: Preparation and Analysis
Created by Matthew Mavko, Portland State University

This page provides instructions for preparing and analyzing passive samplers for measuring gaseous nitrogen dioxide. This method was originally described by Palmes, et al. (1976). It is highly recommended you read through all of the instructions once before beginning, as there are many side notes.

Washing Components

It is essential that all of the parts of the diffusion tube are clean before construction. The stainless screens are best cleaned by soaking in phosphoric acid and distilled water, then rinsed at least three times. Caps and tubes ideally are washed in a sonic bath with distilled water and a detergent such as automatic dishwashing soap or Sparkleen. I have also had luck with generic dishwashing soap, but these have a tendency to leave behind residue and odors. If using a sonic bath, the parts should be left for at least one hour; otherwise, soaking in detergent for several hours will work. After either the bath or soaking, RINSE, RINSE, RINSE with distilled water. All components may be laid out on paper towels to air dry, and should be thoroughly dry before construction.

Constructing tubes

Components necessary for tube construction. See Shopping List at end of document for relevant catalog numbers and pricing.

Two (orange) polyethylene caps, 0.5" ID
Two Stainless steel mesh screens, 0.5" diameter
One acrylic tube: 0.5" OD; 3/8" ID
Triethanolamine (TEA)
Brij-35 (Wetting agent)
Distilled water
Scale
Cleaning detergent (see below)
Phosphoric acid
Clean glassware: 100ml graduated cylinder, 25ml and 200ml beakers
100-1000uL micro-pipettor
20-50uL micro-pipettor (optional)
clean paper towels

There are two methods for preparing the tubes which achieve satisfactory results, although one is preferred over the other. If you have access to micro-pipettors capable of 25-50uL, use the preferred method. Both are illustrated below. Before putting the tubes together, however, the TEA solution must be
prepared.

- Weigh out 1 gram of Brij-35 on a scale. Place in a small beaker and add 9mL distilled water. Heat briefly on a hot-plate to dissolve the solution; the boiling point of Brij-35 is near 110 degrees F.
- In another beaker, combine distilled water and TEA in a 80:20 solution. That is, for 80mL of distilled water, add 20mL of TEA.
- To the 100mL total water/TEA solution, add 167uL (that's micro-liters) of Brij-35. Stir to mix thoroughly.

NOTE: it does not take much to prepare even a large number (e.g. 200) of tubes. If you want, you may cut down the total amount of solution by scaling appropriately. The limiting factor in the solution preparation will be how little Brij-35 solution you are accurately able to measure.

**Preferred method**

For one cap in each pair of caps you have, arrange open side up. Into each cap, place two stainless steel mesh screens, pushing them all the way to the bottom so they lay flat, one on top of the other. Into each cap that now has a pair of screens, use a micropipettor to put 25-50uL (again, micro-liters) onto the surface of the screens.

NOTE: the reason a range is given is that not all micro-pipettors have the same volume increments. I always put in 50uL, but any more than that can cause excess to run down the sides of the tube. Choose a volume in the range that will allow you to only have to put solution in each tube once.

**Alternative method**

If you do not have a micro-pipettor that will measure down to 50uL, use this method. Take a pair of stainless steel screens and sandwich them together. Using a pair of tweezers or needle-nose pliers, grip the screens together and dip into the TEA solution. Lightly dab off the screens on a clean cloth or paper towel and put into the bottom of a cap. Repeat for one cap in each pair of caps.

At this point, there are two options. One is to shove an acrylic tube into each cap that now has a screen, making sure the tube makes contact with the screens, and cap the open end of the tube. It is crucial here not to shove the closing cap on too hard or too far, as it can force excess TEA up into the crack between the outside of the acrylic tube and the inside of the cap with the screens. Placing the closing cap on about half way is good enough. Once all tubes are capped, put them in a sealable bag, label the outside with the date and method of preparation, and put them in cold storage (a normal refrigerator is fine) until ready to use.

Alternatively, if one has access to a clean-air source (i.e. air that is scrubbed clean of ozone, NOx, VOCs and other hydrocarbons, and water), an enclosed chamber can be rigged up to dry out the solution in the open caps before the tubes and closing caps are put on. This will ensure that no excess TEA will run down the inside or outside of the tubes, potentially skewing the analysis. After drying (about 24 hours is sufficient), finish construction as described in the previous paragraph.

**Tube Deployment**

The following are some general guidelines to consider when deploying tubes in the field.
The cap without the screen should be removed upon deployment. Tubes should be placed at least 10cm (4 inches) away from any surfaces—a good way to achieve this is with wire.
Placing tubes out in pairs or triplets may help increase the accuracy of your data and reduce anomalous results.
ALWAYS put out a few capped tubes with your measurement set as blanks as a check against contamination. They are also used in the calculation of NO₂.
Be creative: wire, duct tape, zip ties, and fishing line are your friends. Be sure to place the tubes out of reach and line of sight, 2.5 – 3 meters (8 – 10 feet) off the ground.

**Analysis**

Components necessary for analysis
- Exposed passive samplers
- Sulfanilimide
- Naphthylethylenediamine Dihydrochloride (NEDA)
- Phosphoric acid
- Sodium Nitrite (solid)
- Distilled water
- Scale
- Spectronic-20
- Cuvette that fits into Spectronic-20
- Five test tubes
- Nine 250ml Volumetric flasks; 500ml Erlenmeyer flask; 25ml graduated cylinder
- 20ml, 10ml, 5ml, 1ml glass pipettors
- 100-1000uL micro-pipettor
- Clean paper towels

***Turn on the Spectronic-20 and set the wavelength to 540nm. The instrument needs to warm up for one hour before use.***

**Preparation of Reagent Solution**

Using the scale, weigh out 0.35 grams of NEDA; put into a 250ml volumetric flask and fill with distilled water to the line. Weigh 5.0 grams of sulfanilamide; put into a 250ml volumetric flask. Add to the sulfanilamide 15ml phosphoric acid; fill the flask to the line with distilled water. Note: combining water and phosphoric acid triggers an exothermic chemical reaction; do not be alarmed if the flask becomes warm. When filling each flask with distilled water, add about half the necessary amount and agitate the solution to encourage mixing. Do not fill to the line until the mixture has completely dissolved.

Once both mixtures are completely dissolved, pour the entire contents of the volumetric flask containing the sulfanilamide solution into the 500ml Erlenmeyer flask. Next, add 35.7ml of the NEDA solution to the 500mL flask. Mix well, and cover with a rubber stopper until ready to use.

**Making a Calibration Curve**

The method of analysis to determine the amount of NO₂ captured by the tubes involves measuring the
absorbance of NEDA that has reacted with NO₂. To determine the mass of NO₂ relative to absorbance, a calibration curve must be done using known amounts of NO₂ in solution.

Weigh out 0.70g (0.01mol) of sodium nitrite and add to a 250mL volumetric flask. Fill with distilled water to the line, making sure the solution completely dissolves. Take 1ml of solution and add it to a second volumetric flask and fill with distilled water to the line. This second solution is the stock solution. From the stock solution add the following amounts into each of 5 volumetric flasks:

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After making your standard solutions, add 1.4 ml from each into its own test tube, and add 1.6 ml of sulfanilamide-NEDA solution to each test tube. Let sit 15 minutes. To find the absorbance for each standard solution, follow the steps outlined in the section, "Spectroscopic Analysis of Analyte". Plot your obtained absorbance values versus [NO₂] and apply a simple linear regression. A valid curve will have r² = 0.999 and an intercept near zero. You now have a way to convert absorbance to mass of NO₂. See "Calculation of [NO₂] in Parts Per Billion" for more details.

(An example calibration absorbance curve is shown at the end of the document).

**Preparation of Tubes for Analysis**

Uncap the non-screen end of your exposed tubes and arrange open end up. Using your 100-100uL micro-pipettor (having more than one is helpful here), measure out 1.6ml of the combined sulfanilamide-NEDA solution into each tube AND into the cuvette. Next add 1.4ml distilled water to each tube for a total of 3ml of liquid in each tube AND into the cuvette. The solution will become pink. This coloring is the result of NEDA dye reacting with NO₂ captured by the tubes during exposure. The solution in the cuvette, however, is the blank and should be clear; if it is pink, your sample is contaminated. Let stand for 15 minutes.

**Spectroscopic Analysis of Analyte**

You will now measure the absorbance of each tube. First, the Spectronic-20 needs to be calibrated so we are only measuring the absorbance of the reacted NEDA. This is accomplished by placing the cuvette into the Spectronic-20 with the blank solution and turning the offset dial until the needle reads zero ON THE ABSORBANCE SCALE, NOT THE TRANSMITTANCE SCALE. If the cuvette has a label or marking near the top, always orient the cuvette the same way relative to the marking as the glass will have slight variations in absorbance depending on its orientation. If there is no marking, make one. Remove the cuvette, then empty, rinse, and dry the cuvette.

Now, pour the contents from a tube into the cuvette and measure the absorbance using the Spectronic-20, remembering to orient it the same way for each reading (and the same as the blank reading at the beginning). Record both the absorbance and the tube number. Empty, rinse, and dry the cuvette after each absorbance reading.
Blank tubes should be analyzed in the same manner. The results of all blank absorbance readings may be combined into an average blank absorbance, \( b \), to be used the calculation of NO\(_2\).

**Calculation of [NO\(_2\)] in Parts Per Billion**

Equation 1 below is derived from Fick’s law of diffusion. Several assumptions are made in the calculation of the diffusion rate:
- Constant with temperature
- Not affected by wind or other turbulent flow
- Density of air does not include water vapor, and is for an average temperature of 17°C.

For further discussion of the effects of environmental parameters on diffusion tubes, see Heal, et al. (2000) and Kirby, et al. (2001).

**Definition of relevant variables:**
- \( A_b \) = Absorbance
- \( b \) = Average blank absorbance
- \( l \) = Length of tube [cm]
- \( d \) = Volume of solution [3 mL]
- \( M_w \) = Molecular weight of NO\(_2\) [47 g mol\(^{-1}\)]
- \( s \) = Slope of calibration curve [A L mol\(^{-1}\)]
- \( r \) = Inner radius of tube [cm]
- \( D_L \) = Diffusion coefficient, 0.154 cm\(^2\) s\(^{-1}\)
- \( t \) = Time of exposure [sec]
- \( \rho_a \) = Density of dry air (@ 290 K) [1.21 kg m\(^{-3}\)]

\[
[\text{NO}_2\text{ (ppb)}] = \frac{[(A_b - b) l d M_w (10^9)]}{[s \pi r^2 D_L t \rho_a]} \quad (1)
\]

**Sources**


## Shopping List

Prices and catalogue numbers last checked on 21 November 2005.

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<td>21-278-52</td>
<td>101-1000uL pipettor tips (1000)</td>
<td>18.00</td>
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