LESSON 1.3

Precision and Accuracy

CAREER SPOTLIGHT: Environmental Protection Technician

Occupation Description

Environmental science and protection technicians monitor the environment and investigate sources of pollution and contamination, including those affecting public health.

Technicians often work on teams with scientists, engineers, and technicians in other fields to solve complex problems related to environmental degradation and public health.

Most environmental science and protection technicians work for consulting firms, state or local governments, or testing laboratories.

Education

Environmental science and protection technicians typically need an associate's degree in environmental science, environmental health, or a related degree. Because of the wide range of tasks, environments, and industries, there are jobs that do not require postsecondary education and others that require a bachelor's degree.

Potential Employers

The largest employers of environmental science and protection technicians are as follows:

Management, scientific, and technical consulting services	23%
Local government, excluding education and hospitals	21%
Testing laboratories	12%
State government, excluding education and hospitals	7%
Engineering services	5%

Watch a video about environmental protection technicians: https://cdn.careeronestop.org/OccVids/OccupationVideos/19-4091.00.mp4

Career Cluster

Agriculture, Food & Natural Resources

Career Pathway

Environmental Service Systems

Career Outlook

- Salary Projections:
  Low-End Salary, $29,040
  Median Salary, $46,540
  High-End Salary, $80,710
- Jobs in 2018: 34,800
- Job Projections for 2028: 38,000 (increase of 9%)

Algebra Concepts

- Use significant digits.
- Collect data with precision and accuracy.

Is this a good career for me?

Environmental science and protection technicians:

- Confer with clients to exchange information.
- Record research or operational data.
- Prepare scientific or technical reports or presentations.
- Develop environmental sustainability plans or projects.
- Direct natural resources management or conservation programs.

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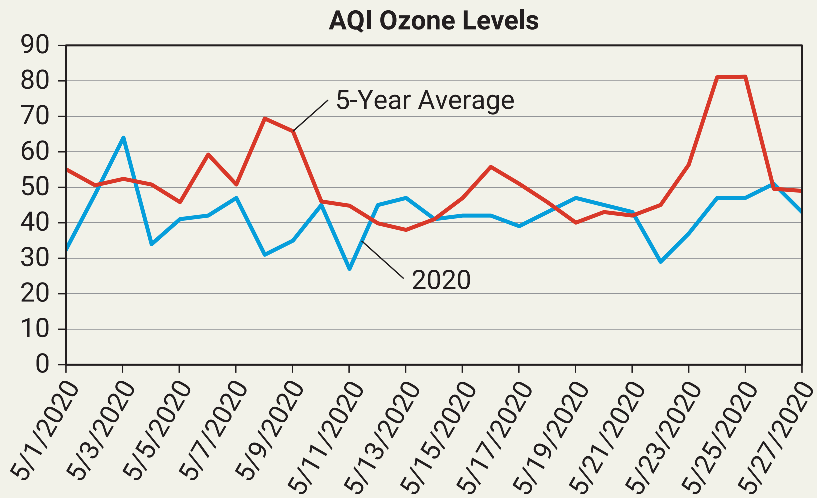
Lesson Objective

In this lesson, you will look at how an environmental protection technician collects, records, and interprets data using significant digits with precision and accuracy.

1 Step Into the Career: Interpreting Data Using Significant Digits

One type of environmental protection technician is an air quality technician. An air quality technician is monitoring the ozone levels in several cities in the Midwest, including Youngstown, Ohio. The Air Quality Index (AQI) for ozone levels each day from May 1 to May 27 is shown by the blue line in the graph. AQI levels below 50 are good, and levels between 50 and 100 are moderate. The 5-year average values show the average AQI of the previous 5 years on each day. How can the technician summarize the data that she has collected in the graph and table?



Day	**5/1**	**5/2**	**5/3**	**5/4**	**5/5**	**5/6**	**5/7**	**5/8**	**5/9**
AQI	33	48	64	34	41	42	47	31	35
5-Year Average	55	50.6	52.4	50.8	45.8	59.2	50.8	69.4	65.8
Day	**5/10**	**5/11**	**5/12**	**5/13**	**5/14**	**5/15**	**5/16**	**5/17**	**5/18**
AQI	45	27	45	47	41	42	42	39	43
5-Year Average	46	44.8	39.8	38	41	47	55.8	51	45.8
Day	**5/19**	**5/20**	**5/21**	**5/22**	**5/23**	**5/24**	**5/25**	**5/26**	**5/27**
AQI	47	45	43	29	37	47	47	51	43
5-Year Average	40	43	42	45	56.4	81	81.2	49.6	49

Devise a Plan

Step 1: Describe the days in May where the AQI levels were good or moderate. Compare this to the 5-year average.

Step 2: Find the number of days in May where the AQI level is greater than the 5-year average.

Step 3: Find the average AQI levels and the average of the 5-year averages for the month of May. Explain how to choose the number of significant digits for the averages.

Step 4: Summarize the results from Steps 1, 2, and 3.

Walk Through the Solution

Step 1: The AQI levels were good every day except two, May 3 and May 26. The 5-year average includes 13 days where the air quality is moderate.

Step 2: The AQI levels have been above average on 7 of the 27 days.

Step 3: The sum of the AQI levels for the month of May is 1135. To find the average AQI levels, divide by the number days, 27.

$$\frac{1135}{27} = 42.\overline{037}\text{, or about } 42$$

The sum of the 5-year averages for the month of May is 1396.2. To find the average of the 5-year averages, also divide by 27.

$$\frac{1396.2}{27} = 51.7\overline{1}\text{, or about } 52$$

Use two significant digits since the reported data is only given to two significant digits.

Step 4: The technician can conclude that air quality has been good on all but two days, which is much fewer than the 13 days where the 5-year average is moderate. The number of days that had an AQI level above average is 7, which is much less than half the total number of days. The average AQI level for the month of May is about 42, while the 5-year average for the same number of days is about 52. So, the air quality has been better than average this month than in the previous five years.

On the Job: Apply Interpreting Data Using Significant Digits

1. The data in the table shows the AQI in Youngstown, Ohio, for the month of April. How can the technician compare the April AQI levels to the AQI levels for the month of May?

44	43	40	44	34	44	41	42	43	41
44	46	37	43	43	40	39	45	44	47
41	41	40	42	47	38	40	43	48	49

a. Describe the number of days where the AQI levels were good or moderate.

b. Find the average AQI level for April. Give your answer to the appropriate number of significant digits.

c. Use the answers from Parts (a) and (b) to compare with the AQI levels for the month of May.

2 Step Into the Career: Collecting Data with Precision and Accuracy

One job for an environmental protection technician is as a water quality specialist. A water quality specialist collects data about contaminants in public water supplies before and after treatment to check for levels of different pollutants and ensure that the water is safe for consumption and bathing. A technician tests new tools for accuracy and precision.

The technician has prepared a testing solution with 0.90 parts per million of chlorine and measures the solution repeatedly with each of two new tools. The results are shown in the tables.

Which tool is more accurate? Which tool is more precise?

Tool A – Chlorine (parts per million)					
0.83	0.87	0.95	0.77	1.01	0.75
0.89	0.78	0.89	0.87	1.04	1.02
1.00	0.94	1.01	0.85	0.93	0.89

Tool B – Chlorine (parts per million)					
0.84	0.87	0.94	0.88	0.93	0.91
0.83	0.90	0.81	0.85	0.87	0.84
0.85	0.93	0.80	0.89	0.86	0.84

Devise a Plan

Accuracy is how close a measurement is to the actual value. **Precision** is the closeness of repeated measurements.

Step 1: Find the average parts per million for each tool.

Step 2: Find the range of data for each tool.

Step 3: Compare the means and ranges for the tools.

Walk Through the Solution

Step 1: The sum of the measurements from Tool A is 16.29 parts per million. Divide by the number of measurements to find the average for Tool A.

$$\frac{16.29}{18} = 0.905 \text{ parts per million}$$

The sum of the measurements from Tool B is 15.64 parts per million. Divide by the number of measurements to find the average for Tool B.

$$\frac{15.64}{18} = 0.86\overline{8} \text{ parts per million}$$

Step 2: The range is the difference between the minimum and maximum measurements.

The minimum for Tool A is 0.75 parts per million, and the maximum is 1.04 parts per million. The range is $1.04 - 0.75 = 0.29$ parts per million.

The minimum for Tool B is 0.80 parts per million, and the maximum is 0.94 parts per million. The range is $0.94 - 0.80 = 0.14$ parts per million.

Step 3: Since the amount of chlorine in the testing solution is 0.90 parts per million, Tool A is more accurate because its mean is closer to the actual value. Since the range of the measurements for Tool B is less than the range for Tool A, Tool B is more precise.

On the Job: Apply Collecting Data with Precision and Accuracy

2. A technician is determining which of two tools to use to measure the lead in the water of people's homes. She tests the tools using a solution that has 25 parts per billion. Which tool is more precise? Which is more accurate? Explain.

Tool A – Lead (parts per billion)							
24	27	29	29	29	25	28	25
26	25	28	27	29	29	26	29

Tool B – Lead (parts per billion)							
31	30	35	34	19	17	17	28
19	34	17	16	34	16	21	31

3 Step Into the Career: Using the Precision of Collected Data

The table shows the results of tests for fluoride. The two significant digits reflect the precision of the measurements to two decimal places.

What is the average level of fluoride in the water? Is this above the maximum contaminant level (MCL) of 4 parts per million?

Fluoride					
0.79	0.44	0.75	0.69	0.45	0.35
0.73	0.77	0.65	0.42	0.69	0.70
0.72	0.77	0.46	0.70	0.53	0.74
0.75	0.58	0.44	0.60	0.64	0.61
0.57	0.67	0.66	0.73	0.76	0.82
0.73	0.79	0.68	0.71	0.77	0.79

Devise a Plan

Step 1: Explain what units should be used to collect data about fluoride.

Step 2: Find the average level of fluoride from the 36 samples. Determine how many digits to use for the average.

Step 3: Compare the measure to the MCL.

Walk Through the Solution

Step 1: The data in the table should be in parts per million to compare with the MCL.

Step 2: The sum of the testing results is 23.65 parts per million. To find the average level of fluoride in the samples, divide the sum by the number of samples, 36.

$$\frac{23.65}{36} = 0.6569\overline{4}$$

Since all measurements are given to two significant digits, use two significant digits in your answer. The average level of fluoride in the water is about 0.66 parts per million, assuming the measures shown here are in those units.

Step 3: Compare the average to 4 parts per million.

The MCL of 4 parts per million is much greater than 0.66 parts per million, so the fluoride levels in this water supply are safe.

On the Job: Apply Using the Precision of Collected Data

3. The table shows the results of tests for lead in the water in a group of homes in parts per billion. What is the average level of lead in the water of these homes? Is this above the *action level* of 15 parts per billion? An action level indicates the level that a substance is considered harmful or toxic.

Lead							
5	1	1	2	5	0	12	0
23	14	11	8	1	6	67	21
7	16	5	3	4	13	6	8
13	8	9	12	10	4	3	5

a. Explain which units should be used to measure the lead in the water.

b. Find the average lead levels from the 32 samples. Determine how many digits to use for the average.

c. Compare the average to the action level.

Career Spotlight: Practice

4. Paint from several different rooms of a house were tested for lead. If there is 0.5% of lead in paint, then it is leaded paint and needs to be remediated. The table shows the results of each sample.

Room	Kitchen	Bathroom	Bedroom	Living Room	Dining Room	Hallway	Garage
% Lead	0.13	0.07	0.48	0.21	0.06	0.11	0.00

a. How should the technician determine whether there is lead paint in the home?

b. How does the number of significant digits affect a summary of the data?

c. What should the technician suggest about the existence of lead paint in this house?

5. A lake that is used for drinking water was tested for total coliform bacteria each day for the last three weeks. The highest level of coliform allowed is 5%. Determine whether this water is safe from coliform.

Total Coliform in Water Sample (%)						
1.0	0.2	1.7	1.4	0.3	0.5	1.7
0.1	0.8	0.6	0.3	1.1	0.5	0.4
0.5	1.6	0.0	0.5	1.2	0.4	0.1

QUICK TIP

Compare the data values to the highest level of coliform allowed.

a. What is the average level?

b. What is the range of levels detected?

c. Is the lake water in violation? Explain.

6. The table shows the total reported on-site releases of toxic chemicals for 10 years in the state of Colorado. How can an environmental protection technician report this data?

Total On-Site Releases of Toxic Chemicals					
Year	2009	2010	2011	2012	2013
Pollutants (lb)	17,133,966	18,749,924	21,781,162	23,628,003	22,480,412
Year	2014	2015	2016	2017	2018
Pollutants (lb)	23,939,087	21,795,641	24,725,558	26,978,291	22,920,283

a. What is the range of the data?

b. What is the trend shown in the data?

c. How would you describe the average reported on-site releases of toxic chemicals in Colorado over these 10 years?

7. A soil mixture of 85 parts per billion is used to test two new tools to measure lead in soil. Which is more precise? Which is more accurate?

QUICK TIP

Find the mean and range for each set of data.

Tool A – Lead (parts per billion)							
86	85	90	84	85	83	81	86
82	88	85	90	82	88	85	90

Tool B – Lead (parts per billion)							
79	84	73	83	75	90	80	83
90	85	84	89	72	71	88	92

Career Spotlight: Check

8. The table shows the test results for a disinfectant in a city's water supply from 24 days last month. The maximum level allowed is 4 parts per million. Determine whether the water supply is safe from disinfectant.

Disinfectant (parts per million)					
1.7	2.5	1.8	1.5	0.7	3.7
0.4	0.5	2.4	2.9	0.7	1.0
0.2	3.4	1.1	3.7	1.9	2.3
0.3	4.0	1.0	1.3	3.4	0.6

Select the answer from each box that makes the sentence true. Use the correct number of significant digits.

The water supply [**a.** is / **b.** is not] safe because the [**a.** average / **b.** greatest / **c.** range in] level of disinfectant

detected in these samples is [**a.** $1.791\overline{6}$ / **b.** about 1.79 / **c.** about 1.8] parts per million.

9. The table shows the results of tests for copper in the water for a group of homes in parts per million. Which best describes the average level of copper in the water of these homes?

Copper							
1.09	1.06	0.28	0.3	0.85	0.58	0	1.12
1.5	0.44	0.75	0.35	0.16	0.14	0.15	0.13
0.4	0.85	0.09	0.02	0.33	0	0.11	0.3
0.18	0.11	0.12	0.04	0.1	0.08	0.15	0.19

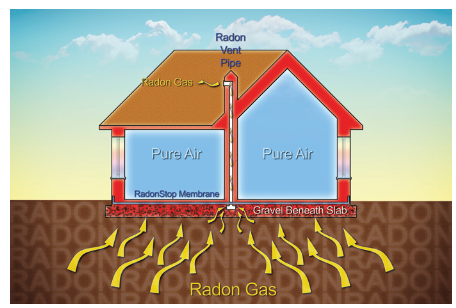
A. 0.37 parts per million

B. 0.374 parts per million

C. 0.3741 parts per million

D. 0.4 parts per million

10. To test a home for radon, a common but potentially dangerous gas, the air in a room is sampled once every hour for a period of hours. The federal government recommends people consider fixing homes with levels of radon that average above 2 pCi/L. How would you suggest the technician advise the homeowner using these results?



Time of Day (P.M.)	12:11	1:11	2:11	3:11	4:11	5:11	6:11	7:11
Radon Levels (pCi/L)	3.5	2.6	2.3	1.7	1.0	0.8	0.6	1.2

Select the answer from each box that makes the sentence true.

The radon level [**a.** is relatively / **b.** is not] safe because the [**a.** average / **b.** greatest / **c.** range in] level of radon detected in these samples was [**a.** about 1.7 / **b.** 1.7125 / **c.** about 2] pCi/L, which is [**a.** greater than / **b.** less than] the level where action is recommended.

Photo credit: Francesco Scatena/Shutterstock.com

11. Soil from a group of homes in a neighborhood was tested for lead. If there are 150 parts per million of lead in the soil, then homeowners should take actions to reduce their exposure to the lead in the soil. Select all the statements that are true.

Lead (parts per million)							
17	53	28	63	35	24	30	93
30	95	245	641	128	174	101	45
36	55	60	58	45	37	34	138
141	104	125	117	155	120	373	205

a. The average lead level is exactly 112.65625 parts per million.

b. The average lead level is about 113 parts per million.

c. The average lead level is below the action level.

d. The average lead level is above the action level.

e. The neighborhood is safe from lead in the soil.

f. Six homes have a lead level above the action level.

12. The action level for copper is 1.3 parts per million. How many homes are above the action level for copper?

Photo credit: Happy_Nati/Shutterstock.com

13. The levels of mercury in the blood, in micrograms per liter, of two groups are shown in the table. The two groups were studied from 2000 to 2010. How could a technician use this data to suggest a plan of action? Explain.

	Year					
Meals with Fish in Past 30 Days	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**
None	0.61	0.43	0.38	0.37	0.36	0.50
6 or More	3.36	2.34	2.07	1.84	1.95	2.11

14. The table shows the results of tests for two tools measuring the levels of peroxide in a 1.2% solution. Which best describes the precision and accuracy of the tools?

Tool A – Peroxide (% solution)							
1.3	1.3	0.9	0.9	1.5	1.7	1.0	1.5
1.4	1.6	1.7	1.8	1.3	0.9	1.4	1.2

Tool B – Peroxide (% solution)							
0.9	1.1	0.9	0.9	1.3	1.0	1.4	1.5
0.9	1.0	0.9	1.4	1.3	1.4	1.5	1.0

A. Tool A is more precise and more accurate.

B. Tool B is more precise and more accurate.

C. Tool A is more precise, and Tool B is more accurate.

D. Tool B is more precise, and Tool A is more accurate.