# DUML WATER QUALITY CURRICULUM

COMMUNITY SCIENCE FOR 9TH-12TH GRADE


DUKE MARINE LAB COMMUNITY SCIENCE

Duke | NICHOLAS SCHOOL OF THE ENVIRONMENT
DUKE UNIVERSITY MARINE LAB

# WELCOME!

Thank you teachers for all the hard work you do day-in and day-out inspiring our kids. Our hope is that this Water Quality Curriculum will provide you with hands-on and meaningful activities that get your students out into nature, give your students opportunities to make positive change in their communities, and foster your students' sense of environmental stewardship for their community.

This version of the Duke University Marine Lab Water Quality Curriculum is the result of many collaborators from Duke University Marine Lab, The University of North Carolina-Institute of Marine Sciences, and North Carolina State University. The ideas in this curriculum resulted from current research at DUML and UNC-IMS, suggestions from teachers, as well as community organizations working to make sure our waterways are clean. We could not have done this alone, so thank you to everyone who has made this Curriculum better. A special thanks goes out to Rachel Noble -- a Distinguished Professor at UNC-IMS. Dr. Noble's research and her commitment to community and clean waterways funded many of the pilot projects in this Curriculum -- thank you for your commitment Dr. Noble!

Lastly, thank you to all of the teachers for your willingness to teach our youth. We continue to be inspired by your students, their creativity, and their passion for making the world a better place… one cleaned waterway at a time!

Regards,

**Liz DeMattia**
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Director, Community Science Initiative
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Nicholas School of the Environment

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Sea Grant North Carolina
UNC INSTITUTE OF MARINE SCIENCES

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**Version 3 Booklet Editor**: Anjali Boyd

# INTRODUCTION

Our oceans, beaches and coastal waterways are full of many land-based items that do not naturally belong there. Plastics, metals, rubber, fabrics, abandoned boats, derelict fishing gear, pesticides, fertilizer and more make their way into our waterways and have created an enormous water quality problem. In Eastern North Carolina's 3,000 plus miles of coastline, the issue of water quality is especially poignant because pollution and marine debris negatively affects the health of our marine environment. Activities that depend on healthy waterways generate over 2 billion dollars of GDP ocean economy for NC [1].

This Water Quality Curriculum combines community science at the Duke University Marine Laboratory (DUML) Community Science Initiative and University of North Carolina - Institute of Marine Sciences (UNC-IMS) with hands-on water quality and stormwater literacy activities and research. Our hope is that your students participate in the community science research, showcase their results with the local community, are inspired to do even more research, and inspire others to help make a positive difference in our waterways.

As teachers, you know your class and students best. Please feel free to deliver the activities in a time frame that works best for your classroom. Topics and activities can be focused over a few weeks, spread out over a month, or peppered throughout the semester. We also have included optional activities that allow your students to further research local stormwater and water quality issues.

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[1]North Carolina's Ocean Economy: A First Assessment and Transitioning to a Blue Economyhttps://ncsea-grant.ncsu.edu/ncseagrant_docs/products/2010s/NC_Ocean_ Economy_White_Paper.pdf

# CONTENTS

# WORKBOOK ROADMAP

1

## CLASSROOM PREPARATIONS

These background activities are used to introduce the topics of: how to ask questions in science, water quality, and stormwater. These activities set the stage for the community science field research (Adopt-A-Drain) and for independent research.

2

## COMMUNITY SCIENCE FIELD RESEARCH

This community science field research (Adopt-A-Drain) is designed to highlight how storm water can affect local water quality. By using microplastics as a model, students can see how storm water transports waste into our waterways. Students collect data, analyze their results and then create ways to disseminate their results

3

## CREATIVE ENGAGEMENT

These community engagement activities are designed so that the dissemination products from the students (i.e., videos, powerpoints, posters, lesson plans) can be shared with the general public. By sharing their data/results, students develop a sense of civic engagement within their community.

4

## OPTIONAL: INDEPENDENT RESEARCH OPTIONS

These optional independent research extensions build on the Adopt-A-Drain research and let students create hypotheses and test for the presence/absence of pesticides/nutrients in local storm water.

5

## APPENDIX

All worksheets and supporting documents are located in the Appendix section at the end of the workbook.

# CLASSROOM PREPARATIONS

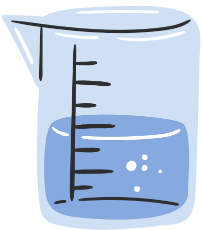
## LESSONS

- LESSON 1: MAKING SCIENCE SIMPLE: HOW TO FORMULATE A RESEARCH QUESTION
- LESSON 2: WHAT IS STORMWATER? LECTURE & DISCUSSION
- LESSON 3: IMPERVIOUS VS. PERVIOUS SURFACES ACTIVITY

## TOPIC
Introduction to science and how to generate a research question

## INTRODUCTION
This lesson plan was created to help students understand the basic goal of science. The students will discuss definitions of science, learn how to break down research questions, and how to effectively communicate research questions of their own.

## OBJECTIVES
Students will be able to:
- Discuss/describe/tell what science is
- Analyze research questions
- Assess what a good research question looks like
- Devise their own research questions



## END OF LESSON GOAL:
- Students will be able to explain how scientific inquiry heps us understand the world
- Confidently generate their own research questions

## MATERIALS:
- Powerpoint (PPT) slides to guide the lesson
- Whiteboard and marker
- Worksheet (Appendix, pg. 28)

## NOTES

# MAKING SCIENCE SIMPLE

## KEY POINTS

- Science is not scary
- Science can be easily defined
- We can talk about science in a lot of different ways, but we are all using science to answer questions
- We can generate research questions with 3 key components
  - A subject, a verb, and an object
  - An independent variable, a verb, and a dependent variable
  - How does ____ affect ____ ?

## NOTES

## ACTIVITY PLAN:

The activity plan provides background information for the powerpoint, cues on discussion, and help with the worksheet.

## CLASS DISCUSSION

- Ask students "what are you curious about?". This question can be specific to things in nature or not. The purpose is to engage students in the lesson.
  - Write their answers on the board to highlight examples and have their words/ideas be part of the lesson

## INTRODUCTION TO SCIENCE (15 minutes)

- Ask students "what is science?"
  - Think-Pair-Share
    - Give students several minutes to write a definition in their own words
    - Pair off with another student and discuss what they wrote
    - Share definitions with the class
      - Write key words from the students' definitions on the board
      - Compare/contrast students' definitions
  - Give several definitions of science on a PPT slide.
    - Compare/contrast the students' and the provided definitions
  - Emphasize that science is a tool to answer questions, explain relationships, and help us understand the world

## TALKING ABOUT SCIENCE (15 minutes)

Ask students "why do you think science is confusing?" This will help to understand their point of view.

- Describe two main reasons for confusion:
  - Poor communication-- people often don't know how to effectively communicate what they are studying
  - Different ways to talk about science-- different people talk about cause and effect in different ways
- Write cause and effect on the white board
  - Ask "what does cause mean?"
    - (n) person or thing that gives rise to an action, phenomenon, or condition
  - Ask "what does effect mean?"
    - (n) the change that is the result of an action
    - Ask the students to identify synonyms for each

## NOTES

Table 1. Examples of different ways to talk about cause and effect

| CAUSE | EFFECT |
|---|---|
| Independent variable (the variable that is manipulated in an experiment) | Dependent variable (the variable that changes as a result of the IV) |
| X | Y |
| Stimulus | Reaction |
| Driver | Response |
| Process | Pattern |
| Agent | Factor |
| Treatment | Impact |
| Predictor variable | Measured variable |
| Manipulated variable | Experimental variable |
| Explanatory variable | Explained variable |
| etc... | etc... |

## RESEARCH QUESTIONS (20 minutes)

You can use science to understand the world around you

- A scientific research question can be boiled down into a simple formula
  - Ask "What are three basic parts of a sentence?"
    - Subject -- the noun that is performing the action
    - Verb -- the action
    - Object -- what receives the action
  - In science, these components can be thought of as
    - Cause
    - Verb
    - Effect
  - How does ____ VERB ____ ?
    - Example: How does light affect plant growth?
    - Example: Does fishing reduce catch size?
- Have students identify the independent variable, dependent variable, and verb of the 5 published titles on the Science Is Simple worksheet (Appendix, pg. 28)
  - Circle the independent variable, box the dependent variable, and underline the verb
- Have students write out the research questions from the titles on the worksheets (Appendix, pg. 28)
  - PPT example-- How does shoreline geomorphology influence success of restored oyster reefs?
- Generate your own research question
  - Provide potential variables on a PPT slide for students to choose from so it's not as daunting, but encourage them to come up with their own!

## NOTES

# WHAT IS STORMWATER?

## TOPIC

Introduction to stormwater sources, impacts, and solutions. This lesson should be used with Lesson 3 (Impervious vs. Pervious Surfaces Activity).

## INTRODUCTION

This discussion-based lesson will teach students the basics of stormwater. The students will define stormwater, identify sources of stormwater, stormwater impacts on water quality, and discuss potential mitigation measures. Students will learn that stormwater is a problem for them, locally.

## ACTIVITY PLAN (45 - 60 minutes):

The activity plan below provides background information for the powerpoint and cues for student discussion.

### CLASS DISCUSSION

- Ask students to define stormwater in their own words
  - Definition-- stormwater is water that occurs in abnormal quantities that results from rain or snowmelt
- Write key words and common themes from definitions on the board
  - Potential keywords include: runoff, pervious surface, impervious surface, pollution, non-point source, point source

## MATERIALS:

- Powerpoint (PPT) slides to guide the lesson

## OBJECTIVES

- Discuss how humans have impacted the natural water cycle
- Hypothesize how stormwater influences water quality
- Identify stormwater prevention methods

## NOTES

# WHAT IS STORMWATER?

## THE NATURAL WATER CYCLE SLIDE

- Discuss the water cycle
  - Define evaporation, evapotranspiration, condensation, infiltration, runoff
  - Note the size of the arrows in the water cycle
- Think-Pair-Share
  - Give students several minutes to think about how humans have changed the natural water cycle
  - Pair off with another student and discuss
  - Share with the class
    - Write key words and common themes on the board

## THE "URBAN" WATER CYCLE SLIDE

- Ask students what has been altered with human development?
  - Note the size of the arrows in the urban water cycle
- Definition: stormwater runoff is rainfall or snowmelt that flows over the ground surface. It is created when rain falls on roads, driveways, parking lots, rooftops and other paved surfaces that do not allow water to soak into the ground.

## NOTES

## STORMWATER RUNOFF SLIDE

- Show this slide and discuss the different types of runoff you see
  - From roofs, gutters, yards, etc.

# WHAT IS STORMWATER?

## HOW DOES STORMWATER INFLUENCE WATER QUALITY? SLIDE

- Think-Pair-Share
  - Give students several minutes to think about the environmental and human health impacts of stormwater
  - Pair off with another student to discuss
  - Share with the class
- Why is stormwater runoff bad?
  - It can harm fish and other wildlife, results in habitat change, reduces recreation, etc.
- Show a news headline of a waterbody near you to emphasize that this is a local problem
  - i.e. *The Neuse River Is Sick, and Advocates Blame the Pork and Poultry Industries*
  - Give students a news article to read
    - Identify the location, source of the problem, and the impact

## PREVENTION METHODS SLIDE

- Ask students if they can come up with ways to prevent or decrease stormwater runoff
- Discuss the various methods.

## NOTES

# IMPERVIOUS VS. PERVIOUS SURFACES ACTIVITY

## INTRODUCTION

This hands-on activity is designed to reinforce the concepts of impervious surfaces and stormwater taught in the What is Stormwater Activity by letting students explore their schoolyard in order to make predictions about infiltration rates and test different surfaces.

## OBJECTIVES

- Identify impervious and pervious surfaces
- Make hypotheses about how water will flow on different surfaces
- Test the hypotheses
- Develop actions the school can take to reduce stormwater runoff

## MATERIALS:

- Bottles filled with water
- Timer

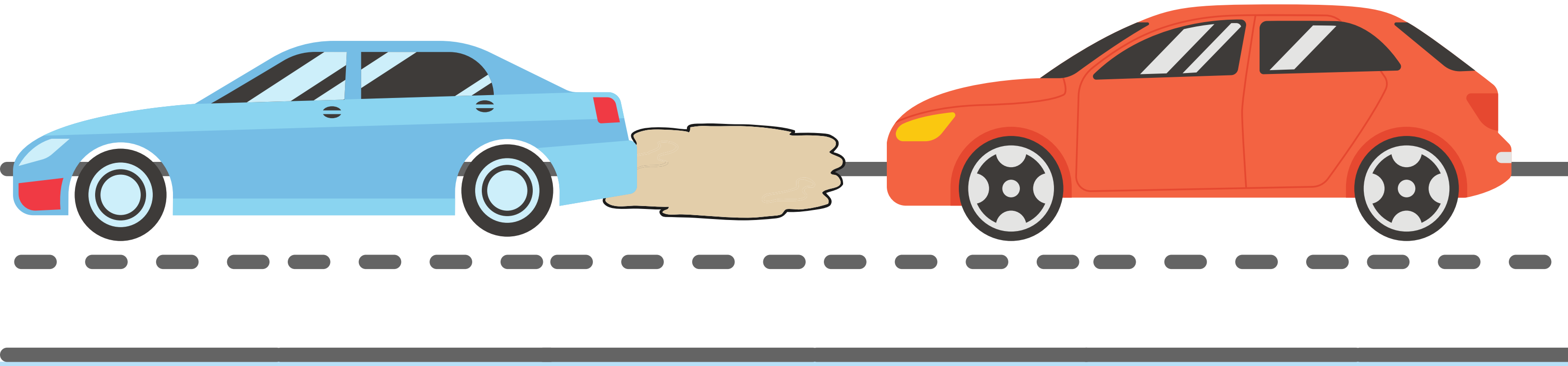
## NOTES

## ACTIVITY PLAN: (45 - 60 minutes)

The activity plan provides background information for the powerpoint, cues on discussion, and help with the worksheet.

## CLASS DISCUSSION

- Class discussion on types of outdoor surfaces (i.e. impervious and pervious).
    - Define and list examples of each.
    - Ask students to define stormwater in their own words.
        - Impervious surface examples: Driveways, sidewalks, parking lots, roads
        - Pervious surface examples: Gardens, wetlands, forests, yards



# IMPERVIOUS VS. PERVIOUS SURFACES ACTIVITY

## TESTING SURFACES

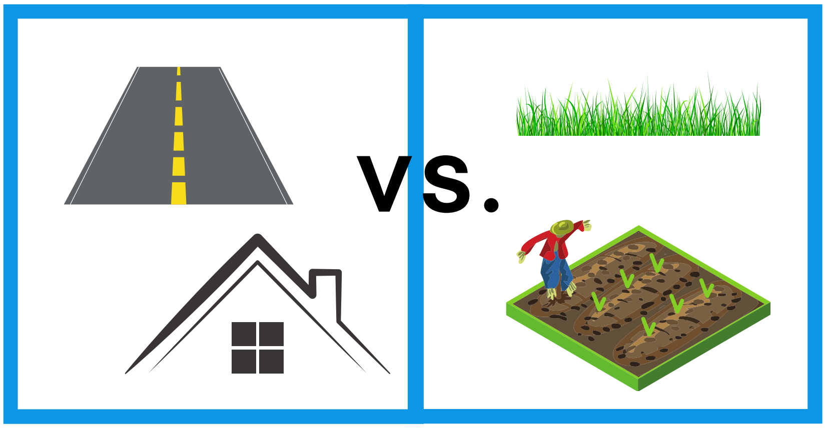
- Take class outside to "test" their schoolyard surfaces.
- Locate an area of grass/vegetation
- Pour about half a water bottle onto the ground and observe how the water infiltrates or seeps into the ground. If you want to quantify the observations, have students record how long it takes for the water to be absorbed.
  - Explain how the soil absorbs the water, much like it would absorb rain or stormwater.

- Locate area of impervious surface (parking lot, sidewalk) and pour about half a water bottle onto this surface and observe how the water flows across and does not infiltrate into the ground as easily.
  - If you want to quantify the observations, have students record how long it takes for the water to be absorbed. Note: water may not be absorbed on impervious surfaces, so you may have to set a time limit (60-90 seconds).
  - Explain the process of rain or storm water flowing across all impervious surfaces until it reaches a bigger body of water (stream, lake, estuary).

## GRAPH

- Once back in the classroom, create a class graph of the data on the whiteboard. Discuss the quantitative differences between the surface absorption times.
- Break students into small groups. Have students come up with lists of actions the school can take to decrease stormwater runoff and increase water infiltration.
  - Write up actions in an informative text
  - Share group's ideas with class

## NOTES



# COMMUNITY SCIENCE FIELD RESEARCH

## LESSONS

- ADOPT-A-DRAIN TUTORIAL

# ADOPT-A-DRAIN TUTORIAL

## INTRODUCTION

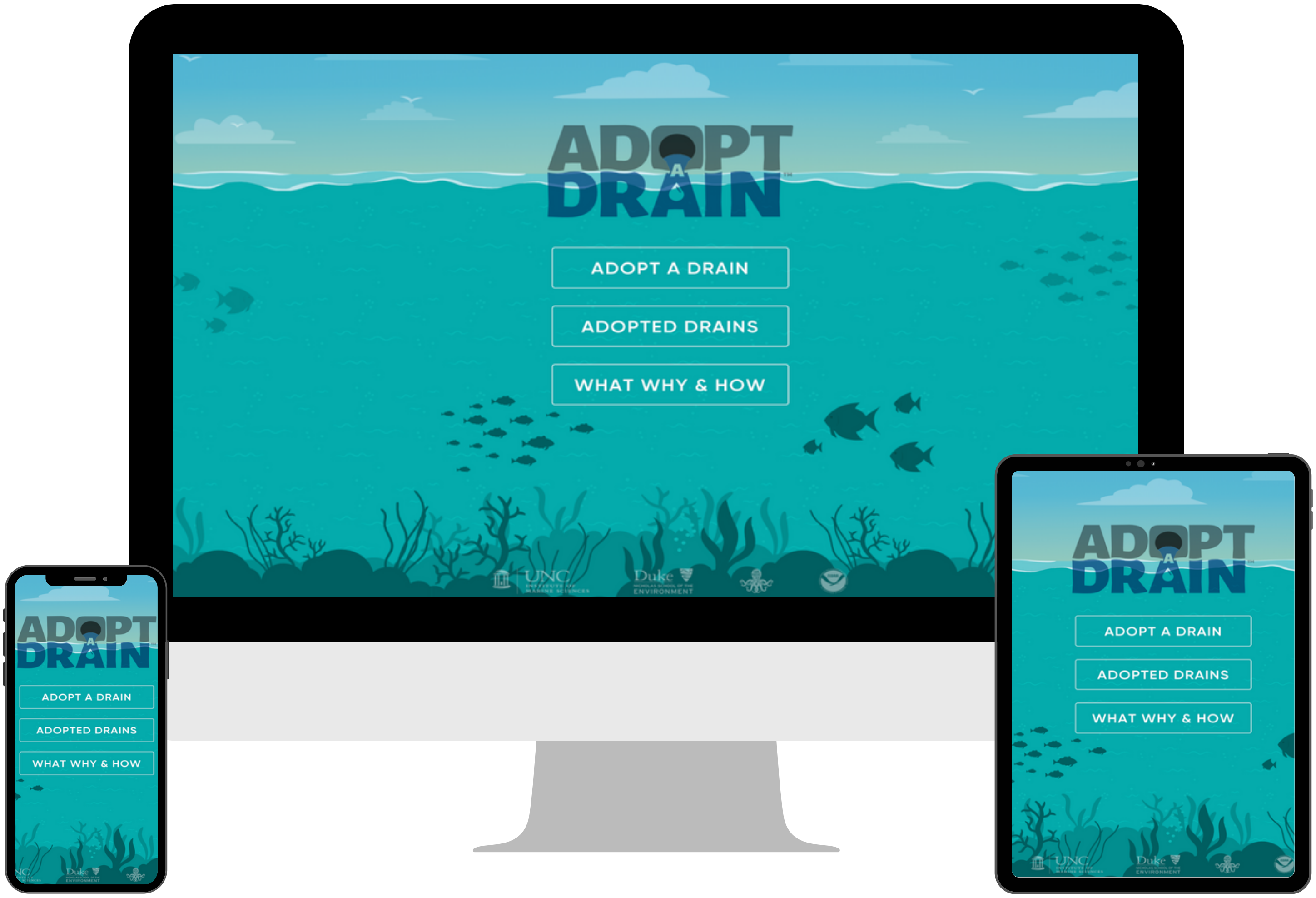
This app was created to quantify types of pollution that citizen scientists prevent from becoming marine debris through periodic clean-ups. It is also uses micro and meso plastic as a model to understand how non-visible parts of water pollution (i.e., pesticides, fertilizers, bacteria, etc.) enter our waters through storm drains.

## OBJECTIVES

- Collect and record data
- Form hypotheses for sources of marine debris
- Identify and discuss patterns and trends in data

## MATERIALS:

- Powerpoint slides (PPT) with step-by-step instructions for how to use AdoptADrain
- Website: https://adoptadrain.app/home



# ADOPT-A-DRAIN TUTORIAL

## ACTIVITY PLAN: (45 - 60 minutes)

Before you jump into the tutorial, review what you've learned with your students

- What is stormwater?
- Compare/contrast pervious and impervious surfaces. List examples of each.
- What are the sources of marine debris? (or other pollutants to waterways)
- What are the impacts of marine debris? (or other pollutants to waterways)

## NOTES

### CREATE YOUR ACCOUNT

Have students create their AdoptADrain accounts at https://adoptadrain.app/home

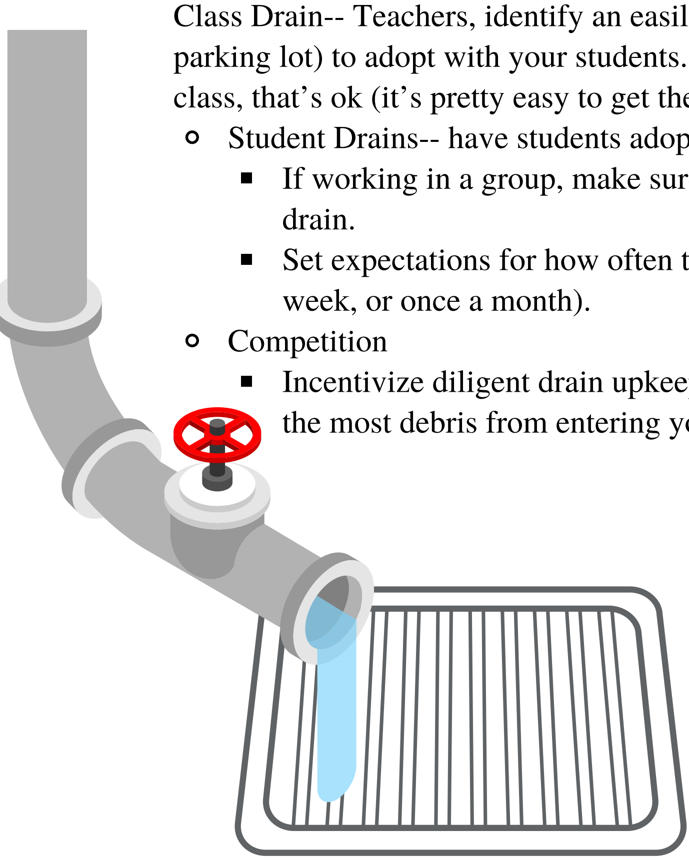
### TUTORIAL

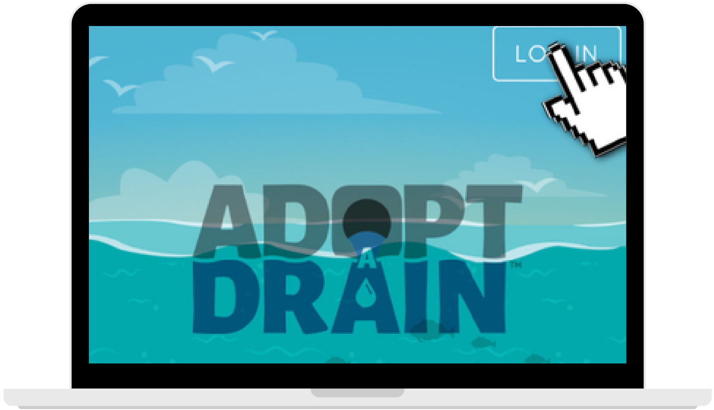
Complete the AdoptADrain powerpoint tutorial

### ADOPT A DRAIN!

Class Drain-- Teachers, identify an easily accessible drain ahead of time (perhaps in your school parking lot) to adopt with your students. If there is not an easily accessible drain to practice with your class, that's ok (it's pretty easy to get the hang of without class practice).

- Student Drains-- have students adopt drains, either individually or with a group.
    - If working in a group, make sure each student has the login information for their selected drain.
    - Set expectations for how often to collect trash and record the data (once a week, every other week, or once a month).
- Competition
    - Incentivize diligent drain upkeep with a friendly classroom competition for who can prevent the most debris from entering your local waterways.





# CREATIVE ENGAGEMENT

## SECTION OVERVIEW

This community engagement section is centered around giving students a voice for their research and the data they collect in their community.

# CREATIVE ENGAGEMENT

## OVERVIEW

This community engagement section is centered around giving students a voice for their research and the data they collect in their community. One way to get their information out to the community is using social media to present local water quality issues to their community in a creative and informative manner. Let your students be creative -- they know, navigate and understand the ever-changing social media landscape; and likely will create inventive ways to share their data, their projects and even extra research with the broader community. The goal of presenting their work to the public is to illustrate how our students are public stewards and to help illustrate how stormwater and water quality is affecting our community.

## POSSIBILITIES INCLUDE:

- Presentations to school boards or community leaders on their water quality research -- with their data graphs!
- Public service announcements about stormwater and water quality, social media posts about stormwater and water quality with graphs, pictures, videos or more (worksheet on pg. 32).

## OBJECTIVES

- At the end of this activity students will be able to:
    - Develop talking points that aid in explaining the issues of stormwater and water quality to others.
    - Describe and discuss the role of stormwater and water quality to their community.
    - Use social media to increase the reach of their message.

## NOTES

# CREATIVE ENGAGEMENT

## ACTIVITY PLAN

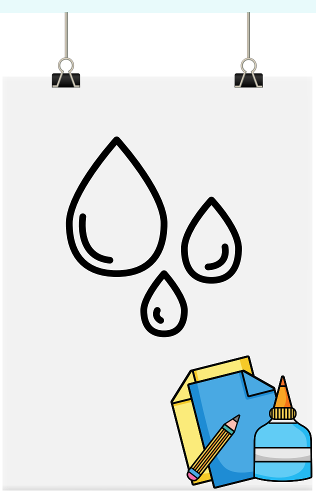
- How do you display data?
- How can you create an infographic about your work?
- How can you make a PSA?
- For all of these types of communication there are four main questions:
    - What do we want the audience to KNOW?
    - How do we want the audience to FEEL?
    - What do we want the audience to SEE? (only if you are doing a presentation/video/social media piece)
    - And after seeing/listening to your communication, what do we want the audience to DO?

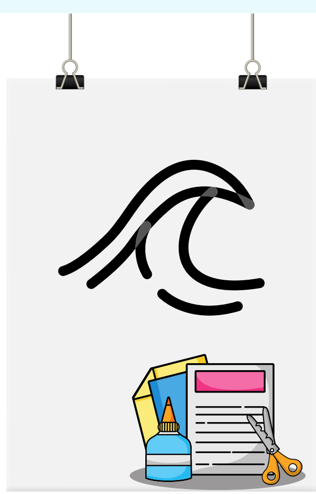
## RESOURCES:

- Examples of Good PSAs: Kids Safety Internet PSA - (:34) (https://www.youtube.com/watch?v=PS-t78Z1exQ)
- Active For Life Public Service Announcement (PSA) (:33) (https://www.youtube.com/watch?v=2syJ1bAMOvc)
- Kids Ask the Candidates for President to Debate Science (:30) (https://www.youtube.com/watch?v=yvTr9z9e3MA)

## TEACHER TIPS:

Have students use background information from the AP Environmental Studies class or Earth and Environmental Studies class. While students collect background information, have them keep track of evidence and statistics that shock and surprise them, and also explain the topic. Then, the students will be even more prepared to write a script or design their infographic. Let your students be creative -- help them with data, but then allow them to work in groups to create fun and interesting ways to communicate!





# OPTIONAL: INDEPENDENT RESEARCH OPTIONS

## LESSONS

- FERTILIZERS & PESTICIDES

# FERTILIZERS & PESTICIDES

## TOPIC

Water quality, scientific method, and statistics

- The ‘Fertilizers in Your Water’ worksheet has an optional statistics extension

## INTRODUCTION

This lesson was created to demonstrate that some types of pollution can’t be seen with the naked eye. Unlike marine debris, which is often in the form of large and visible garbage, there are many pollutants that dissolve in water. Examples of these “invisible” pollutants are fertilizers, bacteria from waste, and pesticides. While we cannot see these pollutants directly, we can often see their impacts!

## OBJECTIVES:

Students will:

- Discuss and describe different types of stormwater pollutants and hypothesize about their potential sources
- Generate and test hypotheses
- Conduct their own experiment
- Collect local environmental science data that is linked to their community
- Graph their data and interpret their graphs
- Evaluate data using basic statistics (optional with the ‘Fertilizers in Your Water’ extension worksheet)
- Discuss their results and show key findings of their research
- Discuss possible ways to control and reduce the sources of pollutants

## NOTES

# FERTILIZERS & PESTICIDES

## END OF LESSON GOALS:

- Create figures to visually display the results of the water quality activity
- Generate plausible explanations for why the results look the way they do
- Discuss future research or how you would change your methods
- Think about how individuals, families and communities can improve water quality
- Talk about the importance of good water quality for animals, pets, and recreation


## MATERIALS FOR FERTILIZER (NITROGEN) EXPERIMENT

- Nitrogen testing strips
  - https://www.carolina.com/environmental-science-water-quality/nitrogen-and-nitrogen-nitrogen-water-test-strips-vial-of-50/652736.pr
  - https://www.hach.com/nitrogen-and-nitrogen-test-strips/product?id=7640211606
  - Note: Nitrogen values and units will depend on which test strips you use
- Collected rainwater and stormwater samples
- Recycled plastic containers (i.e. yogurt cups or  water bottles with the top cut off to allow for better water collection) to use as sampling containers for rainwater and stormwater.
- Glove on one hand for sampling to prevent contamination by human hands (preferred)
- Fertilizers in Your Water Worksheet (Appendix, pgs. 35-37)
- Fertilizers in Your Water Statistics Extension (Appendix, pg. 41-47)
  - Statistics Resources (Appendix, pg. 65)
  - T-Table (Appendix, pg. 66)

# FERTILIZERS & PESTICIDES

### MATERIALS FOR PESTICIDE EXPERIMENT:

- Pesticide tablets
  - https://www.renekabio.com/products/food-safety-tests/pesticide-detection-test-cards/
- Collected rainwater and stormwater samples
- Recycled plastic containers (i.e. yogurt cups or water bottles with the top cut off to allow for better water collection) to use as sampling containers for rainwater and stormwater.
- Glove on one hand for sampling to prevent contamination by human hands (preferred)
- Dropper or disposable pipet
- Pesticides in Your Water Worksheet (Appendix, pgs. 57-60)

## NOTES

## ACTIVITY PLAN:

Teachers can choose their own adventure with this lesson. Options include: 1) fertilizer activity, 2) pesticide activity, or 3) fertilizer activity with statistics extension.

1. Ask ‘is pollution always visible’
2. Discuss types of pollution found in water, and how they get into waterways
   a. Marine debris
   b. Nutrients like nitrogen (nitrate, nitrite, ammonia and phosphate)
   c. Bacteria (found in human and warm-blooded animal waste)
   d. Chemicals (oils, materials from car tires, detergents, pesticides, fertilizers)

**NOTES**

3. Define pesticides
   a. *A pesticide is any substance used to kill, repel, or control certain forms of plant or animal life that are considered to be pests.***
4. If conducting the fertilizer activity, watch nutrient pollution video (https://www.youtube.com/watch?v=vCicSNnKUvM)
   a. Identify sources of nutrient pollution
   b. What are the negative impacts of nutrient pollution?
   c. Can you think of potential solutions?
5. If conducting pesticide activity, watch pesticides video (https://www.youtube.com/watch?v=TZlZlluOyho&feature=youtu.be)
   a. Identify sources of pesticide pollution
   b. What are the negative impacts of pesticide pollution?
   c. Can you think of potential solutions?
6. Run the experiment -- detailed instructions are found on the worksheets on pages (33-34 & 55-56)
   a. Organize students into groups of 3-5 individuals
   b. Assign each student group a treatment (i.e. rainwater or stormwater)
   c. Have students work in small groups with their fertilizer or pesticide worksheets to identify the research question, hypotheses, and assigned treatment
   d. Distribute sampling supplies

*Angus J.F. (2012) Fertilizer Science and Technology. In: Meyers R.A. (eds) Encyclopedia of Sustainability Science and Technology. Springer, New York, NY. https://doi-org.proxy.lib.duke.edu/10.1007/978-1-4419-0851-3_193

**Pesticides. 2020. Retrieved from https://www.niehs.nih.gov/health/topics/agents/pesticides/index.cfm

# APPENDIX

## WORKSHEETS

- Making Science Simple: How To Formulate A Research Question
- Making Science Simple: How To Formulate A Research Question (Key)
- PSA Worksheet
- Fertilizers In Your Water Experiment Instructions
- Fertilizers In Your Water Worksheets
- Fertilizers In Your Water Worksheets (Key)
- Fertilizers In Your Water Statistics Extension Worksheets
- Fertilizers In Your Water Statistics Extension Worksheets (Key)
- Pesticides In Your Water Experiment Instructions
- Pesticides In Your Water Worksheets
- Pesticides In Your Water Worksheets (Key)
- Statistics Additional Resources
- T-Table

# MAKING SCIENCE SIMPLE: HOW TO FORMULATE A RESEARCH QUESTION WORKSHEET

**Student/group name:**

**Date:**

**What is science?**

**Identify synonyms for Cause and Effect**

| CAUSE | EFFECT |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

# MAKING SCIENCE SIMPLE: HOW TO FORMULATE A RESEARCH QUESTION WORKSHEET

**Circle the independent variable, underline the verb, and box the dependent variable in the following article titles. Then rewrite the title into a research question.**

*Parasites enhance resistance to drought in coastal ecosystems*

*Climate change and invasion may synergistically affect native plant reproduction*

*Soy consumption reduces risk of ischemic stroke: a case-control study in Southern China*

*The influence of antibiotics on gut bacteria diversity*

*The impact of shellfish farming on common bottlenose dolphins' use of habitat*

**Generate your own research question that includes an independent variable, verb, and dependent variable.**

# MAKING SCIENCE SIMPLE: HOW TO FORMULATE A RESEARCH QUESTION WORKSHEET (KEY)

**Student/group name:**

**Date:**

**What is science?**

Student answers

Definitions from PPT

Similarities

**Identify synonyms for Cause and Effect**

| CAUSE | EFFECT |
|---|---|
| Independent variable (the variable that is manipulated in an experiment) | Dependent variable (the variable that changes as a result of the IV) |
| X | Y |
| Stimulus | Reaction |
| Driver | Response |
| Process | Pattern |
| Agent | Factor |
| Treatment | Impact |
| Predictor variable | Measured variable |
| Manipulated variable | Experimental variable |
| Explanatory variable | Explained variable |
| etc... | etc... |

# MAKING SCIENCE SIMPLE: HOW TO FORMULATE A RESEARCH QUESTION WORKSHEET (KEY)

**Circle the independent variable, underline the verb, and box the dependent variable in the following article titles. Rewrite the title into a research question.**

*Parasites enhance resistance to drought in coastal ecosystems*

*How do parasites enhance resistance to drought?*

*Climate change and invasion may synergistically affect native plant reproduction*

*How does climate change and invasion affect native plant reproduction?*

*Soy consumption reduces risk of ischemic stroke: a case-control study in Southern China*

*How does soy consumption reduce risk of stroke?*

*The influence of antibiotics on gut bacteria diversity*

*How do antibiotics influence gut bacteria diversity?*

*The impact of shellfish farming on common bottlenose dolphins' use of habitat*

*How does shellfish farming influence dolphin use of habitat?*

**Generate your own research question that includes an independent variable, verb, and dependent variable.**

## PSA WORKSHEET -- GENERATING IDEAS

**PSA STEP Two:**
Analyze the PSA examples and then answer/discuss these questions on your own. After finishing this sheet, discuss with your partner.

PSA Title to Analyze__________________________________

*What did the PSA want the audience to KNOW?*

*What did the PSA want the audience to FEEL?*

*What did the PSA want the audience to SEE?*

# FERTILIZERS IN YOUR WATER EXPERIMENT INSTRUCTIONS

## FERTILIZER EXPERIMENT STEPS

1. Each treatment group (i.e. rainwater or stormwater) will need 5 recycled containers to collect samples (e.g. yogurt containers or plastic water bottles with the tops cut off). Label each sampling container with the treatment (e.g. Rainwater), location (e.g. Emma's house), and sample number (e.g. Sample #1). Then collect your samples (one sample per container) using a gloved hand for collecting the samples. Each group should collect at least 5 samples from the chosen site within your treatment. Try to be very careful to only sample the rainwater or stormwater, and not include soil in your sample collection.
   a. R*ainwater* sampling groups: In order to collect rainwater you will need a container with a large surface area to collect the rain more quickly (e.g. yogurt container or plastic water bottles with the tops cut off). Place your five containers on a flat surface during a rain event to collect rainwater. Be sure that the collecting containers are far enough off the ground so that they are not contaminated by floodwaters and/or dirt/debris bouncing up from heavy rain into the collecting bottles.
   b. S*tormwater* sampling groups: In order to collect stormwater you will need to find puddles, ditches, creeks, and/or storm drains with stormwater running into the drain. Place the container into the water and fill with at least a 1/2 cup of stormwater. Repeat this with the four containers at the same site. Make sure to scoop the water in a manner away from your hand (so as not to get contamination from your hands).

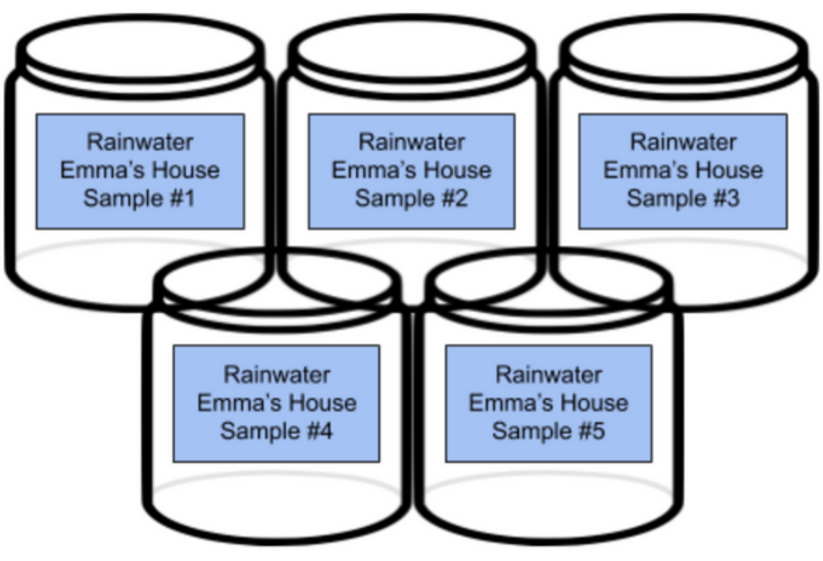



**Figure 1.** Example for how to label your samples.

# FERTILIZERS IN YOUR WATER EXPERIMENT INSTRUCTIONS

2. How to test each sample of rainwater or stormwater (collected in the recycled water bottles) for fertilizer:
    a. Use one nitrogen testing strip for each bottle of collected water. Dip the strip into the sample, and wait two minutes, and then compare the color to the color gauge on the testing strip box to determine the amount of the nitrogen in your sample.Write down the corresponding nitrogen values (based on the color of your testing strip) on your data sheet. Try to have more than one person in each group look at the strip and determine the matching color to confirm the findings.

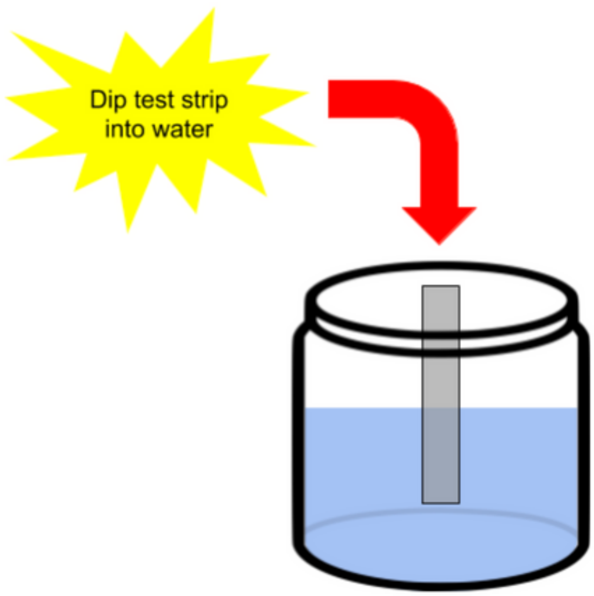



**Figure 2.** Only use one strip per sample container.

# FERTILIZERS IN YOUR WATER WORKSHEET

**Student/group name:**

**Date:**

With an ever increasing global population, agriculture and the production of food have become very important. Unfortunately, it is now common for us to use chemicals such as fertilizers and pesticides, along with other agricultural practices, to increase crop yields and make food more appealing, thus increasing the number of people fed. However, the use of fertilizers and pesticides does not come without consequences. Fertilizers are used to boost food production across most of farming (even fish farming!), and are not just used by major farms and growers. They are also used by small-scale farmers to boost the amount of food produced. When it rains, fertilizer that is not used by the plants or absorbed into the soil runs off into local waters (ditches, creeks, streams, and rivers). The fertilizers contain nitrogen and phosphorus which can cause an unnatural amount of algae to grow in the water. This is why you sometimes see algae floating at the top of a lake, ditch or creek. The algae can make it difficult for fish and other animals to feed, and can sometimes even be toxic to wildlife and pets using the water to drink.

Today, you will determine the presence or absence of fertilizers in your water samples!

Identify the following:

**Research question(s):**

**Null Hypothesis:**

# FERTILIZERS IN YOUR WATER WORKSHEET

**Alternative Hypothesis:**

**Assigned Treatment:**

Record your nitrogen results in the following table. Then record your classmates' results.

| Sample # | Rainwater | Stormwater |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |

Calculate the mean nitrogen value for the rainwater treatment and the stormwater treatment.

Mean: $\overline{X} = \frac{\textit{sum of the values}}{\textit{sample size}}$

Rainwater: ______________

Stormwater: ______________

# FERTILIZERS IN YOUR WATER

## FERTILIZER GRAPH

Show the results of your experiment with a bar graph. Label the mean.

What will be your X-axis (independent variable)?

What will be your Y-axis (dependent variable)?

Discuss why your results look the way they do. Does your alternative hypothesis match your results? Where do you think fertilizer in your samples are coming from? How would your results change if you added more stormwater sites (e.g. stormwater near a lawn, vs. near a farm, vs. your school parking lot)?

# KEY: FERTILIZERS IN YOUR WATER WORKSHEET

**Student/group name:**

**Date:**

With an ever increasing global population, agriculture and the production of food have become very important. Unfortunately, it is now common for us to use chemicals such as fertilizers and pesticides, along with other agricultural practices, to increase crop yields and make food more appealing, thus increasing the number of people fed. However, the use of fertilizers and pesticides does not come without consequences. Fertilizers are used to boost food production across most of farming (even fish farming!), and are not just used by major farms and growers. They are also used by small-scale farmers to boost the amount of food produced. When it rains, fertilizer that is not used by the plants or absorbed into the soil runs off into local waters (ditches, creeks, streams, and rivers). The fertilizers contain nitrogen and phosphorus which can cause an unnatural amount of algae to grow in the water. This is why you sometimes see algae floating at the top of a lake, ditch or creek. The algae can make it difficult for fish and other animals to feed, and can sometimes even be toxic to wildlife and pets using the water to drink.

Today, you will determine the presence or absence of fertilizers in your water samples!

Identify the following:

ANSWERS WILL VARY SLIGHTLY

**Research question(s):**

How does sample type (i.e. rainwater or stormwater) affect the amount of fertilizer in the water?

Does one sample (i.e. rainwater or stormwater) type have more or less nitrogen than another?

**Null Hypothesis:**

There will be no difference in fertilizer amount between the rainwater and stormwater samples.

The mean nitrogen value for rainwater will equal the mean nitrogen value for stormwater.

The wording of this response is very specific to the type of statistical test your students will be introduced to in the optional statistics worksheet. It is ok if this is not how they express what the null hypothesis is, so long as they express that there will be no difference for the null hypothesis.

# KEY: FERTILIZERS IN YOUR WATER WORKSHEET

**Alternative Hypothesis:**

There will be a difference in nitrogen between the rainwater and stormwater samples.

There will be more nitrogen in the stormwater samples than the rainwater samples

Some students might think there will be less nitrogen in the stormwater. That's fine!

**Assigned Treatment:**

Rainwater OR Stormwater (depending on the group students have been assigned to)

Record your nitrogen results in the following table. Then record your classmates' results.

The nitrogen values can be nitrate or nitrite depending on the test strips.

| Sample # | Rainwater | Stormwater |
|---|---|---|
| 1 | 0 ppm | 2 ppm |
| 2 | 0 ppm | 5 ppm |
| 3 | 0 ppm | 2 ppm |
| 4 | 0.5 ppm | 10 ppm |
| 5 | 0 ppm | 5 ppm |
| 6 | 0 ppm | 5 ppm |
| 7 | 0.5 ppm | 10 ppm |
| 8 | 0.5 ppm | 5 ppm |
| 9 | 0 ppm | |
| 10 | 0.5 ppm | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |

Depending on the test strips you use, the units may be: parts per million (ppm) or milligrams per liter (mg/L)

Calculate the mean nitrogen value for the rainwater treatment and the stormwater treatment.

Mean: $\overline{X} = \frac{\textit{sum of the values}}{\textit{sample size}}$

Rainwater: 0.2 ppm

Stormwater: 5.5 ppm

# KEY: FERTILIZERS IN YOUR WATER

## FERTILIZER GRAPH

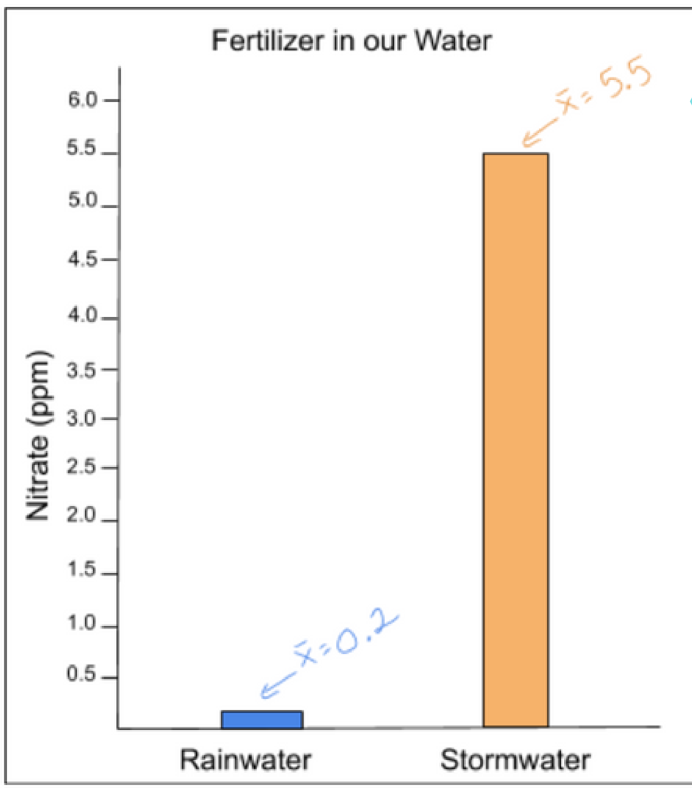
Show the results of your experiment with a bar graph. Label the mean.

What will be your X-axis (independent variable)?

Water Sample (e.g. rainwater)

What will be your Y-axis (dependent variable)?

Nitrate (ppm)




Encourage students to hand draw their graphs! It helps them understand their data!!

Discuss why your results look the way they do. Does your alternative hypothesis match your results? Where do you think fertilizer in your samples are coming from? How would your results change if you added more stormwater sites (e.g. stormwater near a lawn, vs. near a farm, vs. your school parking lot)?

The majority of our rainwater samples had 0 ppm of nitrate, with an average of 0.2 ppm for all of our rainwater samples. The stormwater samples had an average of 5.5 ppm of nitrate. These results match our alternative hypothesis that there is a difference between rainwater and stormwater in terms of fertilizer in the water. Fertilizer in our stormwater samples might come from lawn maintenance or nearby farms. If we collected stormwater from our school parking lot, we might not have any nitrate in our samples because I don't think our school uses fertilizer. However, if we got more stormwater samples near the farm down the road, I think we'd see more nitrate in our stormwater due to the farm's fertilizer use.

# FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

**Student/group name:**

**Date:**

With an ever increasing global population, agriculture and the production of food have become very important. Unfortunately, it is now common for us to use chemicals such as fertilizers and pesticides, along with other agricultural practices, to increase crop yields and make food more appealing, thus increasing the number of people fed. However, the use of fertilizers and pesticides does not come without consequences. Fertilizers are used to boost food production across most of farming (even fish farming!), and are not just used by major farms and growers. They are also used by small-scale farmers to boost the amount of food produced. When it rains, fertilizer that is not used by the plants or absorbed into the soil runs off into local waters (ditches, creeks, streams, and rivers). The fertilizers contain nitrogen and phosphorus which can cause an unnatural amount of algae to grow in the water. This is why you sometimes see algae floating at the top of a lake, ditch or creek. The algae can make it difficult for fish and other animals to feed, and can sometimes even be toxic to wildlife and pets using the water to drink.

Today, you will determine the presence or absence of fertilizers in your water samples!

Identify the following:

**Research question(s):**

**Null Hypothesis:**

# FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

**Alternative Hypothesis:**

**Assigned Treatment:**

## DATA COLLECTION

Record the nitrogen values for your group's samples in Table 1. Make sure to label the treatment for your group (i.e. rainwater or stormwater) and label the units for nitrogen.

**Table 1.** Individual group results

| Treatment: ______________________ | |
|---|---|
| **Sample #** | **Nitrogen Value** |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |

# FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

Count the number of samples and calculate the mean, variance, and standard deviation for your samples using the equations listed below. Record the statistics in Table 2.

Sample Size: $n$ = *the number of data points per sample group*

Mean: $\overline{X} = \frac{\text{sum of the values}}{\text{sample size}}$

Variance: $S^2 = \frac{\sum (X_i - \overline{X})^2}{n-1}$

Standard Deviation: $\sigma = \sqrt{S^2}$

**Table 2.** Individual group statistics

| Treatment: ____________________ | |
|---|---|
| **Sample Size (n)** | |
| **Mean ($\overline{X}$)** | |
| **Variance ($S^2$)** | |
| **Standard Deviation ($\sigma$)** | |

Aggregate the class stormwater and rainwater values into a shared spreadsheet (e.g. Google Sheets). From your classroom data, you will determine whether there is a significant statistical difference in the nitrogen values in your rainwater and stormwater samples. To test the statistical difference in your collected data, you will use an independent samples t-test. This type of statistical test is used to compare the means of two separate groups of data. To conduct this test, you will use the sample size (n), mean (X), and variance (S2) that you will calculate with the **data from the whole class**. You will also calculate the standard deviation ($\sigma$) to include in your graph.

1. What are the two treatment groups that the class collected data for?

Treatment 1:

Treatment 2:

# FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

## STATISTICAL ANALYSIS

The null hypothesis for this type of statistical test is that there is no difference between the two treatment groups' means. The alternative hypothesis is that there is a difference between the two groups' means.

$H_0$: mean Nitrogen values of stormwater samples = mean Nitrogen values of rainwater samples
$H_a$: mean Nitrogen values of stormwater samples ≠ mean Nitrogen values of rainwater samples

2. Do you think there will be a significant difference between the means of the stormwater and rainwater samples for nitrogen? Explain.

3. Using the classroom data, determine the sample size ($n$), mean ($\bar{x}$), variance ($s^2$), and standard deviation($\sigma$) for each treatment group. Record the statistics in Table 3.

Sample Size: $n$ = *the number of data points per sample group*

Mean: $\bar{X} = \frac{\text{sum of the values}}{\text{sample size}}$

Variance: $S^2 = \frac{\sum (X_i - \bar{X})^2}{n-1}$

Standard Deviation: $\sigma = \sqrt{S^2}$

| **Table 3.** | Rainwater | Stormwater |
|---|---|---|
| Sample Size (n) | | |
| Mean ($\bar{X}$) | | |
| Variance ($S^2$) | | |
| Standard Deviation ($\sigma$) | | |

# FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

## STATISTICAL ANALYSIS

A calculated t-value is a test statistic that helps you compare your sample means to the null hypothesis. This value incorporates sample mean, sample size, and sample variability. As the difference between the sample data and the null hypothesis increases, the absolute value of the t-value increases*.

4. Using your values in Table 3, calculate the t-value for nitrogen using the formula below. Make sure you report the absolute value if your calculated t-value is negative!

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

$t =$ ____________________________

A critical t-value is used to explain what t-value you'd expect to get simply by chance. To calculate the critical t-value, you need to determine your degrees of freedom (df) and your alpha level (). For our data, we will set the alpha level to 0.05. This means that there is only a 5% likelihood that we will reject our null hypothesis when it is actually true**.

5. Determine the degrees of freedom using the formula below.

$$df = n_1 + n_2 - 2$$

$df =$ ______________________

*Understanding t-Tests: t-values, and t-distributions. 2016. Retrieved from https://blog.minitab.com/blog/adventures-in-statistics-2/understanding-t-tests-t-values-and-t-distributions

**Understanding Hypothesis Tests: Significance Levels (Alpha) and P values in Statistics. 2015. Retrieved from https://blog.minitab.com/blog/adventures-in-statistics-2/understanding-hypothesis-tests-significance-levels-alpha-and-p-values-in-statistics#:~:text=The%20significance%20level%2C%20also%20denoted,there%20is%20no%20actual%20difference.

6. Look up the critical t-value in the t-table based on your degrees of freedom (df) and alpha level (a)for the two tailed t-test. What is the critical t-value?

$t_{critical}$ = ____________________

If the calculated t-value is larger than the critical t-value, then you reject your null hypothesis. If the calculated t-value is smaller than the critical t-value, then you fail to reject your null hypothesis.

7. Is the calculated t-value larger or smaller than the critical t-value?

8. Based on your calculated t-value and critical t-value, will you reject your null hypothesis? What does it mean to reject (or fail to reject) your null hypothesis for this experiment? Explain.

# FERTILIZERS IN YOUR WATER

## FERTILIZER GRAPH

Show the results of your experiment with a bar graph. Label the mean.

What will be your X-axis (independent variable)?

What will be your Y-axis (dependent variable)?

Discuss why your results look the way they do. Does your alternative hypothesis match your results? Where do you think fertilizer in your samples are coming from? How would your results change if you added more stormwater sites (e.g. stormwater near a lawn, vs. near a farm, vs. your school parking lot)?

# KEY: FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

**Student/group name:**

**Date:**

With an ever increasing global population, agriculture and the production of food have become very important. Unfortunately, it is now common for us to use chemicals such as fertilizers and pesticides, along with other agricultural practices, to increase crop yields and make food more appealing, thus increasing the number of people fed. However, the use of fertilizers and pesticides does not come without consequences. Fertilizers are used to boost food production across most of farming (even fish farming!), and are not just used by major farms and growers. They are also used by small-scale farmers to boost the amount of food produced. When it rains, fertilizer that is not used by the plants or absorbed into the soil runs off into local waters (ditches, creeks, streams, and rivers). The fertilizers contain nitrogen and phosphorus which can cause an unnatural amount of algae to grow in the water. This is why you sometimes see algae floating at the top of a lake, ditch or creek. The algae can make it difficult for fish and other animals to feed, and can sometimes even be toxic to wildlife and pets using the water to drink.

Today, you will determine the presence or absence of fertilizers in your water samples!

Identify the following:

ANSWERS WILL VARY SLIGHTLY

**Research question(s):**

How does sample type (i.e. rainwater or stormwater) affect the amount of fertilizer in the water?

Does one sample (i.e. rainwater or stormwater) type have more or less nitrogen than another?

**Null Hypothesis:**

There will be no difference in fertilizer amount between the rainwater and stormwater samples.

The mean nitrogen value for rainwater will equal the mean nitrogen value for stormwater.

The wording of this response is very specific to the type of statistical test your students will be introduced to in the optional statistics worksheet. It is ok if this is not how they express what the null hypothesis is, so long as they express that there will be no difference for the null hypothesis.

# KEY: FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

**Alternative Hypothesis:**

There will be a difference in nitrogen between the rainwater and stormwater samples.

There will be more nitrogen in the stormwater samples than the rainwater samples.

Some students might think there will be less nitrogen in the stormwater. That's fine!

**Assigned Treatment:**

Record the nitrogen values for your group's samples in Table 1. Make sure to label the treatment for your group (i.e. rainwater or stormwater) and label the units for nitrogen.

## DATA COLLECTION

Record the nitrogen values for your group's samples in Table 1. Make sure to label the treatment for your group (i.e. rainwater or stormwater) and label the units for nitrogen.

Nitrogen values can be nitrate or nitrite depending on test strips. Units will also depend on test strips.

**Table 1.** Individual group results

Make sure your students know how many samples they will be testing. Aim for at least 5 samples, but feel free to collect more!

| Treatment: Stormwater | |
|---|---|
| Sample # | Nitrogen Value |
| 1 | 2 ppm |
| 2 | 5 ppm |
| 3 | 2 ppm |
| 4 | 10 ppm |
| 5 | 5 ppm |

Depending on the test strips you use, the units may be: parts per million (ppm) or milligrams per liter (mg/L)

# KEY: FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

Count the number of samples and calculate the mean, variance, and standard deviation for your samples using the equations listed below. Record the statistics in Table 2.

Sample Size: $n$ = *the number of data points per sample group*

Mean: $\bar{X} = \frac{\text{sum of the values}}{\text{sample size}}$

Variance: $S^2 = \frac{\sum (X_i - \bar{X})^2}{n-1}$

Standard Deviation: $\sigma = \sqrt{S^2}$

Statistics can be calculated in a spreadsheet. Here is an example for individual data and classroom data. https://docs.google.com/spreadsheets/d/1oGm_81QHciSfBoS14QDnRrIJM971B1KYZQoAmGM6y3g/edit?usp=sharing

**Table 2.** Individual group statistics

This is for individual group practice before you aggregate all of the class data. These individual group statistics will not be used in the following statistical analysis.

| Treatment: Stormwater | |
|---|---|
| **Sample Size (n)** | 5 samples |
| **Mean ($\bar{X}$)** | 4.8 ppm |
| **Variance ($S^2$)** | 10.7 |
| **Standard Deviation ($\sigma$)** | 3.27 |

Aggregate the class stormwater and rainwater values into a shared spreadsheet (e.g. Google Sheets). From your classroom data, you will determine whether there is a significant statistical difference in the nitrogen values in your rainwater and stormwater samples. To test the statistical difference in your collected data, you will use an independent samples t-test. This type of statistical test is used to compare the means of two separate groups of data. To conduct this test, you will use the sample size (n), mean (X), and variance (S2) that you will calculate with the data from the whole class. You will also calculate the standard deviation ($\sigma$) to include in your graph.

1. What are the two treatment groups that the class collected data for?

Treatment 1: **Rainwater**

Treatment 2: **Stormwater**

# KEY: FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

## STATISTICAL ANALYSIS

The null hypothesis for this type of statistical test is that there is no difference between the two treatment groups' means. The alternative hypothesis is that there is a difference between the two groups' means.

$H_0$: mean Nitrogen values of stormwater samples = mean Nitrogen values of rainwater samples
$H_a$: mean Nitrogen values of stormwater samples ≠ mean Nitrogen values of rainwater samples

2. Do you think there will be a significant difference between the means of the stormwater and rainwater samples for nitrogen? Explain.

No, because I don't think fertilizers are commonly used in our area. Therefore, the nitrogen levels will be the same for rainwater and stormwater. Low levels in both.

OR

Yes, because I've seen a lot of fertilizer being used where we collected stormwater. So stormwater would have higher mean N values than rainwater.

3. Using the classroom data, determine the sample size ($n$), mean ($\bar{x}$), variance ($s^2$), and standard deviation($\sigma$) for each treatment group. Record the statistics in Table 3.

Sample Size: $n$ = *the number of data points per sample group*

Mean: $$\bar{X} = \frac{\text{sum of the values}}{\text{sample size}}$$

Variance: $$S^2 = \frac{\sum (X_i - \bar{X})^2}{n-1}$$

Standard Deviation: $$\sigma = \sqrt{S^2}$$

| **Table 3.** | Rainwater | Stormwater |
|---|---|---|
| Sample Size (n) | 10 | 8 |
| Mean ($\bar{X}$) | 0.2 ppm | 5.5 ppm |
| Variance ($S^2$) | 0.067 | 9.43 |
| Standard Deviation ($\sigma$) | 0.26 | 3.07 |

# KEY: FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

## STATISTICAL ANALYSIS

A calculated t-value is a test statistic that helps you compare your sample means to the null hypothesis. This value incorporates sample mean, sample size, and sample variability. As the difference between the sample data and the null hypothesis increases, the absolute value of the t-value increases*.

4. Using your values in Table 3, calculate the t-value for nitrogen using the formula below. Make sure you report the absolute value if your calculated t-value is negative!

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

t-values: Student can calculate this value in a spreadsheet, but should show which values go in the formula on the worksheet.

$$t = \frac{0.2 - 5.5}{\sqrt{\frac{0.067}{10} + \frac{9.43}{8}}} = \left| -4.87 \right| = 4.87$$

$t =$ 4.87 ppm

A critical t-value is used to explain what t-value you'd expect to get simply by chance. To calculate the critical t-value, you need to determine your degrees of freedom (df) and your alpha level (). For our data, we will set the alpha level to 0.05. This means that there is only a 5% likelihood that we will reject our null hypothesis when it is actually true**.

5. Determine the degrees of freedom using the formula below.

$$df = n_1 + n_2 - 2$$

$df =$ 10 + 8 - 2 = 16

*Understanding t-Tests: t-values, and t-distributions. 2016. Retrieved from https://blog.minitab.com/blog/adventures-in-statistics-2/understanding-t-tests-t-values-and-t-distributions

**Understanding Hypothesis Tests: Significance Levels (Alpha) and P values in Statistics. 2015. Retrieved from https://blog.minitab.com/blog/adventures-in-statistics-2/understanding-hypothesis-tests-significance-levels-alpha-and-p-values-in-statistics#:~:text=The%20significance%20level%2C%20also%20denoted,there%20is%20no%20actual%20difference.

# KEY: FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

6. Look up the critical t-value in the t-table based on your degrees of freedom (df) and alpha level (a)for the two tailed t-test. What is the critical t-value?

$t_{critical}$ = 2.12

If the calculated t-value is larger than the critical t-value, then you reject your null hypothesis. If the calculated t-value is smaller than the critical t-value, then you fail to reject your null hypothesis.

7. Is the calculated t-value larger or smaller than the critical t-value?

The absolute value of the calculated t-value (4.87) is larger than the critical t-value (2.12)

8. Based on your calculated t-value and critical t-value, will you reject your null hypothesis? What does it mean to reject (or fail to reject) your null hypothesis for this experiment? Explain.

We will reject our null hypothesis. This means that there is a statistically significant difference between the nitrogen in our rainwater and stormwater samples!

# KEY: FERTILIZERS IN YOUR WATER STATISTICS EXTENSION

## FERTILIZER GRAPH

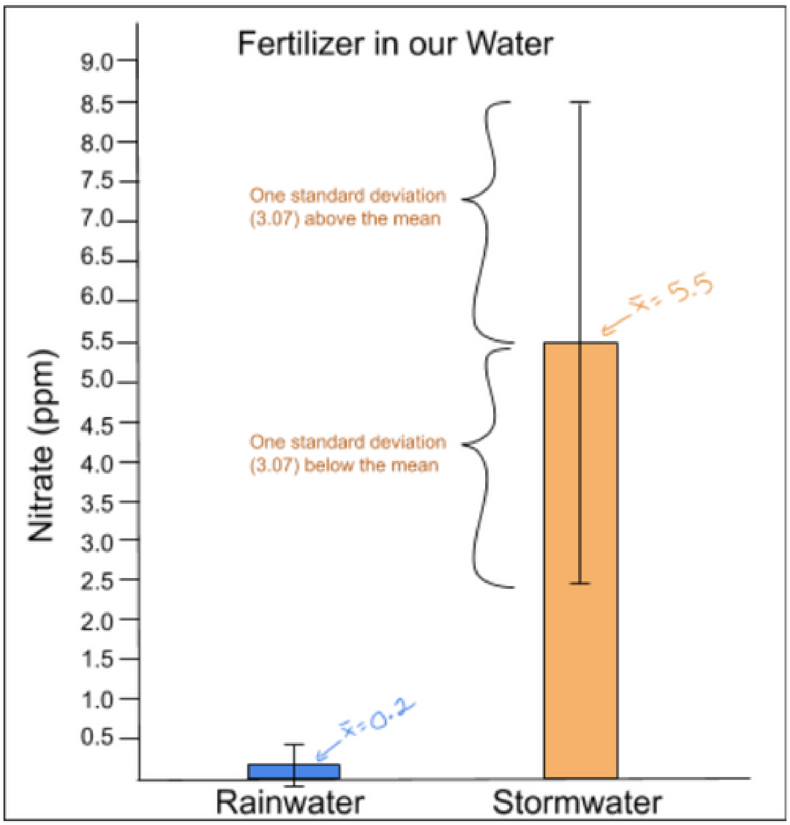
Show the results of your experiment with a bar graph. Label the mean.

What will be your X-axis (independent variable)?

Water Sample (e.h. rainwater)

What will be your Y-axis (dependent variable)?

Nitrate value (ppm)




Discuss why your results look the way they do. Does your alternative hypothesis match your results? Where do you think fertilizer in your samples are coming from? How would your results change if you added more stormwater sites (e.g. stormwater near a lawn, vs. near a farm, vs. your school parking lot)?

The majority of our rainwater samples had 0 ppm of nitrate, with an average of 0.2 ppm for all of our rainwater samples. The stormwater samples had an average of 5.5 ppm of nitrate. These results match our alternative hypothesis that there is a difference between rainwater and stormwater in terms of fertilizer in the water. Fertilizer in our stormwater samples might come from lawn maintenance or nearby farms. If we collected stormwater from our school parking lot, we might not have any nitrate in our samples because I don't think our school uses fertilizer. However, if we got more stormwater samples near the farm down the road, I think we'd see more nitrate in our stormwater due to the farm's fertilizer use.

# PESTICIDES IN YOUR WATER EXPERIMENT INSTRUCTIONS

## PESTICIDE EXPERIMENT STEPS

1. Each treatment group (i.e. rainwater or stormwater) will need 5 recycled containers to collect samples (e.g. yogurt containers or plastic water bottles with the tops cut off). Label each sampling container with the treatment (e.g. Rainwater), location (e.g. Emma's house), and sample number (e.g. Sample #1). Then collect your samples (one sample per container) using a gloved hand for collecting the samples. Each group should collect at least 5 samples from the chosen site within your treatment. Try to be very careful to only sample the rainwater or stormwater, and not include soil in your sample collection.
   a. *Rainwater sampling groups*: In order to collect rainwater you will need a container with a large surface area to collect the rain more quickly (e.g. yogurt container or plastic water bottles with the tops cut off). Place your five containers on a flat surface during a rain event to collect rainwater. Be sure that the collecting containers are far enough off the ground so that they are not contaminated by floodwaters and/or dirt/debris bouncing up from heavy rain into the collecting bottles.
   b. *Stormwater sampling groups*: In order to collect stormwater you will need to find puddles, ditches, creeks, and/or storm drains with stormwater running into the drain. Place the container into the water and fill with at least a 1/2 cup of stormwater. Repeat this with the four containers at the same site. Make sure to scoop the water in a manner away from your hand (so as not to get contamination from your hands).

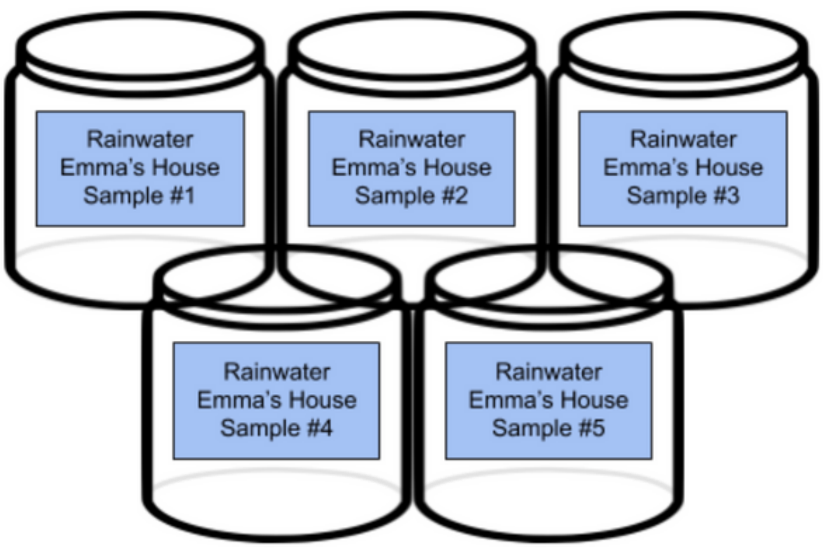



**Figure 1.** Example for how to label your samples.

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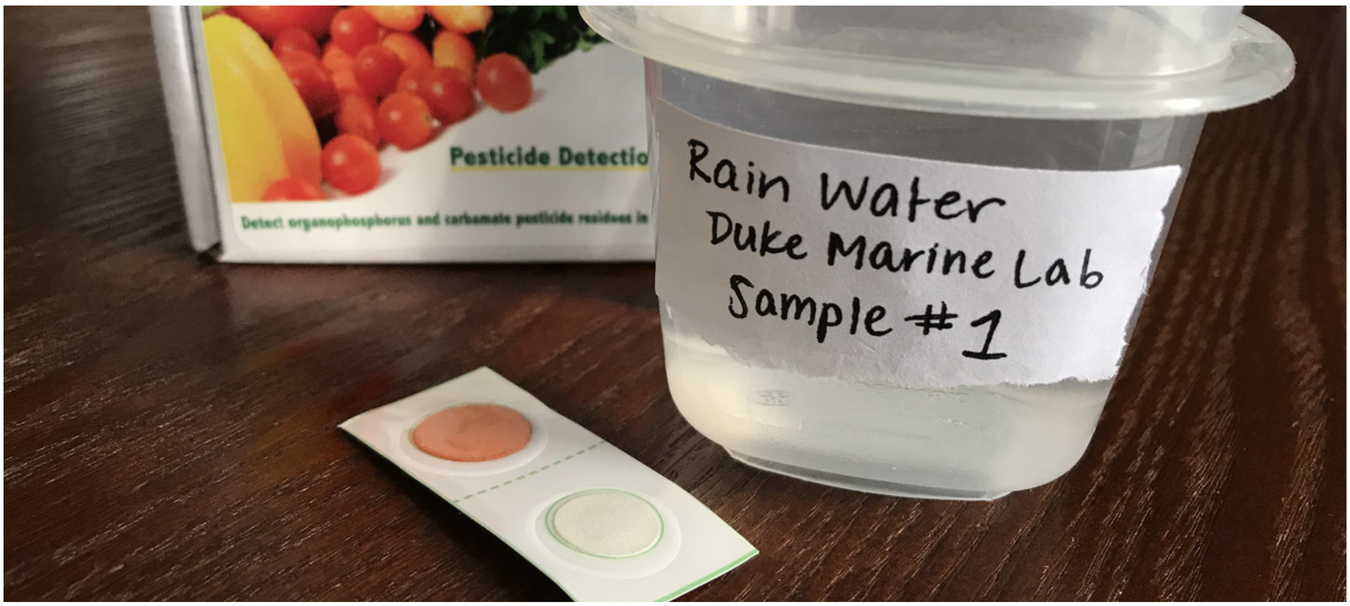
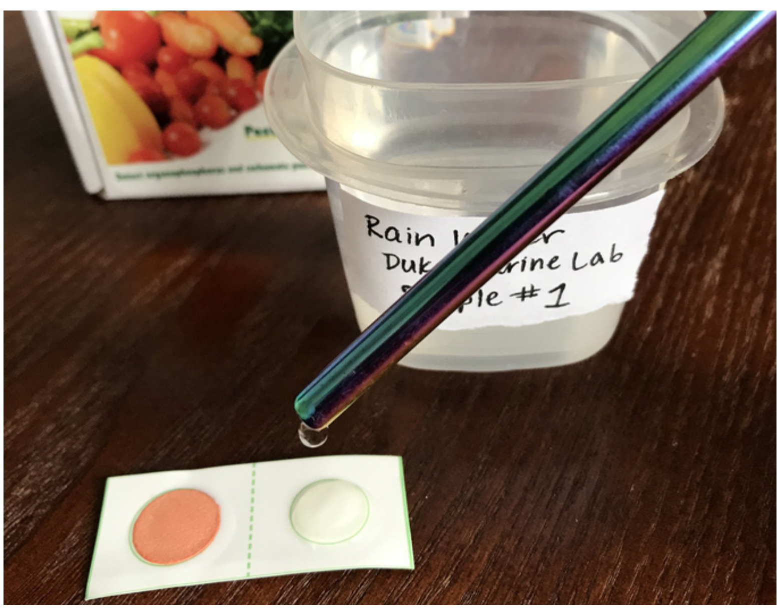
2. Testing for pesticides:
    a. Remove the protective film from the pesticide card.
    b. Use a dropper to fully cover the white disc of the pesticide card with your water sample.
    c. Make sure the white disc is fully covered with the sample solution.
    d. Let the pesticide card sit for 10 minutes.
    e. Fold the card in half, with the white and red discs facing each other.
    f. Pinch the white and red discs together for 3 minutes.
    g. Open the pesticide card and record the concentration results (negative, low, or high).
    h. Record the results in the data table.



# PESTICIDES IN YOUR WATER WORKSHEET

**Student/group name:**

**Date:**

Farming and agricultural food production has never been more important. Unfortunately, feeding the growing population is becoming increasingly difficult due to pests and insects that damage the crops. Over the last few decades it has become common for most farmers to use pesticides to control insects and parasites that damage crops. Pesticides are "any substance used to kill, repel, or control certain forms of plant or animal life that are considered to be pests"*. The application of pesticides, along with other agricultural practices, protects the plant and can actually increase crop yields, thus reducing economic losses and increasing the number of people fed! However, the use of pesticides does not come without consequences. Pesticides can cause serious short-term and long-term damage to animals, including humans. Pesticides can cause problems with reproduction, animal growth, and animal hormones. The effects of pesticides in water can sometimes be serious, and if seafood is grown in contaminated water, consuming the seafood can cause health problems.

Today, you will determine the concentration of pesticides in your water samples!

Identify the following:

**Research question(s):**

**Null Hypothesis:**

*Pesticides. 2020. Retrieved from www.niehs.nih.gov/health/topics/agents/pesticides/index.cfm

# PESTICIDES IN YOUR WATER WORKSHEET

**Alternative Hypothesis:**

**Assigned Treatment:**

## DATA COLLECTION

Record your pesticide concentration results in the following table. Then record your classmates' results.

| Sample # | Rainwater | Stormwater |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |

# PESTICIDES IN YOUR WATER WORKSHEET

Use the data in the table above to determine the number of times the class results showed the following:

Stormwater Negative:

Stormwater Low:

Stormwater High:

Rainwater Negative:

Rainwater Low:

Rainwater High:

# PESTICIDES IN YOUR WATER WORKSHEET

## PESTICIDE GRAPH

Create a bar graph to show the frequency each concentration occurred for each treatment

What will be your X-axis (independent variable)?

What will be your Y-axis (dependent variable)?

Discuss why your results look the way they do. Does your hypothesis match your results? Where do you think pesticides in your samples are coming from? How would your results change if you added more stormwater sites (e.g. stormwater near a lawn, vs. near a farm, vs. your school parking lot)?

# KEY: PESTICIDES IN YOUR WATER WORKSHEET

**Student/group name:**

**Date:**

Farming and agricultural food production has never been more important. Unfortunately, feeding the growing population is becoming increasingly difficult due to pests and insects that damage the crops. Over the last few decades it has become common for most farmers to use pesticides to control insects and parasites that damage crops. Pesticides are "any substance used to kill, repel, or control certain forms of plant or animal life that are considered to be pests"*. The application of pesticides, along with other agricultural practices, protects the plant and can actually increase crop yields, thus reducing economic losses and increasing the number of people fed! However, the use of pesticides does not come without consequences. Pesticides can cause serious short-term and long-term damage to animals, including humans. Pesticides can cause problems with reproduction, animal growth, and animal hormones. The effects of pesticides in water can sometimes be serious, and if seafood is grown in contaminated water, consuming the seafood can cause health problems.

Today, you will determine the concentration of pesticides in your water samples!

Identify the following:

ANSWERS WILL VARY SLIGHTLY

**Research question(s):**

How does sample type (i.e. rainwater or stormwater) affect the presence (or concentration; high, low, negative) of pesticides?

Does one sample type have pesticides more frequently than another?

**Null Hypothesis:**

There will be no difference in pesticides between the rainwater and stormwater samples.

The mean number of times that pesticides are present in rainwater will equal the mean number of times that pesticides are present in stormwater.

*Pesticides. 2020. Retrieved from www.niehs.nih.gov/health/topics/agents/pesticides/index.cfm

# KEY: PESTICIDES IN YOUR WATER WORKSHEET

**Alternative Hypothesis:**

There will be a difference in pesticides between the rainwater and stormwater samples.

There will be more pesticides in the stormwater samples than the rainwater samples.

**Assigned Treatment:**

Rainwater OR Stormwater (depending on the group students have been assigned to)

## DATA COLLECTION

Record your pesticide concentration results in the following table. Then record your classmates' results.

| Sample # | Rainwater | Stormwater |
|---|---|---|
| 1 | Negative | Low |
| 2 | Negative | Low |
| 3 | Low | High |
| 4 | Negative | Negative |
| 5 | Negative | Low |
| 6 | Negative | Low |
| 7 | High | Negative |
| 8 | Negative | High |
| 9 | Low | Negative |
| 10 | Low | Negative |
| 11 | Negative | High |
| 12 | Negative | High |
| 13 | Negative | Low |
| 14 | Low | Low |
| 15 | High | Negative |

# KEY: PESTICIDES IN YOUR WATER WORKSHEET

Use the data in the table above to determine the number of times the class results showed the following:

Rainwater Negative: **9**

Rainwater Low: **4**

Rainwater High: **2**

Stormwater Negative: **5**

Stormwater Low: **6**

Stormwater High: **4**

# KEY: PESTICIDES IN YOUR WATER WORKSHEET

## PESTICIDE GRAPH

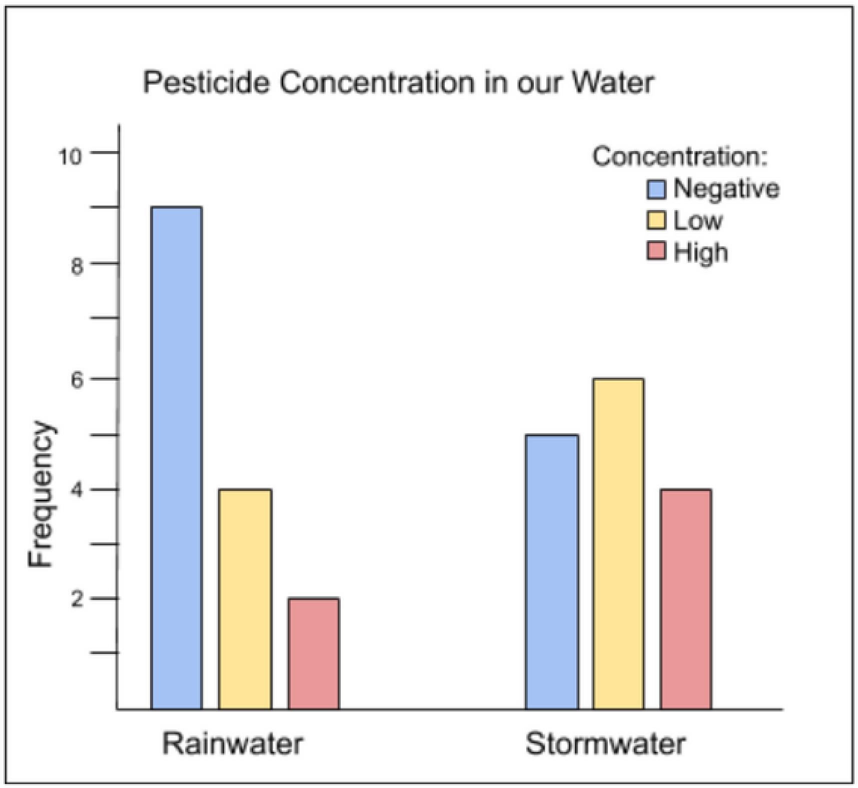
Create a bar graph to show the frequency each concentration occurred for each treatment

What will be your X-axis (independent variable)?

Sample Type (e.g. Treatment, Water Sample, Site, etc.)

What will be your Y-axis (dependent variable)?

Frequency of Occurrence




Discuss why your results look the way they do. Does your hypothesis match your results? Where do you think pesticides in your samples are coming from? How would your results change if you added more stormwater sites (e.g. stormwater near a lawn, vs. near a farm, vs. your school parking lot)?

The majority of our rainwater samples showed negative results for pesticides. Our stormwater samples had a higher frequency of low and high concentration results than our rainwater samples. This matches our alternative hypothesis that there is a difference between rainwater and stormwater in terms of pesticide concentration. I'm surprised that rainwater had any pesticides at all. This may be a result of cross-contamination in our samples. Pesticides in our stormwater might come from lawn maintenance or nearby farms. If we collected stormwater from our school parking lot, we might not have any pesticides in our samples because I don't think our school uses pesticides. However, if we got more stormwater samples near the farm down the road, I think we'd see more frequency of low and high concentration of pesticides.

# FERTILIZERS IN YOUR WATER WORKSHEET

## STATISTICS: Additional Resources

- Understanding t-Tests: t-values and t-distributions
  - https://blog.minitab.com/blog/adventures-in-statistics-2/understanding-t-tests-t-values-and-t-distributions
- Understanding Hypothesis Tests: Significance Levels (Alpha) and P values in Statistics
  - https://blog.minitab.com/blog/adventures-in-statistics-2/understanding-hypothesis-tests-significance-levels-alpha-and-p-values-in-statistics#:~:text=The%20significance%20level%2C%20also%20denoted,there%20is%20no%20actual%20difference.
- Independent t-test - Explained Simply (5 minute videos)
  - Part 1: https://www.youtube.com/watch?v=3azuAaOJack&t=5s
  - Part 2: https://www.youtube.com/watch?v=X3xUn40ycyM
  - Part 3: https://www.youtube.com/watch?v=nG-MOrtNgt8
  - Part 4: https://www.youtube.com/watch?v=PfBKBuYYb3o
  - Part 5: https://www.youtube.com/watch?v=IQgeSeRKkVY
  - Part 6: https://www.youtube.com/watch?v=wFp61RpDnA0
  - Part 7: https://www.youtube.com/watch?v=HqdvffPGgw0

# T-TABLE

| cum. prob | $t_{.50}$ | $t_{.75}$ | $t_{.80}$ | $t_{.85}$ | $t_{.90}$ | $t_{.95}$ | $t_{.975}$ | $t_{.99}$ | $t_{.995}$ | $t_{.999}$ | $t_{.9995}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **one-tail** | **0.50** | **0.25** | **0.20** | **0.15** | **0.10** | **0.05** | **0.025** | **0.01** | **0.005** | **0.001** | **0.0005** |
| **two-tails** | **1.00** | **0.50** | **0.40** | **0.30** | **0.20** | **0.10** | **0.05** | **0.02** | **0.01** | **0.002** | **0.001** |
| **df** | | | | | | | | | | | |
| 1 | 0.000 | 1.000 | 1.376 | 1.963 | 3.078 | 6.314 | 12.71 | 31.82 | 63.66 | 318.31 | 636.62 |
| 2 | 0.000 | 0.816 | 1.061 | 1.386 | 1.886 | 2.920 | 4.303 | 6.965 | 9.925 | 22.327 | 31.599 |
| 3 | 0.000 | 0.765 | 0.978 | 1.250 | 1.638 | 2.353 | 3.182 | 4.541 | 5.841 | 10.215 | 12.924 |
| 4 | 0.000 | 0.741 | 0.941 | 1.190 | 1.533 | 2.132 | 2.776 | 3.747 | 4.604 | 7.173 | 8.610 |
| 5 | 0.000 | 0.727 | 0.920 | 1.156 | 1.476 | 2.015 | 2.571 | 3.365 | 4.032 | 5.893 | 6.869 |
| 6 | 0.000 | 0.718 | 0.906 | 1.134 | 1.440 | 1.943 | 2.447 | 3.143 | 3.707 | 5.208 | 5.959 |
| 7 | 0.000 | 0.711 | 0.896 | 1.119 | 1.415 | 1.895 | 2.365 | 2.998 | 3.499 | 4.785 | 5.408 |
| 8 | 0.000 | 0.706 | 0.889 | 1.108 | 1.397 | 1.860 | 2.306 | 2.896 | 3.355 | 4.501 | 5.041 |
| 9 | 0.000 | 0.703 | 0.883 | 1.100 | 1.383 | 1.833 | 2.262 | 2.821 | 3.250 | 4.297 | 4.781 |
| 10 | 0.000 | 0.700 | 0.879 | 1.093 | 1.372 | 1.812 | 2.228 | 2.764 | 3.169 | 4.144 | 4.587 |
| 11 | 0.000 | 0.697 | 0.876 | 1.088 | 1.363 | 1.796 | 2.201 | 2.718 | 3.106 | 4.025 | 4.437 |
| 12 | 0.000 | 0.695 | 0.873 | 1.083 | 1.356 | 1.782 | 2.179 | 2.681 | 3.055 | 3.930 | 4.318 |
| 13 | 0.000 | 0.694 | 0.870 | 1.079 | 1.350 | 1.771 | 2.160 | 2.650 | 3.012 | 3.852 | 4.221 |
| 14 | 0.000 | 0.692 | 0.868 | 1.076 | 1.345 | 1.761 | 2.145 | 2.624 | 2.977 | 3.787 | 4.140 |
| 15 | 0.000 | 0.691 | 0.866 | 1.074 | 1.341 | 1.753 | 2.131 | 2.602 | 2.947 | 3.733 | 4.073 |
| 16 | 0.000 | 0.690 | 0.865 | 1.071 | 1.337 | 1.746 | 2.120 | 2.583 | 2.921 | 3.686 | 4.015 |
| 17 | 0.000 | 0.689 | 0.863 | 1.069 | 1.333 | 1.740 | 2.110 | 2.567 | 2.898 | 3.646 | 3.965 |
| 18 | 0.000 | 0.688 | 0.862 | 1.067 | 1.330 | 1.734 | 2.101 | 2.552 | 2.878 | 3.610 | 3.922 |
| 19 | 0.000 | 0.688 | 0.861 | 1.066 | 1.328 | 1.729 | 2.093 | 2.539 | 2.861 | 3.579 | 3.883 |
| 20 | 0.000 | 0.687 | 0.860 | 1.064 | 1.325 | 1.725 | 2.086 | 2.528 | 2.845 | 3.552 | 3.850 |
| 21 | 0.000 | 0.686 | 0.859 | 1.063 | 1.323 | 1.721 | 2.080 | 2.518 | 2.831 | 3.527 | 3.819 |
| 22 | 0.000 | 0.686 | 0.858 | 1.061 | 1.321 | 1.717 | 2.074 | 2.508 | 2.819 | 3.505 | 3.792 |
| 23 | 0.000 | 0.685 | 0.858 | 1.060 | 1.319 | 1.714 | 2.069 | 2.500 | 2.807 | 3.485 | 3.768 |
| 24 | 0.000 | 0.685 | 0.857 | 1.059 | 1.318 | 1.711 | 2.064 | 2.492 | 2.797 | 3.467 | 3.745 |
| 25 | 0.000 | 0.684 | 0.856 | 1.058 | 1.316 | 1.708 | 2.060 | 2.485 | 2.787 | 3.450 | 3.725 |
| 26 | 0.000 | 0.684 | 0.856 | 1.058 | 1.315 | 1.706 | 2.056 | 2.479 | 2.779 | 3.435 | 3.707 |
| 27 | 0.000 | 0.684 | 0.855 | 1.057 | 1.314 | 1.703 | 2.052 | 2.473 | 2.771 | 3.421 | 3.690 |
| 28 | 0.000 | 0.683 | 0.855 | 1.056 | 1.313 | 1.701 | 2.048 | 2.467 | 2.763 | 3.408 | 3.674 |
| 29 | 0.000 | 0.683 | 0.854 | 1.055 | 1.311 | 1.699 | 2.045 | 2.462 | 2.756 | 3.396 | 3.659 |
| 30 | 0.000 | 0.683 | 0.854 | 1.055 | 1.310 | 1.697 | 2.042 | 2.457 | 2.750 | 3.385 | 3.646 |
| 40 | 0.000 | 0.681 | 0.851 | 1.050 | 1.303 | 1.684 | 2.021 | 2.423 | 2.704 | 3.307 | 3.551 |
| 60 | 0.000 | 0.679 | 0.848 | 1.045 | 1.296 | 1.671 | 2.000 | 2.390 | 2.660 | 3.232 | 3.460 |
| 80 | 0.000 | 0.678 | 0.846 | 1.043 | 1.292 | 1.664 | 1.990 | 2.374 | 2.639 | 3.195 | 3.416 |
| 100 | 0.000 | 0.677 | 0.845 | 1.042 | 1.290 | 1.660 | 1.984 | 2.364 | 2.626 | 3.174 | 3.390 |
| 1000 | 0.000 | 0.675 | 0.842 | 1.037 | 1.282 | 1.646 | 1.962 | 2.330 | 2.581 | 3.098 | 3.300 |
| ***z*** | 0.000 | 0.674 | 0.842 | 1.036 | 1.282 | 1.645 | 1.960 | 2.326 | 2.576 | 3.090 | 3.291 |
| | 0% | 50% | 60% | 70% | 80% | 90% | 95% | 98% | 99% | 99.8% | 99.9% |
| | **Confidence Level** | | | | | | | | | | |

Online t-chart. Retrieved from http://www.ttable.org/