



EARTHECHO WATER BY DESIGN

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DESALINATION DESIGN ACTIVITY



PRESENTED in PARTNERSHIP with **NORTHROP GRUMMAN**

Foundation



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This activity has been adapted from: *Hands-on Activity: Do as the Romans: Construct an Aqueduct!* © 2013 by Regents of the University of Colorado; original © 2004 Worcester Polytechnic Institute. Contributed by the Center for Engineering Educational Outreach, Tufts University. Accessed 2017, https://www.teachengineering.org/activities/view/construct_an_aqueduct

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EARTHECHO WATER BY DESIGN DESALINATION DESIGN ACTIVITY

INTRODUCTION

This design challenge is in support of launching your students from passive to active learners through a cross-curricular, hands-on team challenge in direct correlation to real world issues of water conservation. These lessons will help students understand how materials are separated, the need for freshwater conservation, and ultimately how a desalination plant works. The design challenge portion will have your students creating companies and prototype desalination plants.

SUMMARY

1. Subject(s): Science, Technology, Engineering, and Math
2. Topic or Unit of Study: Desalination, Water, Freshwater Resources
3. Grade/Level: 6-8
4. Objective: As a result of these activities, students will be able to:
 - a) Understand that water is a key element for life on Earth and that human population growth is a major contributor to water scarcity.
 - b) Explore and understand how materials can pass through membranes and be separated
 - c) Explore and understand how a desalination plant works.
 - d) Analyze how desalination may have both long and short-term consequences for the health of people and the natural environment.
 - e) Create a team and a campaign for or against desalination.
 - f) Design and build a prototype desalination plant.
5. Time Allotment: 5-6 Periods of 55 minutes

Learning Context

This unit can follow an introduction to atoms to demonstrate the following concepts:

- The interaction and motions of atoms explain the properties of matter.
- Thermal energy affects particle motion and physical state.
- Resource availability affects organisms and ecosystem population.



TEACHER BACKGROUND

Only 1% of the total water resources on Earth are available as fresh drinking water. Of that amount, 30% is lost to leaks in plumbing systems. In addition, 90% of sewage and 70% of industrial waste is put into the water supply. As a result, nearly 1 billion people do not have access to safe drinking water. Combine the above statistics with global warming and less rainfall in many areas around the world, and it's clear that water scarcity is a major problem and we need to start looking at possible solutions.

Chicago is perched on one of the world's most plentiful fresh drinking water sources - one of the Great Lakes. However, even people who live near the Great Lakes need to care about water scarcity and ways to obtain fresh water. As we have seen in places like Flint, Michigan, we cannot take fresh water for granted. Flint is basically surrounded by fresh water sources but still had a major crisis with contaminated water. Cleaning up and conserving our freshwater supply will help, but the Great Lakes and other fresh water sources cannot provide drinking water for everyone.

Israel has had to find ways to build its society and economy in one of the most water-starved places on the planet. One of their solutions has been desalination. The methodology has come a long way since Greek sailors boiled water and collected the drinkable droplets. In desalination, water is drawn out of the sea and then pumped through a series of filters to separate the brine and yield fresh water. Once desalinated, the water tastes like ordinary tap water. Researchers from the University of Chicago have teamed up with scientists in Israel to look at new ideas for how to obtain drinking water and improve the desalination process. According to one researcher, "Desalination gives you the power to control your [water] supply. Up until a few decades ago, you were waiting for rain or digging a well. Now that you can desalinate, it's game-changing. You can produce efficient water from the sea, which is important because rivers can dry out, and lakes and aquifers can dry out."

According to the International Desalination Association, there are close to 18,500 desalination plants in 150 countries, and expanded use of the technology could drastically increase water supplies for water-starved nations. But desalination isn't problem-free. The main issue, as with many filtration systems, is the buildup of microbes on filter surfaces. It makes an already costly approach to creating drinking water even costlier.



Student Materials

A. Understanding the Separation of Substances

Multiply quantities for all of your classes (Materials described are for one class of 36 students sitting at 9 tables (4 students/ table))

- 9 eggs - 1 per table
- White vinegar - enough to fully submerge each egg
- 9 clear containers (small plastic cups) - 1 per table
- Distilled water - enough to fully submerge three eggs in containers
- Tap water - enough to fully submerge three eggs in containers
- Corn syrup or very salty water - enough to fully submerge three eggs in containers
- Hand lens or magnification option on cell phone
- Gloves for students handling egg (not everyone needs gloves, only those rinsing the egg)
- Rulers
- Triple beam balances or scales
- Safety goggles

B. Creating a Desalination Company (Part One) and Prototype Desalination Plant (Part Two)

Each company needs:

- No. 10 tin can (this large size can is ~6 3/16-in diameter x 7-in height [15.72 cm x 17.78 cm] and is most commonly used by food service companies for tomatoes, ketchup, pie filling, refried beans, pizza sauce, etc.; ask for this size at restaurants or your school's cafeteria; Indian restaurants buy this size to make some of their food, so ask for their used cans before they throw them out; alternative: any other large tin can, such as a 2-lb coffee can)
- 1 piece of aluminum foil, 12 x 12 in (30 x 20 cm)
- 2 plastic containers (any type will do)
- 5-10 Popsicle sticks
- plastic soda bottle, 20 fl oz (566 ml) size
- hot plate
- 3-5 cups, 9 fl oz (266 ml) or 16 fl oz (473 ml) size
- eye protection (goggles or safety glasses)
- oven mitt, to safely move tin can on hot plate
- saltwater circuit, as created in the associated Saltwater Circuit activity
- Design Worksheet, one per team
- Reflection Worksheet, one per person



For the entire class to share:

- roll of aluminum foil
- salt, enough for 20-25 g per group
- water, enough for 32 fl oz (946 ml) per group
- duct tape
- masking tape
- measuring cups or graduated cylinders, to measure ml of water
- triple beam or digital scale, to measure grams of salt
- ice, enough for about 2-4 cups per group (expect to use 1 large bag of ice for two class periods; sometimes school cafeterias have an ice maker; otherwise bags of ice are available at grocery stores and gas stations)
- cooler, to keep the ice cold

Safety Issues

- Have students use goggles or safety glasses for eye protection.
- Hot plates get extremely hot. Students should not touch their hot plate or 'desalination plant' while the hot plate is on. If you have safety concerns about your students using a hot plate, you could try using a lamp to heat the water. This activity could also be done with simple solar desalination devices and placed outside.

Before the Activity

- Gather materials.
- Cut the aluminum foil into 12 x 12 in (30 x 30 cm) pieces, one per team. Cut a few extra sheets in case some teams are unable to build a working plant on their first try and need more than one piece.
- Make copies of the Student Handouts.
- For Day 3 and Day 4, have a cooler full of ice.
- Ask each company to write a summary paragraph describing their model plant and its performance.
- Conclude by having each company add on to their original presentations and explain their desalination plant and company to the class.

A. Optional Demonstration Activity: Understanding Separation of Substances Using Chicken Egg Membranes (1.5 days)

- This demonstration is to help your students explore how solutions are moved through membranes and how substances are separated. This activity will help students understand the process of removing salt from seawater as part of the desalination lesson.



Distribute Supplies and Observation Preparation

- A. Pass out Phenomena Observation and Explanation Sheet (Student Handout #1)
- B. Tell students to be prepared to make careful observations
- C. Read directions on Phenomena Sheet

PART I. - Initial Observations and Explanation of Background Phenomena (Diagram #1 & Diagram #2)

(Student Handout #1)

- A. Each table should label their container with table and class period
- B. Students place their egg in their container
- C. Fully submerge the egg in vinegar and leave until next day.
- D. Record observations for 10 - 15 minutes. Allow students to use hand lens or cell phones to closely observe shell. Students can complete Diagram #1 and #2 during this time. (Students should notice bubbles forming on the shell and a foamy substance accumulating on top of the water)
- E. Provide an area for students to remove remaining shell by rinsing with water and very gently rubbing off shell.
- F. After egg is removed, students should record qualitative and quantitative observations using photos and measurement tools
- G. Clean up: Pour contents down the drain, rinse cup, and replace egg after measurements

NOTE: You may skip Part I by removing the shells for students prior to lesson by videoing yourself removing shells and taking measurements. Videoing will allow students to complete Diagram #1 and #2 and is available for absent students.

PART II. Foreground Phenomena - Membrane-bound Egg Behavior Prep

- A. Instruct students to obtain appropriate supplies for their table
 - Tables 1 - 3 : Enough tap water to submerge egg
 - Tables 4 - 6: Enough distilled water to submerge egg
 - Tables 7 - 8: Enough corn syrup/ salty water to submerge egg
- B. Place container in designated area until tomorrow

PART III. NEXT DAY: Foreground Phenomena - Membrane-bound Egg Behavior (Diagram #3)

- A. Observe** - Students observe egg by carefully removing the egg from the solution and rinsing quickly in tap water.
- B. Record** - Students record qualitative and quantitative data, using photos and measurement tools.
- C. Scout** - Arrange for "Scout(s)" to visit other tables and obtain data for *each type* of solution, possibly using a simple chart on the back of Phenomena Sheet and share with the rest of the table.
- D. Individual** - Provide 5-7 minutes of individual time to work. Be sure to *remind* students to clearly label their diagrams. **IMPORTANT:** Have students mentally practice how they will use their diagram to explain their thinking. Provide sentence starters to allow all students to enter the conversation with confidence. Model the tone and pacing for the discourse you expect students to engage in.



- E. Small Group** - Each student has 1 minute to share their diagram and explanation. *Remind* students that they are not allowed make corrections, interrupt, or distract the speaker.
- F. Whole class** - On chart paper or projected document, take explanation ideas from each table - Ask low risk question, such as: what was an interesting idea you heard at your table. *Remind* students that you are not correcting anyone's initial ideas, you are simply bringing them out in the open so they may be discussed during the learning process.
- G. Summarize** common ideas students have about why the egg behaves differently in each solution.

B. PART One - 2 days and Part Two - 4 days

Creating a Desalination Company (Part One) and Prototype Desalination Plant (Part Two)

The steps listed below are the best way to present and have your students work in teams to create prototype desalination plants. This part of the lesson is lengthy and will take several class periods to complete.

Day 1:

- Use Student Handout #3 to begin the brainstorm process and have students break into groups to create their Desalination Companies and then their prototype desalination plants.

NOTE: If students are having a hard time getting started, [show this 3:46 video on how to make a simple solar distillation set up.](#)

Day 2:

- Show students the materials available to build their model desalination plants. Have one or two sets available for them to examine.
- Review the steps of the engineering design process (using Student Handout #2).
- Give teams time to brainstorm ideas and come up with labeled diagrams and drawings of what they intend to create with the given materials. Encourage them to get several ideas down on scrap paper. Use the worksheet to document the final design.
- Review and approve designs. Acceptable designs are detailed, labeled diagrams that show what the model plant will be made of and look like.

Day 3:

- Give companies time to construct their model desalination plants.
- Once a company has completed their model, have the team begin testing. Give each team 20 to 35 grams of salt, 32 fl oz (946 ml) of water and 2-4 cups of ice. (Use about a 3:1 ratio of water to salt. During the testing phase, set hot plates to their highest setting.)
- Once a company has its plant running, have team members take turns visiting other groups' stations to ask questions about their designs, fill out Student Handouts #3-#5.



- After the desalination plants have been running for 20 minutes or so, have the company check to see if they are collecting water.
- If no water is collected, direct students to analyze their design and redesign with improvements.
- Before the class period is up, have students make notes on what worked and what didn't.
- While going from company to company, note the kinds of designs and their major features, so as to prepare for the next class period when you will begin with an overview of different designs.

Day 4:

- To help students reach a working design, spend about 10 minutes at the beginning of the class drawing three different designs on the board and leading a class discussion about what would work and not work. You could incorporate student design examples observed from Day 3.
- Give companies about five minutes to revise and improve their designs.
- Replenish any materials students may need and give students time to build and test their revised model desalination plants.

Example of a working design:

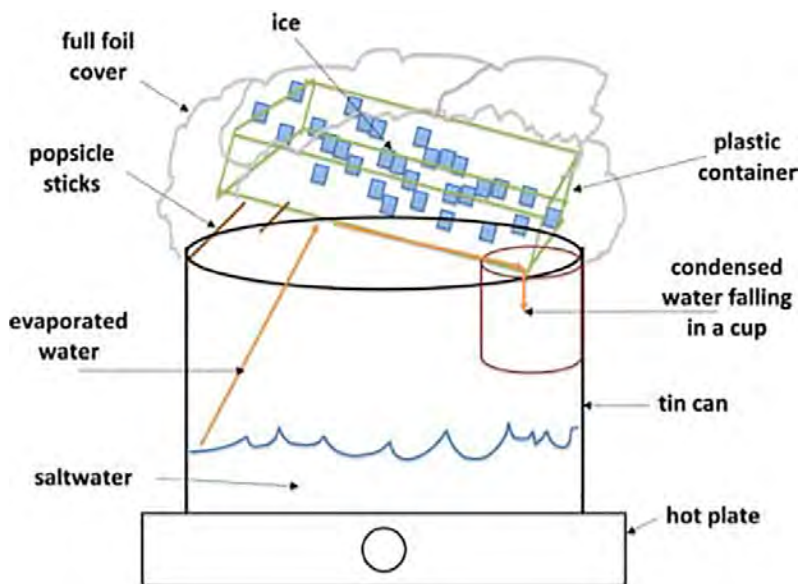
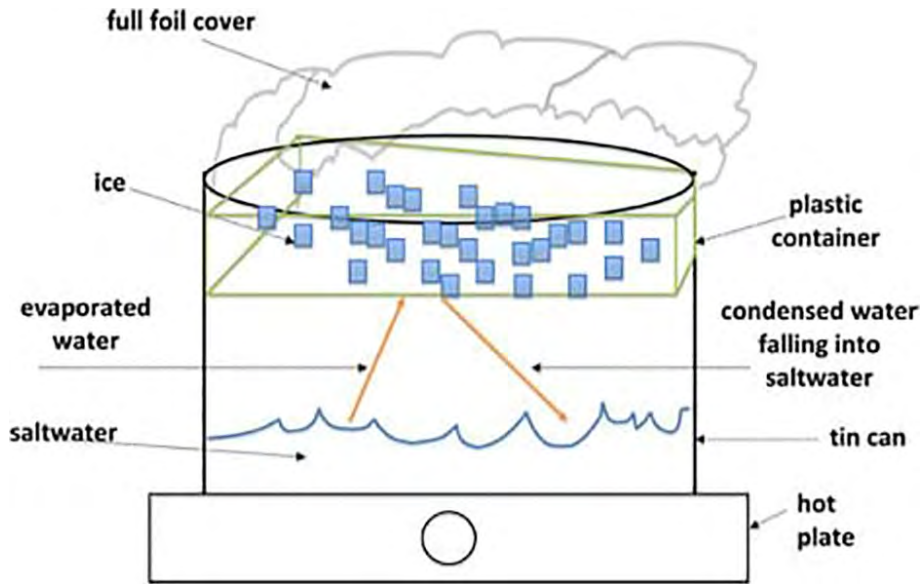


Image Citation: "Water Desalination Plant - Activity." www.teachengineering.org, www.teachengineering.org/activities/view/cub_desal_lesson01_activity2.



Example for a Failed Design:



It is possible that not all companies will achieve a working design by the end of Day 3. This does not mean the company has failed. In engineering – much is learned from failures. The design drawn in Figure 1 does not have a chance to work; the water that is evaporated by the hot plate condenses on the bottom of the plastic bin and falls back into the original saltwater solution. The design team failed to consider how to collect the water that condenses at the bottom of the plastic bin.

STUDENT HANDOUTS

PHENOMENA OBSERVATION AND EXPLANATION SHEET (Handout #1)

Name _____

Directions: Complete Diagrams #1 - #3 by making careful observations. Write and sketch anything that clarifies your actions, observations, and explanations.

Removing Shell

Diagram #1 – What do you do?

Egg PRIOR to vinegar

Mass _____ g

Diagram #2 – What do you observe?

Egg AFTER vinegar

Mass _____ g

Effects of Liquid

Our egg was submerged in _____.

Diagram #3 Observations

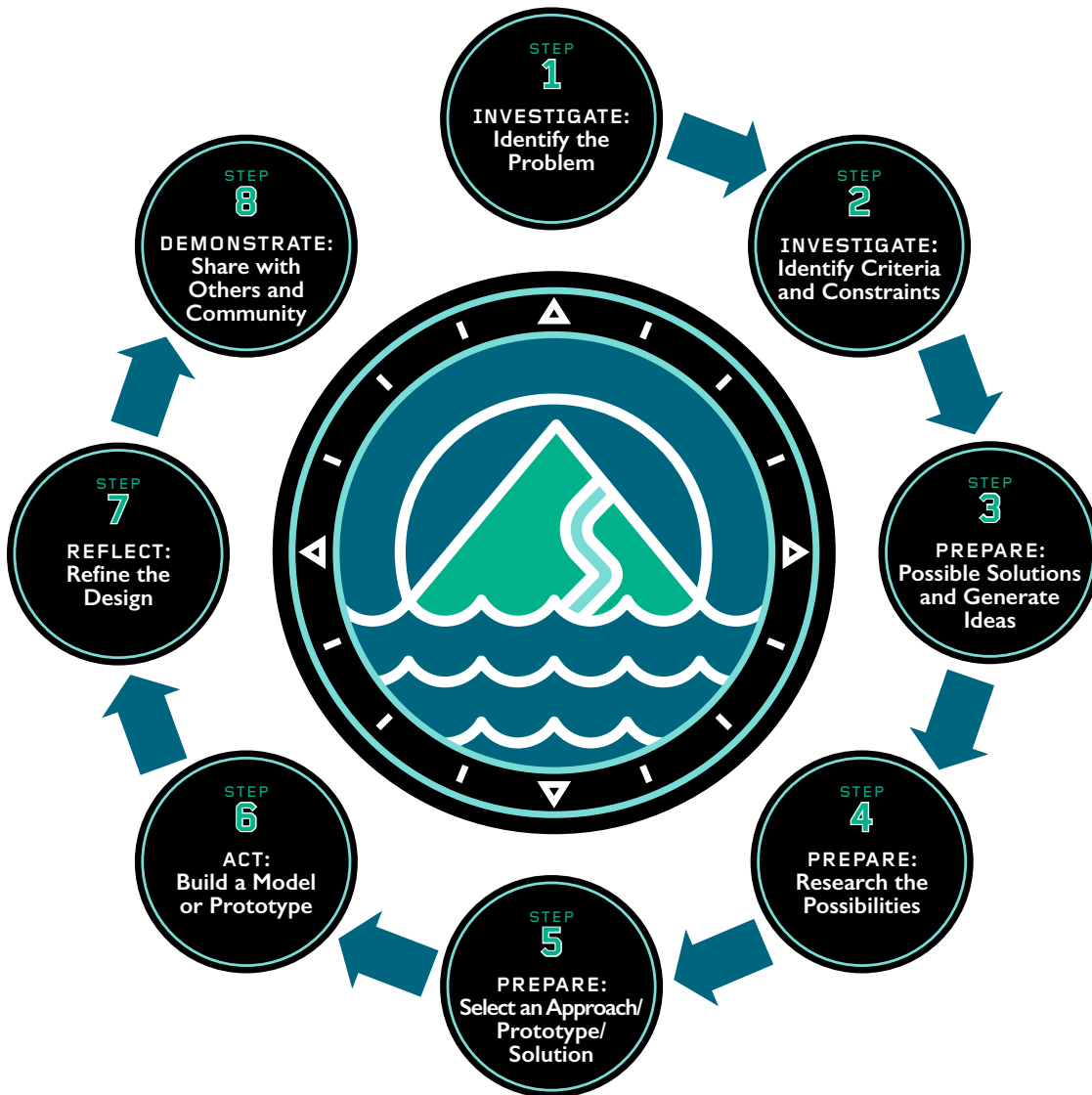
Diagram #3 Explanations

AFTER egg in solution overnight

Mass _____ g



ENGINEERING DESIGN PROCESS



Components of a Desalination Plant

Using the system components shown below, draw a system diagram for your water desalination plant. You can use the system components as many times as you want, but you must include a clean water tank and a waste tank.

COMPONENTS OF A DESALINATION PLANT (Student Handout #3)

Using the system components shown below, draw a system diagram for your water desalination plant. You can use the system components as many times as you want, but you must include a clean water tank and a waste tank.

Company Name: _____ Your Name: _____ Date: _____



WATER DESALINATION PLANT ACTIVITY — DESIGN WORKSHEET (Student Handout #3)

Design #1

In the space provided below, sketch your desalination plant.

*Use labels to describe the materials you will be using.

Questions

1. Did you collect any water? What volume of water was collected (in ml)?
2. If you did not collect water, how could you improve your design?

Teacher approval: _____ Date: _____



Company Name: _____ Your Name: _____ Date: _____

WATER DESALINATION PLANT ACTIVITY — DESIGN WORKSHEET (Student Handout #4)

Design #2

In the space provided below, redesign your desalination plant.

*Use results from the first design to improve your plant.

Questions

1. Did you collect any water? What volume of water was collected (in ml)?

2. If you did not collect water, how could you improve your design?

Teacher approval: _____ Date: _____



Company Name: _____ Your Name: _____ Date: _____

WATER DESALINATION PLANT ACTIVITY — DESIGN WORKSHEET (Student Handout #5)

Visiting Other Teams

While your desalination plant is working, visit three other companies and compare your design to theirs. Collect information to complete the following sections.

Company #1: _____

1. Company member names:

2. List three differences between their design and yours.

3. Do you think their design will work? Explain why or why not.

Company #2: _____

1. Company member names:

2. List three differences between their design and yours.

3. Do you think their design will work? Explain why or why not.



Company #3: _____

1. Company member names:

2. List three differences between their design and yours.

3. Do you think their design will work? Explain why or why not.



ASSESSMENTS

DESALINATION DESIGN ASSESSMENT RUBRIC

Identifying the problem(s) and brainstorming solutions

Points

Identifying the problem(s) and brainstorming solutions	30 Showed a clear understanding of the problem(s) to solve. Independently brainstormed solutions.	20 Needed some teacher direction to define the problem(s) and brainstorm possible solutions.	10 Needed lots of teacher direction to define the problem(s). Little if any independent brainstorming.	
Working as a team member	25 Worked well together. All team members participated and stayed on task.	15 Some team members were occasionally off task.	10 Most team members were often off task and not cooperating or participating fully.	
Using the design process	25 Team brainstormed main design ideas and tested and improved the design. Final design complete or nearly complete desalination plant, and shows creative problem solving. Explore activities are evident during brainstorming.	15 Some team members were occasionally off task. Final design showed only some elements of a desalination plant. There is some evidence of Explore activities during brainstorming.	10 Team brainstormed few design ideas and did little testing or redesigning. Final design lacks clear design idea(s). There is very little evidence of Explore activities during brainstorming.	
Processing the science and engineering	20 Team gave a strong presentation of its solution to the challenge and showed clear understanding of the science concepts and design process. The company made a thorough analysis of their design and made appropriate re-design as prompted in Elaborate.	10 Team gave a basic presentation of its solution to the challenge and showed basic understanding of the science concepts and design process. The company made some analyses of their design and made some appropriate re-design as prompted in Elaborate.	5 Team gave a weak presentation of its solution to the challenge and showed little understanding of the science concepts and design process. The company made very limited analysis of their design and made few to no re-designs as prompted in Elaborate.	

total



RESOURCES

- <http://earthecho.org/expeditions> specifically <https://youtu.be/Sk2GK3MRCJ0?feature=shared>
- <http://science-class.net/archive/science-class/Biology/Osmosis.htm>
- <https://www.youtube.com/watch?v=KTW7BS7tV8k&feature=youtu.be>

CITATIONS

- Rodriguez, Alex. "For water's sake, Chicago researchers reach across the seas to Israel", Chicago Tribune, January, 2015.

EDUCATIONAL STANDARDS

NGSS STANDARDS

Performance Expectations

MS-ESS3-2.

Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

SEP – Analyzing and Interpreting Data

DCI – Natural Hazards ESS3.B

CCC – Graphs, charts, and images can be used to identify patterns in data

Connections to Engineering, Technology, and Applications of Science

The influence of science, engineering, and technology in Society and the Natural World – The uses of technologies and any limitation on their use are driven by 1.) individual or societal needs, desires, and values; 2.) by the findings of scientific research; and 3.) by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies region to region over time.

Performance Expectations

MS-ESS3-3. - Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

SEP – Constructing explanations and designing solutions

DCI – ESS3.C: Human Impacts on Earth Systems

- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.



- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise.

CCC – Cause and Effect

- Relationships can be classified as causal or correlational, and correlational does not necessarily imply causation

Performance Expectations

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth’s systems.

SEP - Engaging in Argument from Evidence

- Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

DCI - ESS3.C Human Impacts on Earth Systems

- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise.

CCC - Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World:

Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

