

Introduction to Human Geography Using ArcGIS Online

Chapter 12 Exercises

Exercise 12.1: US air pollution: Where is it bad and where is it improving?

Introduction

At a national scale the United States ranks among countries with the cleanest air. However, as we all know, there can be great spatial variation in air pollution within national borders. And just as pollution varies over space, levels of air pollution also have temporal variation—levels can rise and fall over time as economic activity and pollution controls change. In this exercise you will look at particulate matter air pollution by metropolitan area in the United States and identify the places with the highest levels. You will then calculate the rate of change in air pollution from 2000 to 2016 to see if pollution is getting better or worse in metropolitan areas.

Objectives

- Classify metro areas based on levels of particulate matter air pollution.
- Evaluate why air pollution varies spatially.
- Evaluate why air pollution varies temporally.

- 1. Open the Chapter 12 US Air Pollution map and sign in to your ArcGIS Online account: <https://arcg.is/qzjir>**

The map contains the following layer:

- a. **PM2.5 Weighted Annual Mean - ($\mu\text{g}/\text{m}^3$). This is the annual mean value of particulate matter air pollution of metropolitan areas between the years 2000 and 2016. Data is not available for all areas.**

The World Health Organization recommends that PM 2.5 particulate pollution falls at 10 $\mu\text{g}/\text{m}^3$ or less. You will begin by finding the places where this global standard is exceeded.

2. **Hover your cursor over the PM2.5 Weighted Annual Mean layer and select Change Style.**
3. **In step one of the Change Style window, select Yr2016. This shows particulate matter levels for the year 2016. Note again that data is not available for all metro areas.**
4. **In step 2, under Counts and Amounts (Color), select Options.**
5. **For the Theme, click the drop-down arrow and select Above and Below.**

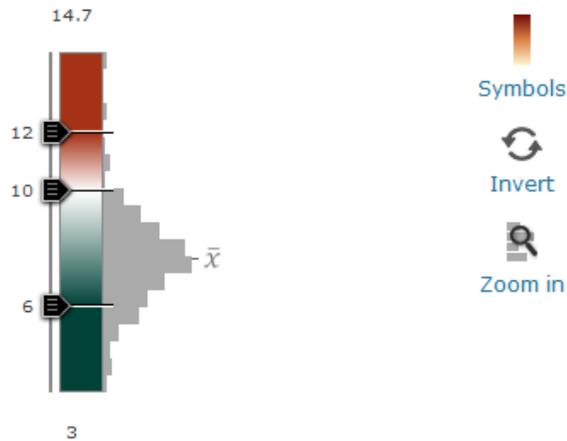
In the color ramp, you want to set the middle value to 10 so that areas that meet the air pollution standard are one color and areas that do not are another color.

6. **Click 9.2 on the left side of the color ramp and change it to 12 (or any other number between the cutoff point of 10 and the maximum value of 14.7). Then click 7.58 and set it to 10.**

Yr2016

Divided By: None

Theme: Above and Below



7. Click OK, then click Done.

Your map now shows the places where particulate matter averages meet World Health Organization standards and places that do not.

Question 12.1.1

Which state has the most metropolitan areas that exceed WHO particulate matter standards?

Next, you will map by quintile so that the metropolitan areas are divided into five groups from most polluted to least.

8. Again, hover your cursor over the PM2.5 Weighted Annual Mean layer and select Change Style.

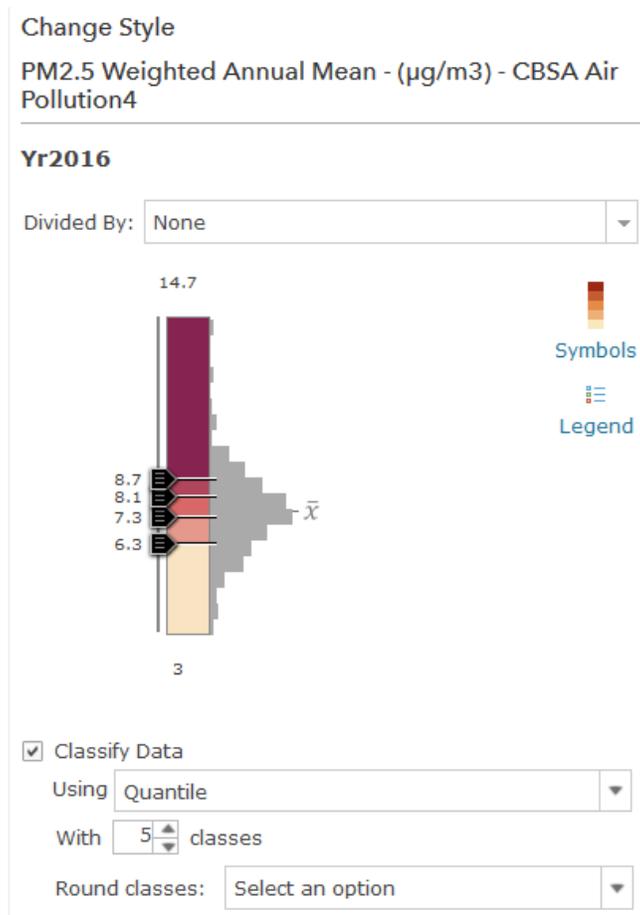
9. In step one of the Change Style window, select Yr2016.

10. In step 2, under Counts and Amounts (Color), select Options.

11. For the Theme, click the drop-down arrow and select High to Low.

12. Check the box next to Classify Data.

13. Set the parameters to Using Quantile with 5 classes.



14. Click OK, then click Done.

Question 12.1.2

List five metro areas from the bottom (lowest) quintile and five from the top quintile (highest) in the table.

Top Quintile (Most Polluted)	Bottom Quintile (Least Polluted)

Question 12.1.3

Locate your metro area or the one closest to you. Which quintile does it lie in?

Question 12.1.4

Based on the Sources of Pollution section of your textbook, which causes are the most significant in your metro area (or the one closest to you)?

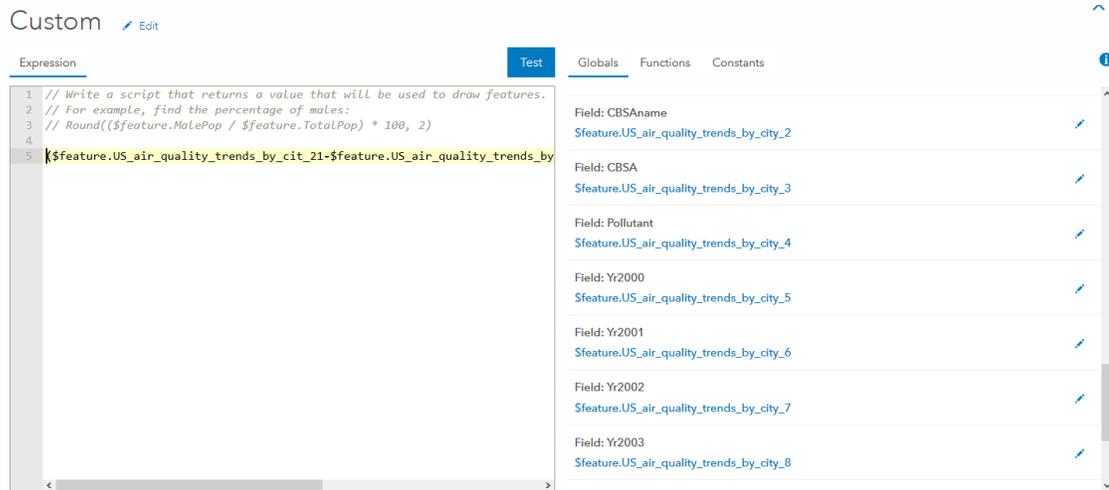
Just as important as current levels of air pollution are temporal trends. Is air getting cleaner or dirtier with time? You will map the percent change in particulate matter air pollution between 2000 and 2016 to see which places are seeing improved air quality and which are seeing a decline.

15. Hover your cursor over the PM2.5 Weighted Annual Mean layer and select Change Style.

16. In step one of the Change Style window, click the drop-down arrow and select New Expression.

17. In the Custom window, calculate the percent change with the following expression:

$$\frac{(\$feature.US_air_quality_trends_by_cit_21 - \$feature.US_air_quality_trends_by_city_5)}{\$feature.US_air_quality_trends_by_city_5} * 100$$



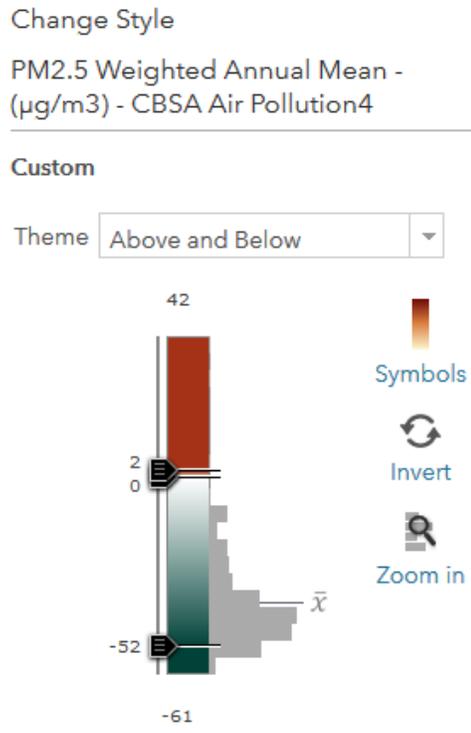
18. Click OK.

The map defaults to Counts and Amounts (Size), but we want to change it to Counts and Amounts (Color).

19. In the Change Style window, Select Counts and Amounts (Color), then click Options.

20. Change the Theme to Above and Below.

21. In the color ramp, click the -26 value and change it to 2 (or a number between our cutoff point of 0 and the maximum value of 0.4). Then change -39.3 to 0.



Your map now shows metro areas with worsening air pollution in one color (above 0) and those with cleaner air in another (below 0). As you can see, air pollution has improved in most places.

Question 12.1.5

Print or take a screenshot of your map.

Question 12.1.6

For your metro area (or one close to you), how has air pollution changed? Based on the shades on your map, did it go down a lot (darker shades) or just a little (lighter shades)?

Question 12.1.7

Based on the air pollution Solutions section of the textbook, which types of controls (or lack of controls) do you think have contributed to the change in your metro area between 2000 and 2016? Your instructor may also ask you to research actions by the state or local air pollution control agency.

Conclusion

Relative to much of the world, air quality in the United States exhibits positive spatial and temporal patterns. Spatially, most metro areas show annual mean levels of particulate matter pollution below WHO thresholds (although daily maximums can still exceed these levels). On top of that, air quality is mostly improving over time. As populations and economic activity grow, the challenge is to make further gains in air quality so that our cities and rural communities become healthier places to live.

Exercise 12.2: Air pollution exposure at a local scale

Introduction

As with all spatial phenomena, patterns of air pollution vary by scale. At a country scale, the expanding economies of middle-income states typically lead to worse pollution than those of higher-income ones. And as you saw in the previous exercise, air pollution levels vary by metropolitan area within countries as well. At a more local scale, studies now show that air pollution is worse within roughly 1,000 feet of freeways, as exhaust, dust, and other particulate matter from passing vehicles accumulates along these roadways. In this exercise you will use data on diesel emissions by census tract in a US city to see if areas within 1,000 feet of freeways

have higher concentrations than those that are further away. You will also calculate the number of people living within 1,000 feet of freeways to see how many are potentially exposed to higher concentrations of pollutants.

Objectives

- Calculate levels of diesel air pollution by distance from freeways.
- Calculate the number of people living within 1,000 feet of freeways.
- Describe how changes in transportation technology may influence air pollution levels along freeways.

1. **Open the Chapter 12 Local Scale Air Pollution map and sign in to your ArcGIS**

Online account: <https://arcg.is/ue0aq>

The map contains the following layers:

- a. **USA Freeway System. This layer shows all major US freeways.**
- b. **Diesel PM. This layer shows the diesel particulate matter level in air ($\mu\text{g}/\text{m}^3$), by census tract.**

The map opens showing the US freeway systems. The Diesel PM layer is not turned on yet.

2. **Zoom to your city and then click the box next to Diesel PM in the Contents pane to turn it on.**

The map shows levels of diesel particulate matter by census tract. Observe the patterns in your city to see if some places have higher concentrations than others.

To test whether diesel pollution is higher close to freeways you will identify census tracts within 1,000 feet of a freeway. You will then compare the average level to that of census tracts not within 1,000 feet of a freeway.

- 3. Hover your cursor over the Diesel PM layer and select Perform Analysis.**
- 4. In the Perform Analysis window, select Find Locations, then click Find Existing Locations.**
- 5. In the Find Existing Locations window, select the Diesel PM layer in step one.**
- 6. Just below step two, click Add Expression.**
- 7. In the Add Expression window, set the expression: Diesel PM, within a distance of, 1000 Feet from USA Freeway System.**

Add Expression

The screenshot shows the 'Add Expression' dialog box. It contains the following elements:

- A dropdown menu with 'Diesel PM' selected.
- A dropdown menu with 'within a distance of' selected.
- A text input field containing '1,000'.
- A dropdown menu with 'Feet' selected.
- The word 'from'.
- A dropdown menu with 'USA Freeway System' selected.
- Two buttons at the bottom right: 'ADD' (blue) and 'CLOSE' (grey).

- 8. Click Add.**

Find Existing Locations

1 Choose layer containing features you want to find using attribute and spatial queries

Diesel PM

2 Build a query to find features

Diesel PM within a distance of 1000 Feet from USA Freeway System

ADD EXPRESSION

9. In step three, give your layer a unique name.

10. Make sure Use current map extent is checked. You only want to analyze the local area see in your map.

11. Click Show credits. If you are using more than about 3 credits, zoom in to a smaller area. Then look at Show credits again and make sure you are at about 3 or less.

12. Click Run Analysis.

Your new layer shows all census tracts within 1,000 feet of a freeway. Next, you will calculate the average value of diesel pollution for these tracts.

13. Hover your cursor over the name of your new layer and Show Table.

14. In the attribute table, click on the DSLPM field heading and select Statistics.

15. Write the average value in the first column of the table (question 12.2.1).

Question 12.2.1

Diesel PM Within 1,000 ft	Diesel PM Not Within 1,000 ft

16. Keep your map zoomed to the same area.

You will now calculate diesel pollution levels for all census tracts in your map view that are not within 1,000 feet of a freeway.

17. Hover your cursor over the Diesel PM layer and select Perform Analysis.

18. In the Perform Analysis window, select Find Locations, then click Find Existing Locations.

19. In the Find Existing Locations window, select the Diesel PM layer in step one.

20. Just below step two, click Add Expression.

21. In the Add Expression window, set the expression: Diesel PM, not within a distance of, 1000 Feet from USA Freeway System.

Add Expression

Diesel PM	not within a distance of	
1,000	Feet	from
USA Freeway System		

ADD

CLOSE

22. Click Add.

23. In step three, give your layer a unique name.

24. Make sure Use current map extent is checked. You only want to analyze the local area see in your map.

25. Click Show credits. You should still be using about 3 credits or less.

26. Click Run Analysis.

Your new layer shows all census tracts not within 1,000 feet of a freeway. If you turn off all layers except for your newest and the freeways you can see which census tracts are selected.

Next, you will calculate the average value of diesel pollution for these tracts.

27. Hover your cursor over the name of your new layer and Show Table.

28. In the attribute table, click on the DSLPM field heading and select Statistics.

29. Write the average value in the second column of the preceding table (question 12.2.1).

Question 12.2.2

Based on the results in the table, are diesel concentrations higher in tracts within 1,000 feet of a freeway? If not, why could this be? You can zoom in to areas with high concentrations and switch the basemap to imagery. You may be able to see land uses that help explain why other areas have high levels of diesel pollution.

Now you will calculate how many people live within 1,000 feet of a freeway in your study area. You will use the same study area as in the previous analysis.

30. Hover your cursor over the USA Freeway System layer and select Perform Analysis.

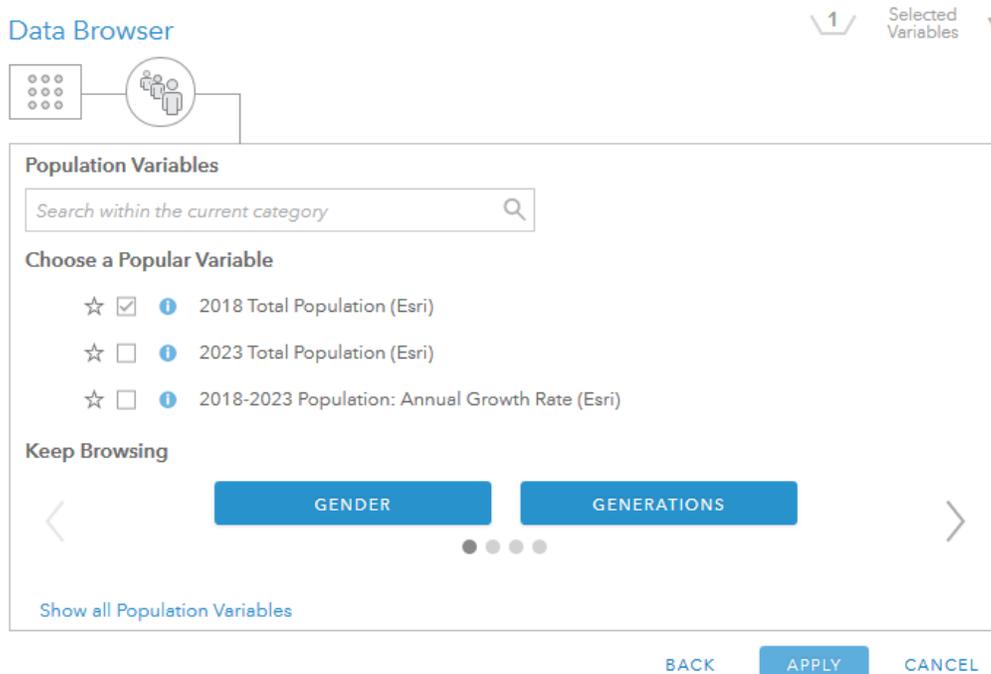
31. In the Perform Analysis window, select Data Enrichment, then click Enrich Layer.

32. In the Enrich Layer window, set step one to USA Freeway System.

33. Just below step two, click Select Variables.

34. In the Data Browser window, click Population.

35. Select the 2018 Total Population (Esri) variable, then click Apply.



36. In step 3, set Line distance to 1000 feet.

37. Check the box next to Return result as bounding areas. This will show the 1,000-foot polygon around all freeways.

Enrich Layer

1 Choose layer to enrich with new data

USA Freeway System

2

2018 Total Population

SELECT VARIABLES 1 Selected Variables

3 Define areas to enrich

Line distance

1,000 Feet

Return result as bounding areas

38. In step 4 give your layer a unique name.

39. Make sure the box is checked next to Use current map extent. You only want data for census tracts in your study area.

40. Click on Show credits. You should use less than 1 credit.

41. Click Run Analysis.

Your new layer shows polygons 1,000 feet from freeways in your study area. Now you will see how many people live in these areas.

42. Hover your cursor over your new layer and select Show Table.

43. In the attribute table, scroll to the far right, click the 2018 Total Population field heading, and select Statistics.

Question 12.2.3.

From the Statistics window, write the Sum of Values. This represents how many people live within 1,000 ft of a freeway in your study area.

Question 12.2.4

What types of changes in transportation technology and emissions controls may help reduce freeway-adjacent pollution levels?

Question 12.2.5

To show that your analysis was completed correctly, turn on your enriched layer around the freeways, the census tracts not within 1,000 ft of a freeway, and USA Freeway System, and submit a screenshot. It should resemble this sample area:



Conclusion

Even within metropolitan areas, levels of air pollution can vary substantially. Cities across the nation are struggling to balance the need for affordable residential housing development in less than ideal places, with the need to protect human health. With technological advancements, one can only hope that the future brings ever cleaner vehicles, so that fewer places are subject to excessive levels of pollution.

Exercise 12.3: Water pollution: sanitation facilities and human health

Introduction

Improved sanitation facilities hygienically separate human excreta from human contact and include various types of flush toilets and latrines connected to sewers, septic tanks, or pits. While these types of facilities are the norm in developed countries, many people in developing countries lack access to them. This results in human waste that contaminates water and soils, leading to human illness and increased death rates. In this exercise you will analyze the relationship between access to sanitary facilities and the death rate from exposure to unsafe water, unsafe sanitation and lack of hygiene. You will also map improvements in access to sanitation facilities between 1990 and 2015.

Objectives

- Describe the spatial relationship between improved sanitation facilities and mortality rates from unsafe water.
- Calculate and compare mortality rates by level of access to improved sanitation.
- Calculate percent change in access to improved sanitation facilities between 1990 and 2015.

1. Open the Chapter 12 Water Pollution and Health map and sign in to your

ArcGIS Online account: <https://arcg.is/9mDnr>

The map contains the following layers:

- a. Mortality Attributed to Unsafe Water. This layer shows the mortality rate per 100,000 people from unsafe water, unsafe sanitation and lack of hygiene in 2012.**
- b. Percent with Improved Sanitation. This layer shows the percent of the population with access to improved sanitation facilities such as toilettes and latrines, from the years 1990 to 2105.**

The map opens showing the percent with improved sanitation for the year 2012. This is the same year for which mortality data is available.

You will begin by visually comparing the improved sanitation layer with the mortality layer.

2. With the Improved Sanitation layer still on, turn the Mortality layer on and off.

Question 12.3.1

Does there appear to be a spatial relationship between a lack of improved sanitation facilities and mortality from unsafe water? Name three countries with high mortality levels and low rates of access to sanitation facilities.

Visual comparisons of map layers are powerful, but they can be complemented by quantitative analysis. Next you will calculate the average mortality rate for the bottom quintile of countries in terms of sanitary facilities and compare that to the worldwide average. To do so, you must first combine data from both map layers using the Join function.

- 3. Hover your cursor over the Percent with Improved Sanitation layer and select Perform Analysis.**
- 4. In the Perform Analysis window, select Summarize Data, then click Join Features.**
- 5. In the Join Features window, select Percent with Improved Sanitation in step one.**
- 6. In step two select Mortality Attributed to Unsafe Water.**
- 7. In step three select Choose the fields to match.**
- 8. For the Target field select Country_codes_latest_ISO3 from the sanitary facilities.**
- 9. For the Join field select Country_codes_latest_ISO3 from the mortality layer.**

These fields will be used to join data from Mortality Attributed to Unsafe Water and Percent with Improved Sanitation, making a single layer with attributes from both.

10. Step four should remain Join one to one.

Join Features

1 Choose target layer

Percent with Improved Sanitation

2 Choose layer to join to target layer

Mortality Attributed to Unsafe Water

3 Select the type(s) of join

Choose a spatial relationship

Choose the fields to match

Country_c... = Country_c... ✕

Target field = Join field

4 Choose join operation

Join one to one

Add statistics (optional)

11. In step five give your layer a unique name.

12. Uncheck Use current map extent to ensure that all countries are included in the join.

13. Click Show Credits. You should use less than 1 credit.

14. Click Run Analysis.

Your new layer now contains attribute data from both input layers.

15. Hover your cursor over the joined layer and click Show Table.

16. In the attribute table, scroll to the far right until you see the Mortality_per_100thousand field.

17. Click the field heading and select Statistics.

18. In the first column of the table (question 12.3.2), write the value for Average.

Question 12.3.2

Mortality per 100,000—All Countries	Mortality per 100,000—Bottom Quintile of Improved Sanitation, 2012

Next, you will filter your joined layer for only the lowest quintile of countries in terms of improved sanitation.

19. Hover the cursor over your joined layer and select Filter.

20. Set the filter so that Yr2012 is at most 39. This selects the 20 percent of countries with the lowest levels of improved sanitation in 2012.

21. Again, hover your cursor over the joined layer and Show Table.

22. In the attribute table, scroll to the far right until you see the Mortality_per_100thousand field.

23. Click the field heading and select Statistics.

24. In the first column of the preceding table (question 12.3.2), write the value for Average.

Filter: Join Features to Percent with Improved Sanitation

Create + Add another expression Add a set

Display features in the layer that match the following expression

Yr2012 is at most 39

Value Field Unique

Ask for values

25. Click Apply Filter.

Your map now shows the bottom 20 percent of countries in terms of improved sanitation in 2012.

As you can see in the question 12.3.2 table, the mortality rate from unsafe water is substantially higher in places with limited improved sanitation facilities. However, even within your selected group of countries, there are variations in mortality rates.

26. To see the variation in mortality rates, hover your cursor over the Mortality Attributed to Unsafe Water layer and select Change Style.

27. In the Change Style window, select Mortality_per_100thousand in step 1.

28. Use the default settings, or, in step 2, select Options under Counts and Amounts (Color) to classify your data.

Question 12.3.3

From your map, name two countries with lower mortality rates. Why can mortality rates be lower in some countries, even when improved sanitation facilities are limited? Consider the role of healthcare quality and access, informational campaigns, and other solutions. Search the Internet for “WHO diarrheal disease prevention” and look for prevention strategies that can help reduce illness and mortality from this cause.

From 1990 to 2012 and on to 2105, most countries have seen strong improvements in the number people with access to improved sanitation. Lastly, map the percent change in the percent of people with improved sanitation between 1990 and 2015.

29. Turn on the Percent with Improved Sanitation layer and turn off all others.

30. Hover your cursor over the Percent with Improved Sanitation layer and select Change Style.

31. In step one of the Change Style window, click the drop-down arrow and select New Expression.

32. In the Custom expression window, use the values for 1990 and 2015 to calculate percent change. The expression is as follows:

```
($feature["GIS_Improved_Sanitation__Yr2015"]-  
$feature["GIS_Improved_Sanitation__Yr1990"])/$feature["GIS_Improved_Sanitation__Yr1990"]*100
```

33. Click OK.

34. Click Select under Counts and Amounts (Color).

35. Click Options under Counts and Amounts (Color).

36. In the Change Style window, check the box next to Classify Data, and set the parameters to Using Quantiles With 5 classes.



37. Click OK, then click Done.

This shows increases in access to improved sanitation facilities between 1990 and 2015.

38. Filter the layer to show only the bottom two quintiles in 1990. These would have been the countries in that year with the lowest levels of improved sanitation facilities, and the places where the most work was needed.

39. Hover your cursor over the Percent with Improved Sanitation layer and select Filter.

40. In the Filter window, set the expression so that Yr2012 is at most 65. This selects the lowest 40 percent of countries in 1990.

41. Click Apply Filter.

As you can see, most countries saw substantial growth in the percentage of people with improved sanitation, yet another piece of evidence that development is making people's lives better as time progresses.

Question 12.3.4

Print or take a screenshot of your map and submit it.

Conclusion

Water pollution, especially from a lack of proper sanitation facilities, is a major vector of disease and an important cause of premature death in developing countries. As you have seen there are clear spatial relationships between access to improved sanitation facilities and mortality from unsafe water. But on a positive note, more people now have access to improved sanitation facilities than in the past. If trends continue, this should lead to ongoing reductions in mortality from waterborne disease.

Exercise 12.4: Land pollution: Superfund sites

Introduction

The Superfund program, officially known as the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), was established to clean up highly toxic sites across the United States, either by property owners or by the US Environmental Protection Agency. Of concern are people in proximity to these sites, who can be exposed to contaminants by inhaling dust or by contact with contaminated surfaces. Additionally, contaminants can be dispersed by wind onto nearby agricultural fields or percolate into groundwater used for drinking or irrigation. In this exercise, you will calculate the number of people within close proximity to Superfund sites to see if they differ in terms of minority status and income from the general US population. You will also examine a Superfund site near you to see exactly which types of contaminants are present and the status of the site's cleanup.

Objectives

- Calculate the number of people potentially exposed to Superfund site toxins.
- Calculate the proportion of minority and low-income residents in proximity to Superfund sites.
- Describe the history and cleanup efforts at a Superfund site near you.

- 1. Open the Chapter 12 Land Pollution: Superfund Sites map and sign in to your ArcGIS Online account: <https://arcg.is/0ruGy4>**

The map contains the following layers:

- a. **Superfund Sites. This layer includes all national priority list Superfund sites as identified by the US Environmental Protection Agency as part of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).**
- b. **Proximity to Superfund Site (National Priorities List). This layer shows census block groups based on their proximity to a national priorities list Superfund site.**

You will begin by calculating the number of people and some basic demographic characteristics within about 2 miles of a Superfund site and comparing them to values for the US.

2. **Hover your cursor over the Proximity to Superfund Site layer and click Show Table.**
3. **In the attribute table, click the Total Population field heading and select Statistics. Write the Sum of Values in the table for question 12.4.1.**
4. **Do the same for the Minority and Low-Income fields but enter the Average value from the Statistics window. This represents the proportion of US residents who are racial/ethnic minorities or low-income.**

Next, you will filter the layer for census block groups that are roughly within a 2-mile radius of Superfund sites.

5. **Hover your cursor over the Proximity to Superfund Site layer and select Filter.**
6. **In the Filter window, set the expression so that Proximity to Superfund is at least 0.3. This proximity value selects census block groups roughly within the desired radius.**

Filter: Proximity to Superfund Site (National Priorities List)

Create + Add another expression Add a set

Display features in the layer that match the following expression

Proximity to Superfund is at least 0.3

Value Field Unique

Ask for values ▼

APPLY FILTER APPLY FILTER AND ZOOM TO CLOSE

7. **Click Apply Filter.**
8. **If necessary, hover your cursor over Proximity to Superfund Site layer and click Show Table again.**
9. **In the attribute table, click the Total Population field heading and select Statistics. Write the Sum of Values in the table for question 12.4.1.**
10. **Do the same for the Minority and Low-Income fields but enter the Average value from the Statistics window.**

Question 12.4.1

	Total Population (Sum of Values)	Minority (Average)	Low Income (Average)
All US Block Groups			
Proximity to Superfund ≥ 0.3			

In the table for question 12.4.1 you can see that there are millions of people with a couple of miles or so of Superfund sites. But the table also shows that some groups are disproportionately close to them.

Question 12.4.2

Do Superfund sites appear to be related to environmental justice (from chapter 4)? In other words, are they disproportionately located near minority or low-income populations? Describe the results in the table.

Next, you will find a Superfund site near you and investigate the types of contaminants present and status of the site's cleanup.

- 11. Make sure the Superfund Sites layer is turned on and zoom to a Superfund site near you.**
- 12. Click the Superfund site point to open the pop-up window. In the window you will see the name of the site.**
- 13. Go to <https://www.epa.gov/superfund/search-superfund-sites-where-you-live>.**

14. In the search box on the EPA website, type the Site_Name from the pop-up window in your map.

The EPA website will take you to a new page that includes a link with the site name.

15. Click on that link.

Question 12.4.3

In your own words, what is the site's background?

Question 12.4.4

Click Cleanup Activities and briefly summarize what has been done.

Question 12.4.5

Click Health & Environment > Contaminant List/Contaminant Information link if it is available.

Write down a few of the contaminant names and contaminated media.

Question 12.4.6

Click Redevelopment, if available. Briefly summarize any redevelopment on the site.

Question 12.4.7

How would you feel about living, working, or spending time on the site after it is cleaned and redeveloped? Do you trust that the cleanup is complete enough to pose no risk to human health?

Conclusion

The Superfund program has been an important component of remediating past problems with improperly disposed of hazardous waste. Many sites have been successfully cleaned and put to new uses, but unfortunately the process has been slower than many hoped for, leaving many sites with contaminants that threaten human health and the natural environment.

Exercise 12.5: Global carbon emissions

Introduction

Carbon dioxide emissions (and other greenhouse gasses) are contributing to global climate change, but the places responsible for most emissions and the places likely to be hardest hit by a warming climate tend to be different. The rich world emits more CO² from fossil fuel use in driving, heating, and electrical production, and manufacturing. Oil producing countries also emit high levels of CO² from gas flaring (the burning of unusable waste gas) at production sites. Yet those who are most vulnerable to climate change are the people of poor countries, who are more vulnerable to flooding, drought, rising food prices, and other global-warming impacts. The dilemma is how to raise the standard of living of the world's people to developed-country levels without further increasing CO² emissions. In this exercise, you will explore CO² emissions per capita by country and visualize emission levels if all countries produced CO² at the same rate as the United States or Denmark.

Objectives

- Identify countries with the highest levels of CO² emissions.
- Calculate global emissions levels under different scenarios.

- Evaluate the best solutions to combat global climate change.

1. Open the Chapter 12 Global Carbon Emissions map and sign in to your ArcGIS

Online account: <https://arcg.is/18vfXT>

The map contains the following layer:

- a. CO₂ Emissions. This layer contains data on carbon dioxide emissions per capita in 2014, as well as the percentage of electricity created with renewable sources and the total population.**
- b. CO₂ Emissions for Denmark and the US. These are layers that you will use to view how emissions would change globally if all countries had CO₂ emissions like those of Denmark or the United States.**

The map opens showing CO₂ emissions per capita by quintile.

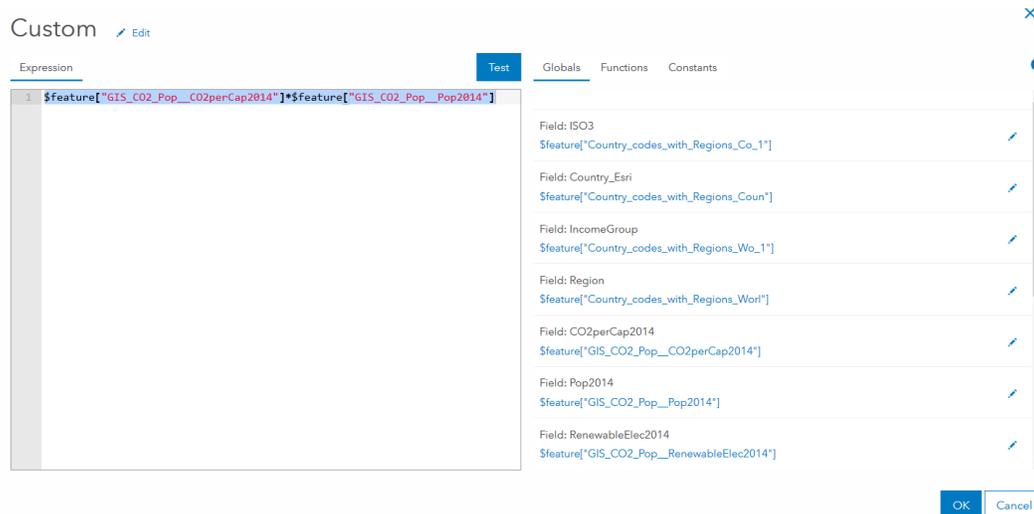
2. Observe the spatial patterns of CO₂ emissions. Generally, poor countries emit less while richer countries emit more. However, even within income groups there is great variation.

Now you will map total CO₂ emissions by multiplying per capita emissions values by the population of each country. This will show the total amount of CO₂ emitted by each country.

3. Hover your cursor over the CO₂ Emissions layer and select Change Style.

4. In the Change Style window, under step one, click the drop-down arrow and scroll down to Custom (Expression).
5. In the Custom window, multiply the CO2perCap2014 field by Pop2014. The expression should be as follows:

`$feature["GIS_CO2_Pop__CO2perCap2014"]*$feature["GIS_CO2_Pop__Pop2014"]`

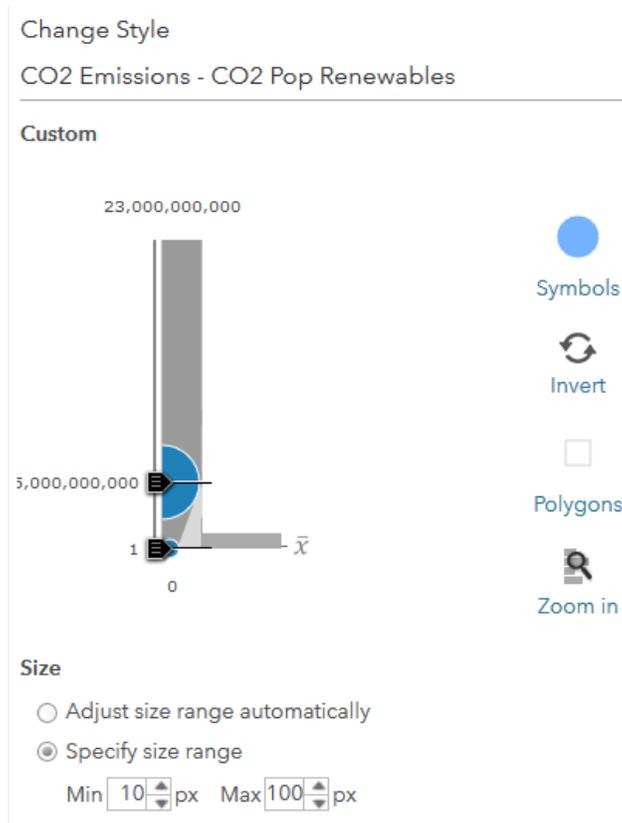


6. Click OK.
7. In step 2 of the Change Style window, click Options under Counts and Amounts (Size).
8. To better visualize the differences in CO² emissions by country, adjust the symbol ramp (see the following image).
9. Set the maximum value to 23,000,000,000.
10. Set the middle value to 5,000,000,000.

11. Set the bottom value to 1.

12. Under Size, specify size range with Min 10 px, and Max 100 px.

13. Click the colored circle above Symbols, select the Fill tab, and change the color.



14. Click OK, then click Done.

Question 12.5.1

Based on your map, which two countries contribute the most CO²?

The United States is a wealthy country with a high standard of living, and many people around the world dream of reaching its level of development. But the US also emits a large

amount of CO² per capita, through driving, industry, heating homes, and more. Next, you will map CO² emissions if all countries emitted CO² at the same per capita rate as the US.

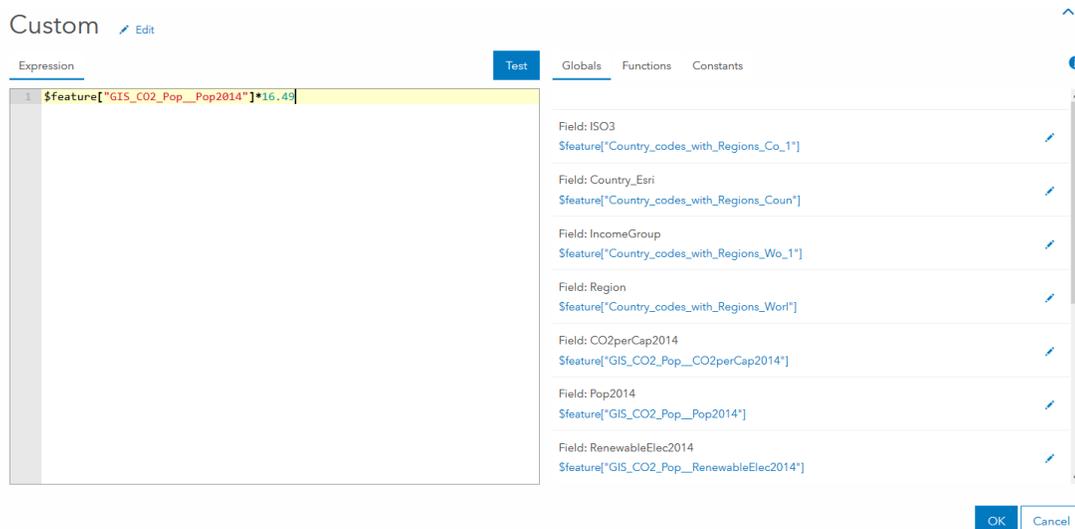
15. Turn on the CO2 Emissions – at US level layer in the Contents pane.

16. Hover your cursor over the CO2 Emissions – at US level layer and select Change Style.

17. In the Change Style window, under step one, click the drop-down arrow and scroll down to Custom (Expression).

18. In the Custom window, multiply Pop2014 by 16.49. This is the per capita CO² emissions value for the US in 2014. The expression should be as follows:

```
$feature["GIS_CO2_Pop__Pop2014"]*16.49
```



19. Click OK.

20. In step 2 of the Change Style window, click Options under Counts and Amounts (Size).

To better visualize the differences in CO² emissions by country, you will adjust the symbol ramp (see the image) as you did previously.

21. Set the maximum value to 23,000,000,000.

22. Set the middle value to 5,000,000,000.

23. Set the bottom value to 1.

24. Under Size, specify size range with Min 10 px, and Max 100 px.

25. Click the colored circle above Symbols, select the Fill tab, and change the color.

26. Click OK, then click Done.

Your map now shows circles representing actual 2014 emissions in one color and emissions levels if all countries had CO² levels like the US in another color.

Question 12.5.2

Based on the map, what would global emissions of CO² look like? Would they increase or decrease in most countries?

Denmark is another wealthy country with a high standard of living, yet it uses more renewable energy and has a much lower CO² per capita rate than the United States. Next, you will map CO² emissions if all countries had per capita emissions like those of Denmark.

27. Turn the CO2 Emissions – at US level layer off and turn on CO@ Emissions – at Denmark’s level layer.

28. Hover your cursor over the CO2 Emissions – at Denmark’s level layer and select Change Style.

29. Repeat the preceding steps for mapping US emissions levels, but multiply by 5.94 instead of 16.49.

Question 12.5.3

Based on the map, which country would still see a substantial increase in CO² emissions? What would happen with emissions from the US? (You can turn the CO² Emissions layer on and off to see change between the two layers.)

Lastly, you will calculate global CO² emissions under the three prior scenarios.

30. Hover your cursor over the CO2 Emissions layer and click Show Table.

31. In the attribute table, click the field name Pop2014 and select Statistics.

32. Write the Sum of Values in all three rows of column B in the table (question 12.5.4).

33. Click the field name for CO2perCap2014 and select Statistics.

34. Write the Average value in the first row of column C.

35. Calculate total global CO² emissions for each scenario in column D by multiplying columns B and C.

Question 12.5.4

(A)	(B) Pop2014 (Sum of Values)	(C) CO ² Per Capita Scenario	(D) Total CO ² Emissions = B * D
CO2 Emissions, 2014			
CO2 Emissions, at US level		16.49	
CO2 Emissions, at Denmark's level		5.94	

Question 12.5.5

Which scenario is best, given the goals of lowering CO² emissions while at the same time providing a high standard of living for the people of the world? Explain your answer.

Question 12.5.6

Even an optimistic scenario, such as reaching emission levels like Denmark's, results in a global increase in CO². Based on the Mitigation section of Solutions in chapter 12, describe how CO² emissions can be further reduced, possibly to average levels below those of 2014?

Question 12.5.7

Based on both the Mitigation and Adaptation sections of the chapter, which do you think are the most cost-effective solutions to global climate change? Explain why.

Conclusion

Combating global climate change is a complex and contentious battle. Smart and earnest people have proposed myriad solutions on how to best tackle this problem as they attempt to promote a higher quality of life for our planet's people, while at the same time trying to prevent catastrophic change to its life-sustaining atmosphere.