LESSON OVERVIEW

Time: 3 50 minute class periods

Subject & Grade Level(s)

MS Earth and Space Sciences (Grades 6-8). This lesson incorporates mathematics and computational thinking concepts and practices.

Brief Overview

In this data science lesson, students practice analyzing and interpreting data in order to answer an investigative question about air pollution in Washington. Student groups first collaborate to graph air pollution data from a city in Washington State. They then compile data as a class in order to observe trends and patterns across cities to make a claim about whether the time of year affects the amount of air pollution in Washington. Through this lesson, students will develop an understanding of foundational data science principles and recognize techniques for manipulating and analyzing data. Students will also gain skills in interpreting trends and patterns in data and writing evidence-based claims. In addition, students will gain an understanding of how air pollution affects human health and the global epidemiology of outcomes attributed to air pollution.

This lesson was originally developed by the Institute for Health Metrics and Evaluation (IHME), an institute affiliated with the University of Washington focused on health metrics sciences (this middle school adaptation of the lesson by Laughing Crow Curriculum). As such, this lesson attempts to introduce students to fundamental data sciences practices that are the work of scientists across fields, including global health. (Image credit: Wikipedia).
STUDENT UNDERSTANDINGS

Anchoring Phenomenon

Exposure to outdoor (ambient) air pollution is a major risk factor for disease for people around the world. There is a wide array of health effects which are believed to be associated with air pollution exposure. Among them are respiratory diseases (including asthma and changes in lung function), cardiovascular diseases, adverse pregnancy outcomes (such as preterm birth), and even death. While air pollution is a global phenomenon, it has very local impacts that can profoundly affect communities in unique and profound ways. In Washington State for instance, increasing temperatures, rapid urbanization, increased manufacturing, and natural disasters can affect the region’s air quality which, in turn, can contribute to poorer health outcomes for residents. In order to alleviate/mitigate the consequences of air pollution in Washington State, we must assess and understand levels and trends of exposure to air pollution to better identify solutions and interventions.

Driving Questions

- How can data be used to understand changing levels of air pollution exposure in the State of Washington?
- How can we present air pollution data in a way that reveals patterns or relationships?
- What are the health effects from outdoor air pollution exposure to Washington residents?
- How can data be used to make predictions and recommendations about air pollution and human health?

Learning Objectives/Success Criteria

Students will be able to...

- Recognize and explain how air pollution affects human health.
- Graph data in order to observe trends and patterns.
- Make a claim about whether the time of year affects the amount of air pollution in Washington and support it with data.
- Generate basic descriptive statistics using a set of data including mean, median, min, and max.
- Interpret trends and patterns of health outcomes related to air pollution by using various forms of data visualization.

Mathematical and Computational Thinking

This lesson was designed to introduce students to data science. It engages students in fundamental data science practices, including manipulating, analyzing, and visualizing data. For each of these steps, students are encouraged to engage in sensemaking around why data is important and how graphing and doing statistical analyses of data extracts meaning from it. The following linked teacher resource may be helpful for framing your approach to computational thinking in the science classroom:

- STEM Teaching Tools Practice Brief #56: Engaging students in computational thinking during science investigations.
**NEXT GENERATION SCIENCE STANDARDS**

This lesson builds toward the following bundle of middle school level Performance Expectations (PEs). Standards marked with an asterisk (*) are concepts or practices aligned to this lesson, but not included in the PE bundle. Hyperlinks direct to relevant sections of the Next Generation Science Standards and *A Framework for K-12 Science Education*.

<table>
<thead>
<tr>
<th>NGSS Performance Expectations</th>
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<tbody>
<tr>
<td><strong>MS-ESS3-3</strong>: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.</td>
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<thead>
<tr>
<th>Disciplinary Core Idea(s)</th>
<th>Crosscutting Concepts (CCCs)</th>
<th>Science and Engineering Practices (SEPs)</th>
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<tbody>
<tr>
<td>ESS3.C Human Impacts on Earth Systems</td>
<td>Systems and systems models *Patterns *Stability and change</td>
<td>Using mathematics and computational thinking Influence of science, engineering, technology, and applications of science *Analyzing and interpreting data</td>
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Connections to Common Core State Standards in Mathematics include the following mathematical practices:

- MP.2 [Reason abstractly and quantitatively](link)
- MP.4 [Model with mathematics](link)
# TEACHER PREPARATION

## Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Description/Source</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Classroom Computer</td>
<td>Computer with internet access, projector, and speakers</td>
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<tr>
<td>Student Computers</td>
<td>Computers need to have access to internet for the last topic/step of the lesson.</td>
<td>1/student or group of students</td>
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<tr>
<td>Student Handouts</td>
<td>Make copies of the student handouts, one of each handout for each group of students.</td>
<td>1/student or group of students</td>
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<tr>
<td></td>
<td>• <strong>Data Science in Global Health</strong> (1/student or group)</td>
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<td></td>
<td>• <strong>Excel spreadsheet</strong>: WA_Air_Pollution_Data. <em>Print this excel document and cut out the different cities so that each group can have the data for just their city.</em></td>
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<tr>
<td>Teacher Slide Deck</td>
<td>Air Pollution slide deck (elements of slide deck below)</td>
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<tr>
<td></td>
<td>• Part I: Introduction to Air Pollution (Slides #1-6)</td>
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<td></td>
<td>• Part II: Air Pollution and Human Health (Slides #7-9)</td>
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<td></td>
<td>• Part III: Data Science and Air Pollution in Washington State (Slides #10-12)</td>
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<td>• Part IV: How Air Pollution is Measured (Slides #13-16)</td>
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<td>• Part V: Compiling Data Across Cities in Washington (Slides #17-22)</td>
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<td></td>
<td>• Part VI: Generating Basic Statistics (Slides #23-30)</td>
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## Notes to Teacher for Preparing to Teach this Lesson

- Computers are required for the last topic/step of this lesson.
- Make copies of the student handouts, as indicated in the materials table above.
- Print out the Excel spreadsheet (Data for Students tab) and cut out the different cities so that each student group will have the data for just their city.
- Decide how to divide the class into groups of 2 or 3 students. Each group will be assigned a city. There are 9 cities, so divide groups accordingly:
  - Anacortes
  - Bremerton
  - Darrington
  - Kent
  - Methow
  - Mountlake Terrace
  - Scotch (Creek) Basin
  - Seattle
  - Tacoma
- An important component of engaging in data practices is having students pause during their computational work to engage in sensemaking together. This teacher resource on science talk and the embedded Student Talk Flow Chart provides ideas of how to structure student-to-student talk and teacher-student talk in equitable ways.
  - **STEM Teaching Tools Practice Brief #35**: How can I foster curiosity and learning in my classroom? Through talk!
<table>
<thead>
<tr>
<th>Topic</th>
<th>Teaching Activities</th>
<th>Student Activities</th>
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<tbody>
<tr>
<td>Warm-up Questions and Investigative Question #1</td>
<td>1.1 Teacher asks students:</td>
<td>1.1 Students provide answers to the warm-up questions.</td>
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<td>• What they know about air pollution or where they have observed air pollution in their community.</td>
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<td>• What they know about how air pollution affects human health. Can the students think of any specific instance/event they know of where air pollution impacted human health?</td>
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<td>• Ideas students have about how they think air pollution might be measured.</td>
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<td>1.2 Teacher reads aloud investigative question (#1) on Slide #1 and has students Turn and Talk to discuss their hypotheses and ideas.</td>
<td>1.2 Students do Turn and Talk.</td>
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<tr>
<td>Presentation on Air Pollution</td>
<td>2.1 Power Point presentation on air pollution, divided into following parts:</td>
<td>2.1 Students listen and ask questions.</td>
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<tr>
<td></td>
<td>• Part I: Introduction to Air Pollution (Slides #1-6)</td>
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<td>• Part II: Air Pollution and Human Health (Slides #7-9)</td>
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<td>• Part IV: How Air Pollution is Measured (Slides #13-16)</td>
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<tr>
<td>Investigable Questions and Identifying Variables</td>
<td>3.1 Teacher divides class into groups of 2 or 3 students (there are 9 cities, so divide groups accordingly) and assigns a city to each group. Distribute copies of the Student Handout: Data Science in Global Health.</td>
<td>3.1 Students sit with their groups.</td>
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<td>3.2 Read overview for Part I on the Student Handout as a class. Give groups a few minutes to write answers to the questions for Part I. Depending on students’ familiarity with variables, the teacher may need to provide more support in identifying variables, possible controls, and making a hypothesis. Part I could be done as a class, if necessary.</td>
<td>3.2 Groups write their answers to the questions for Part I on the handout.</td>
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<tr>
<td>Graphing Data to See Patterns</td>
<td>4.1 Teacher distributes hard copies of city data from the Excel spreadsheet: WA_Air_Pollution_Data, making sure to give each group only the data for their assigned city. Read overview for Part II as a class.</td>
<td>4.1 Groups use Excel spreadsheet of Washington air pollution for their city to make a graph.</td>
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</table>
Note: Optional Slide #31 provides a Washington State map with an approximate plot of each city/region’s location. Optional Slide #32 provides descriptions of the codes in the dataset.

Teacher emphasizes that it is difficult to see patterns/trends or relationships in raw data. By graphing, the data, we can more easily observe any patterns. Depending on students’ familiarity with graphing data, the teacher may need to provide more support in discussing the different types of graphs and which graph might be most appropriate to represent this data and answer the investigative question. Teacher might consider using Excel to show a few different graph types and help students reason through which type of graph might best represent the air pollution data. A line graph would be best, but a bar graph would also work. Groups will also need to decide whether they will make a double or triple line graph (depending on how many years they have data for their city), using three different colors or make separate graphs for each year.

4.2 Groups make a graph (or graphs) to represent the amount of air pollution per month for their city across all years using the Excel spreadsheet: WA_Air_Pollution_Data. Once groups have finished making their graph(s), they should answer the graph analysis questions as a group.

4.3 Teacher brings students back together and asks them report out to the entire class about their findings for their city.

- Teacher projects Slide #17 and reads aloud the topic and the question: *Why do we need to analyze data from across cities in order to make a claim about whether the time of year affects the amount of air pollution in Washington?*
- Teacher solicits ideas from students about why we need to compile data from across cities in order to make a claim about whether the time of year affects the amount of air pollution in Washington. Students should say that since the question is about whether there is a relationship between the time of year and the amount of pollution in Washington, they need to analyze data from multiple cities, not just their assigned city. The more data (air pollution from different cities) they analyze, the more reliable their claim will be.

4.2 Students analyze and interpret the data represented in their graph by answering the graph analysis questions on the handout.

4.3 Students discuss their ideas about why we need to compile data from across cities in Washington (rather than just one city) to make a claim about whether the time of year affects the amount of air pollution.
| Making a Claim and Supporting it with Data | 5.1 Read overview Part III on the Student Handout as a class. Groups are given a few minutes to write a claim that answers Investigative Question #1 and support their claim with data from the table on Slide #18. Leave Slide #18 projected so that students can reference it and include quantitative details in their evidence statement from the table. Depending on students’ skill level with writing claims and evidence, sentence frames written on the whiteboard might be helpful:  
• CLAIM: There _____[is/is not] a relationship between the time of year and the amount of air pollution in Washington.  
• EVIDENCE: Our evidence comes from data on the amount of air pollution each month, measured in 9 cities in Washington during 2014, 2015, and 2016. Of the 9 cities, _____ cities had the highest air pollution in August, followed by _____ cities in September and _____ cities in July. |
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<tr>
<td>4.4 Groups share out the months with the highest air pollution and the months with the lowest air pollution for each year. Teacher tallies these months in the table on Slide #18.</td>
<td>4.4 Groups share out the months with the highest and lowest air pollution for each year. Teacher tallies these months in the table on Slide #18.</td>
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</tbody>
</table>
| 4.5 Teacher reads aloud questions on Slide #18 and solicits students’ responses:  
• Does there appear to be a trend in the highest amount of air pollution and the month(s) across cities?  
• Does there appear to be a trend in the lowest amount of air pollution and the month(s) across cities? | 4.5 Students discuss questions with their group, then a few students share out with the class. |
<p>| 4.6 Teacher projects slide #19 and allows students time to do Turn and Talk for the question, then calls on a couple of students to share their thinking with the class. | 4.6 Students do Turn and Talk for question on Slide #19. |
| 4.7 Teacher projects Slides #20-22 and presents the information on the slides. After the information has been presented, check for understanding by asking the class: According to the information you just learned about wildfires in Washington, what is a likely explanation for why the amount of air pollution is highest in August/during the fall? | 4.7 Students explain that the wildfire season happens during later summer and early fall and is a likely explanation for the higher levels of pollution observed during August and nearby months. |
| 5.1 Groups are given time to write a claim and support it with data. | 5.1 Groups are given time to write a claim and support it with data. |</p>
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>6.1</td>
<td>Teacher projects Slide #23 and reads aloud the topic and question.</td>
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<td>• How do basic statistics help us interpret and gain additional meaning from the data?</td>
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<td>6.2</td>
<td>Teacher projects Slide #24, reads aloud Investigative Question #2 and gives students a minute to discuss the Turn and Talk questions.</td>
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<td>• How does location affect the amount of air pollution in Washington?</td>
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<td>6.3</td>
<td>Teacher explains that in addition to graphing data, another way that scientists organize and interpret data in order to find meaning is through statistical analysis. Next, groups will find some basic statistics for their city’s air pollution and then compare those statistics with another group in order to answer Investigative Question #2: How does location (city) affect the amount of air pollution?</td>
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<td>Continue with the Power Point presentation on basic statistics using Slides #25-29. Introduce the concepts of statistics, mean, median, minimum, and maximum.</td>
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<tr>
<td>6.4</td>
<td>Read overview for Part IV on the Student Handout as a class. Groups complete Student Handout Part IV. First they generate basic statistics for their city.</td>
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<td>Once most groups are finished calculating statistics for their city, teacher projects Slide #30. Each group then pairs up with another group and compares statistics for their city and the other group’s city in order to answer Investigative Question #2 and the additional questions on the handout.</td>
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<td>Teacher might consider providing sentence frames on the whiteboard for the claim and evidence statements:</td>
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<tr>
<td></td>
<td>• CLAIM: _______[city] has a higher mean (or median) level of air pollution than _______[city].</td>
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<td></td>
<td>• EVIDENCE: Our evidence is that the mean (or median) air pollution for all three years (or each separate year) _______ was __________. The mean (or median) air pollution for _______ was __________.</td>
</tr>
<tr>
<td>6.1</td>
<td>Students listen and ask questions.</td>
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<tr>
<td>6.2</td>
<td>Students Turn and Talk to discuss the questions.</td>
</tr>
<tr>
<td>6.3</td>
<td>Students listen and ask questions.</td>
</tr>
<tr>
<td>6.4</td>
<td>Groups calculate mean, median, min, and max. After the statistics have been generated and compared with another group, the two groups collaborate to write a claim that answers Investigative Question #2 and support it with statistics.</td>
</tr>
</tbody>
</table>
| Observing and Asking Questions about the State of Global Air Pollution | 7.1 Read overview for Part V on the Student Handout as a class. Have individual students or groups use computers to explore the State of Global Air map ([http://www.stateofglobalair.org/air#PM](http://www.stateofglobalair.org/air#PM)) and then write their observations and possible investigable questions that they are curious about.

7.2 If any students or groups finish early: they can explore how air pollution levels have changed in different countries over the last couple of decades by following the link to State of Global Air plot view: [http://www.stateofglobalair.org/data/#/air/plot](http://www.stateofglobalair.org/data/#/air/plot)
  - Go to the “Choose a country” tab
    - In the drop down menu, pick one of the countries you identified from the map view.
    - Click on that country name.
  - The plot should generate a yellow line representing PM2.5 levels between 1990 and 2015.
  - To compare the three country PM2.5 in a time series, you can add a country by selecting them in the “+Add countries” drop down menu. | 7.1 Students explore the State of Global Air map, then write observations and investigable questions they are curious about.

7.2 Students who finish early can explore how air pollution levels have changed in different countries in the last couple of decades. |
| Discussion & Wrap-up | 8.1 Students share with the class interesting observations and investigable questions from their exploration on the State of Global Air webpage. An Exit Ticket could be assigned at this point asking students to summarize what they learned from exploring the State of Global Air webpage.  
8.2 Teacher asks students what we can do with this data and results to improve air quality/pollution in Washington. Teacher asks students to generate ideas in their groups. Students report out and teacher writes ideas on the board. | 8.1 Students share interesting observations and investigable questions they came up with while exploring the State of Global Air webpage.  
8.2 Students will ask each other questions and discuss their ideas. |
Student Assessment Opportunities

- Students’ thoughtful participation during class discussions, group share-outs, as well as responses on the Student Handout can all be used for assessment purposes.

Student Handout & Teacher Resources

Student Handouts:
- **Student Handout**: Data Science in Global Health (1/student or group)
- **Excel spreadsheet**: WA_Air_Pollution_Data

Teacher Resources:
- **Air Pollution slide deck** (elements of slide deck below)
  - Part I: Introduction to Air Pollution (Slides #1-6)
  - Part II: Air Pollution and Human Health (Slides #7-9)
  - Part III: Data Science and Air Pollution in Washington State (Slides #10-12)
  - Part IV: How Air Pollution is Measured (Slides #13-16)
  - Part V: Compiling Data Across Cities in Washington (Slides #17-22)
  - Part VI: Generating Basic Statistics (Slides #23-30)

Suggested Lesson Extensions

- For the Introduction, students could be asked to engage in a self-documentation activity around sources of ambient air pollution in their own community and lives. This resource provides an overview of how to engage in this kind of culturally-responsive launch to the lesson.
  - **STEM Teaching Tools Practice Brief #31**: How to launch STEM investigations that build on student and community interests and expertise.
- This lesson could be extended to focus additional time to understanding the health impacts of air pollution on different body systems.
- Students could use the latitude and longitude information provide for each city/region in the dataset to plot the locations using Google Maps.
- Students can also explore how air pollution levels have changed in different countries over the last couple of decades by following the link to State of Global Air plot view: [http://www.stateofglobalair.org/data/#/air/plot](http://www.stateofglobalair.org/data/#/air/plot)
  - Go to the “Choose a country” tab
    - In the drop down menu, pick one of the countries you identified from the map view.
    - Click on that country name.
  - The plot should generate a yellow line representing PM2.5 levels between 1990 and 2015.
  - To compare the three country PM2.5 in a time series, you can add a country by selecting them in the “+Add countries” drop down menu.
**Notes on Adaptations and Inclusivity**

- **Scientific & Computational Vocabulary:** Students may need some support in understanding the terminology embedded in this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. The following list captures some of the scientific, mathematical, and computational terms used in the lesson materials.
  - **Mean:** The mean or average that is used to derive the central tendency of the data in question. It is determined by adding all the data points in a population and then dividing the total by the number of points.
  - **Median:** A simple measure of central tendency. To find the median, we arrange the observations in order from smallest to largest value. If there is an odd number of observations, the median is the middle value. If there is an even number of observations, the median is the average of the two middle values.
  - **Minimum:** The smallest observation (number) in a sample of data.
  - **Maximum:** The largest observation (number) in a sample of data.
  - **Data assessment:** The process of scientifically and statistically evaluating data in order to determine whether they meet the quality required for projects or business processes and are of the right type and quantity to be able to actually support their intended use.
  - **PM2.5:** Refers to atmospheric particulate matter (PM) that have a diameter of less than 2.5 micrometers, which is about 3% the diameter of a human hair.

- **Inclusivity for All Learners:** Consider how the lesson activities may need to be adapted to be accessible for all learners. For example, what accommodations may a student with a visual or mobility impairment need to engage in the computational work? How might you elicit, build connections with, and leverage students’ everyday expertise with data practices? How might you group students with diverse expertise and learning needs into teams so that they can support each other?

**TEACHER RESOURCES**

**Background Information on Air Pollution in Global Health**

- WHO Ambient Air Pollution: Pollutants
  [https://www.who.int/airpollution/ambient/pollutants/en/](https://www.who.int/airpollution/ambient/pollutants/en/)

- Our World in Data: Air Pollution
  Hannah Ritchie and Max Roser, October 2017
  [https://ourworldindata.org/air-pollution](https://ourworldindata.org/air-pollution)

- State of Global Air 2019 Report
  IHME, 4/3/19
Health Impacts of Air Pollution
European Environment Agency, 4/22/16

Air Pollution, Climate, and Health
Breathe Life, Climate & Clean Air Coalition, WHO
https://www.who.int/sustainable-development/AirPollution_Climate_Health_Factsheet.pdf

The Weight of Numbers: Air Pollution and PM2.5
UnDark Magazine and the Pulitzer Center on Crisis Reporting
https://undark.org/breathtaking/

Career Links

The following careers are related to data sciences and global health.

- **Biostatistician**: [https://www.careersinpublichealth.net/careers/biostatisticians/](https://www.careersinpublichealth.net/careers/biostatisticians/)
- **Data analyst**: [https://careerlink.com/quick/data-science-jobs](https://careerlink.com/quick/data-science-jobs)
- **IHME Post-Bachelor Fellow**: [http://www.healthdata.org/about/team/pbf](http://www.healthdata.org/about/team/pbf)

The career of a Data Analyst is featured on the STEM Global Pathways to Global Health Careers poster and accompanying fact sheets (see the Information Technology section):


**Credit**: This activity was originally developed as a high school-level lesson by the Institute for Health Metrics and Evaluation (IHME), a global health organization located in Seattle, WA and adapted for a STEM Global Teacher Workshop in April 2019. Original authors include: Austin Carter, Doctoral Candidate and Researcher, IHME; Joseph Frostad, Doctoral Candidate and Researcher, IHME; Sean Lassiter, Senior Education Program Manager. This middle school-level adaptation was authored by Janneke Petersen for Laughing Crow Curriculum. Lesson plan development and editing supported by Kristen Bergsman of Laughing Crow Curriculum.