GREAT LAKES LEARNING

LESSONS & ACTIVITIES BASED ON THE MONTHLY GREAT LAKES NOW PROGRAM

EPISODE 2208 | COAL ASH AND COMMUNITIES

COMBATTING COAL ASH

Image Credit: Great Lakes Now

OVERVIEW

This lesson will explore the phenomenon of **coal ash contamination in groundwater** and the threat it poses to Lake Michigan and other areas of the Great Lakes waterways. Students will learn about the history of coal ash disposal, the discovery of coal ash in groundwater, and efforts to address the problem.

LESSON OBJECTIVES

- **Know** the historical significance of coal and its ash
- **Understand** why coal ash poses an environmental threat to the Great Lakes
- **Be able to** remove and separate multiple contaminants from a polluted water sample

WHAT YOU'LL NEED

- Computer or mobile device with Internet access to view video and online resources
- Notebooks and pencils
- Chart paper
- Sticky notes
- Markers
- Lab supplies (see individual activities for a full list)
- Copies of the Student Handouts

INTRODUCTION

Coal is a common fossil fuel that naturally contains a lot of heavy metals and other impurities which, if ingested, can cause health issues. Burning coal produces ash that contains those same impurities.

That's why proper disposal and containment of coal ash is important to minimizing environmental risk. But coal ash has been found making its way into ground water and now poses a threat to the nearby freshwater bodies connected to those groundwater reserves, including the Great Lakes. In this lesson, students will explore this phenomenon and the impact it has.

This lesson includes multiple activities, including lab activities, that can span the course of several sessions or be adapted to fit the needs of your group's meeting format.

Some prior knowledge* with which students should be familiar includes:

- earth's layers
- atoms, isotopes, and ions
- combustion and chemical change
- properties and states of matter
- groundwater, water systems

Follow this QR Code or hyperlink to the Episode Landing Page!

Check out our full collection of lessons for more activities related to topics like these.

****The sequence of these activities is flexible, and can be rearranged to fit your teaching needs.***

NGSS CONNECTIONS

Phenomenon: Coal Ash in Groundwater

- MS-4-ESS3-1
- ESS3.A
- 4-PS3-4
- HS-ESS3-6
- SEP-2
- SEP-3
- SEP-6

During the course of the lesson, students will progress through the following sequence** of activities:

- Class discussion to elicit or activate prior knowledge
- A coal-burning demonstration
- Drawing particle diagrams to represent the molecular level before/after a change
- Teacher notes on coal ash
- Watch a segment from *Great Lakes Now*
- Class discussion to debrief the video
- Design a process for removing soluble and insoluble contaminants from water
- Designing a model to explain the coal ash phenomenon

The lesson progresses through three major sections: **launch, activities, and closure.** After the launch of the lesson, you are ready to begin the lesson activities. Once finished with the activities, students will synthesize their learning in the closure. You can select the activities that are best suited for your learners, your teaching goals, and sequence them in a way that makes sense within your learning progression and the scaffolds of the lesson.

If you use this lesson or any of its activities with your learners, we'd love to hear about it!

Contact us with any feedback or questions at:
GreatLakesNow@DPTV.org

TEACHER BACKGROUND INFORMATION

by Great Lakes Now Contributor, Gary G. Abud, Jr.

**This information can be presented by the teacher as notes to students at the teacher's discretion.*

From the well-known charcoal of summer barbecues to Santa's penalty for being naughty, and much more, there's one fossil fuel that has a central place in the ethos of Americana. Coal is formed under the surface of the earth when decayed plant matter experiences high heat and pressure over long periods of time. But coal isn't just used to grill hamburgers on the 4th of July. It has been a central fuel source in the United States for many years. Coal has powered the steam engines on America's earliest railroads, provided the heat-generating fuel source of steel production, and has traditionally been burned to heat the water into steam that then powers electricity-generating turbines in a power plant. The biggest appeal of coal is that it can be burned to generate heat for various purposes.

According to the U.S. Geological Survey (USGS), there are four major categories of coal, which vary in terms of composition and properties. These include anthracite, bituminous, sub-bituminous, and lignite. Each has differing amounts of impurities—other substances that have been incorporated into the coal during the formation process underground—but all of them contain a large portion of carbon that is combustible. That carbon is what makes coal such a valuable substance, but it is also what's responsible for coals carbon footprint. But there are other environmental concerns with coal besides mere carbon dioxide emissions.

If you've ever seen a charcoal grill after dinner is done, you know what's left when the meal is over—ashes. Coal ash results from burning any kind of coal. So, when industrial coal-burning operations finish burning a batch of coal, they are left with literally tons of coal ash. All that coal ash needs to be disposed of, but the problem is that the ash is so light that if it isn't contained in some way it can get into the air creating an ashy dust in the nearby environment. And that can be a problem, because breathing in coal ash dust can cause asthma, lung disease, and even cancer. So, what options can help to contain the coal ash? There are some common approaches. Burying the ash underground allows heavier materials to hold the coal ash down. Putting it in containment chambers is similar to burying it, but typically uses an engineered structure. A third way, not too dissimilar to pouring water on the embers of a campfire, is to combine the coal ash with water, in what are referred to as ash ponds, to keep it wet and heavy enough that it doesn't blow away and contaminate the air.

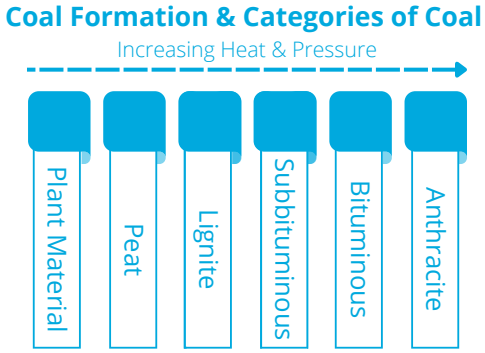


Image Credit: Gary Abud, Jr.

But out of sight and out of mind isn't the end of the story here. That same coal that contained impurities, which sometimes include heavy metals and other elements that can be harmful to people, becomes ash that contains those same impurities. The major difference is that after burning, the carbon has been burned out of the coal, leaving it an ashy substance that is now more concentrated with harmful impurities than the coal itself was. If those impurities get into the water that people consume, they have the ability to cause not just pollution but health issues. In some places, it has been discovered that coal ash is making its way into groundwater, which poses a threat to any major bodies of water that are connected. And that is why the disposal of coal ash is such an environmental concern.

So, how exactly do these harmful metals and other elements of health risk make their way into the coal in the first place? The earth is made up of a variety of naturally-occurring elements (think: most of the Periodic Table.) Those elements are integrated in the rock and soil that is found in the Earth's crust. Some of those elements, like uranium, are extremely heavy, as far as atomic size goes, and as a result unstable. These radioactive isotopes undergo a decay process that breaks the larger elements into smaller ones—think: taking a large bunch of grapes and cutting off a smaller cluster of grapes from it. These byproducts are the smaller metals and other elements, like arsenic, that build up in the rock and soil. Additionally, since coal is made from plants, and plants pull nutrients out of the ground, the plants take in some of those elements that came from the radioactive decay happening underground. These two factors provide the base materials from which coal is formed in a process known as coalification.

Ultimately, any coal ash that contributes harmful substances into groundwater got its start as plants and rocks that contained those harmful substances. And that's why properly disposing of coal ash is an important environmental task.

LESSON LAUNCH

A. Warm Up

The warm up is intended to be structured as teacher-facilitated, whole-group student discussion activities. It helps students to begin thinking about the topic at the center of the lesson.

1. Ask students to list out on a piece of paper **five things that** come to mind when thinking of **coal**.
2. Have students pair up with a partner to share their five ideas with each other. If any ideas appear on both lists, have students circle those.
3. Then, engage students in a whole-group discussion to ask them to share any ideas that were circled.
4. Generate a list of the circled ideas.
5. Ask for volunteers to share any ideas that were not circled that they think are really important to include in this topic.
6. Generate a separate list of those ideas.
7. At the end of making the two lists, have students copy down one single list of all the circled ideas and important ideas in their notebooks or on their paper.
8. Ask students individually to rank the ideas in the list from most to least relevant.
9. Ask for some students to share which term should be most relevant and why they think that is. Engage the whole group in discussion to arrive at consensus about the most relevant idea related to **coal** that they already know about or that came to mind during this exercise.

**Note: quick light charcoal will ignite in about 30 seconds, whereas traditional charcoal takes several minutes. These can be found online or at a store.*

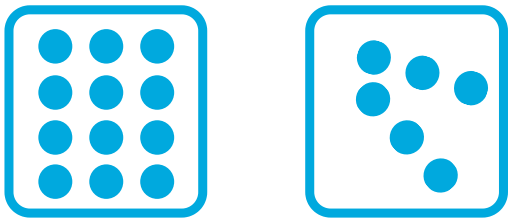
***Note: as an extension, you could put the ashes into water, mix it up, and ask the students to brainstorm how they could remove the ash from the water.*

B. Bridge to Learning

After the warm-up activity has concluded, help students prepare for the learning that is about to come:

- Take a small disk of quick light charcoal* and place it on top of a piece of aluminum foil on a heat safe surface.
- Have students make observations about the coal before and after the burn, including take the mass of the coal before and after burning by massing the foil alone, the coal + foil, and then the burned coal + foil.
- Have students draw a particle diagram of what is going on at the smallest level with the coal before/after burning and discuss what their diagram represents.

Particle Diagrams



coal before burning
uniform composition
more particles (mass)

coal after burning
non-uniform composition
less particles (mass)

- Ask students to turn and talk with a partner and explain what accounts for the comparison of the mass before and after the burning.
- Invite volunteers to provide some explanations of the change in mass. Make sure to guide them to conclude—based on their observations, particle diagrams, and the difference in mass—that something must have left the system during the burning.
- Ask them to make predictions** of what they think is the composition of the coal ash that is left over after burning.

C. Background Information Notes

Explain that we are going to build on these ideas and learn more about coal in this lesson. Then proceed to give the notes from the **Teacher Background Information**.

ACTIVITY 1: WATCH A GREAT LAKES NOW SEGMENT

This activity is a video discussion of a *Great Lakes Now* episode segment.

First, inform students that they will be watching a *Great Lakes Now* segment discussing the toxic coal ash that threatens the Great Lakes region. During the video they need to jot down four things they took away from the video using the **4 Notes Summary Protocol**.

Then, if students are not already familiar, introduce them to the 4 Notes Summary Protocol, which they will use after they finish watching the video, where they write down one of each of the following notes:

- **Oooh!** (something that was interesting)
- **Aaah!** (something that was an ah-ha moment)
- **Hmmm…** (something that left them wanting to know more)
- **Huh?** (a question they have afterward)

Next, have students watch the segment from episode 2208 of *Great Lakes Now* called **Coal Ash and Communities**.

Last, have students complete their individual 4 Notes Summary and then discuss those in groups of 3-4 students.

Teaching Tip: Use the Student Handouts to help students organize their thinking in writing around each of the lesson protocols.

Post-Video Discussion

After the groups have had time to go over their 4 Notes Summaries, invite a handful of students to share out some of their notes, eliciting at least 1-2 of each of the 4 Notes and listing those somewhere for the whole group to see.

Ask students to turn back and talk with their groups to make connections between the *Great Lakes Now* video and what they remember from the warm-up activities.

How is what we saw in the video the related to what we discussed earlier in this lesson during the warm up?

After giving the groups some time to talk, bring the whole group back together for a shareout and discussion of ideas.

In this culminating discussion, the goal is to help students make connections between the video segment and what they discussed during the warm up activities earlier in the lesson about what they knew about coal and coal ash.

Once the discussion finishes, have each student write a "**Sum It Up**" statement in their notebooks. This is a single sentence that captures the big idea of what was just learned.

Have 2-3 students share out their **Sum It Up** statements before concluding this activity.

ACTIVITY 2: READ ABOUT EXTREME WEATHER

The methods of disposing of coal ash into ash ponds and other storage means can be compromised by any environmental conditions resulting in system failures and catastrophic results.

In this activity, students will use a **Think Pair Square Protocol** for discussing what they will read about this very topic.

First, have students partner up and distribute the article **Does extreme weather threaten the hazardous waste sites that border Lake Michigan?** by Gary Wilson from *Great Lakes Now*. Allow time for students to individually read the article, and have them jot down three things they took away from the article using the **Rose Thorn Bud Protocol**—in their notebook or using the handout.

Then, give students time after reading to discuss the article that they read with their partner. Have students share their rose, thorn, and bud with each other, including how those points connect to each other. The pair should come up with a statement to summarize all of their article takeaways.

Next, have two student pairs join up, standing near each other to form the four corners of a square, to discuss the article and what they talked about in their pairs. Encourage them to come to a consensus about which point they found most important or interesting in the article.

Teaching Tip:
If the reading level of the article is going to be tough for some students to read individually, have partners or small groups read the article together aloud.

Image Credit: Great Lakes Now

Last, have each group craft a summary statement of the most important point from their discussion and ask for a volunteer in each group to share that key point with the whole group.

As student groups share their most important point, record their ideas on the board and have students copy the list of student ideas down into their notebooks.

Once the shareout is complete, ask students to return to their groups and discuss one last question* based on the article:

Based on the article, how might extreme weather conditions directly affect the disposal of coal ash and impact the Great Lakes?

After giving the groups some time to discuss this question, invite conversation from the whole group to see what consensus can be reached.

Be sure to encourage students to support their claims with evidence and reasoning as they discuss in the whole group.

ACTIVITY 3: MATTER SEPARATION CHALLENGE

Image Credit: Gary Abud, Jr.

Background:
Removing coal ash from groundwater is crucial to prevent contamination. But just what is involved with removing contaminants from water? In this activity, students will explore the concept of separating different types of matter based the properties of each. This experiment can serve as a model for understanding how large-scale technologies are developed for purifying water.

Materials

- whole pepper corns or poppy seeds
- fine grain sand
- iron filings (optional)
- table salt
- coffee filters or lab-grade filter paper
- funnels
- beakers, flasks, or large drinking cups
- plastic spoons
- paper towel
- a watch glass or a small dish/plate
- water

Procedure
First, review the common states of matter: solid, liquid, and gas, and have students draw particle diagrams to represent matter in each state. Discuss the features of each state and what a representative particle diagram would include. Show students the substances (e.g., sand, poppy seeds, etc.) that will be involved in the experiment. Classify their states.

Next, ask students to consider the relative size of the particles of each and to rank them from largest to smallest. Provide students with the substances and give them time to observe and list out the properties of each. As you monitor the students, you can prompt them to consider properties like magnetism, solubility, density, etc. After observation time, solicit some ideas from students about what they observed and generate a class list.

Then, explain to them that their lab challenge will be to separate a mixture of all the substances put in water and to recover the original substances individually. You can prompt them to focus on the size of particles and how smaller ones require different techniques and tools to remove. Provide students the available tools along with a solution with a mixture of the substances combined in water (or have them prepare their own) before giving time, in groups, for students to to design and carry out their own procedure.

Last, have students record and share out their observations and results from carrying out their experiment with the whole group. Engage them in a discussion about what worked well and what difficulties they encountered. Help them to make connections between the size of the particles, their properties, and the specific techniques and tools that worked to separate the mixture.

Extend their thinking during the discussion by asking them how this experiment could serve as a model for the removal of contaminants like coal ash or its impurities from groundwater. Ask them to consider what challenges might happen when this type of matter separation needs to be done on a large scale.

ACTIVITY 4: MODELING THE COAL ASH IMPACT

In this activity, students will explore and utilize the open source education resource called **Understanding Global Change**—from the University of California Berkeley—for digitally modeling the environmental impact of coal ash.

Begin by directing students to the **Understanding Global Change** website and walk through the *how to use this website* tutorial with them. Have volunteers read aloud each of the descriptions on the tutorial slides as you move through them for the entire class. Review the terms used in the modeling tool to ensure students have an operational understanding of each and perhaps solicit some examples of each from volunteers:

- Causes of Change
- Earth Systems
- Measurable Changes

Check for understanding after the tutorial to make sure students realize how these three components of this modeling framework relate.

Engage students in a discussion to review the process by which coal ash comes to be, how coal is formed, and how coal ash ash poses a threat to human health through the air and water.

Once you've finished reviewing the relevant content from the lesson, inform students that scientists sometimes need to create models in order to visualize and represent a process that has many steps to help make it easier to understand. Explain to them that they will be using this app to model the phenomenon of coal ash affecting the environment in the Great Lakes region. Direct students to the **Construct a Model** tab on the website to begin their work. They can skip the intro and get right to developing their models using the drag and drop app tools.

Teaching Tip:

Make sure to review the Teacher Background Information with students and navigate the Understanding Global Change web app yourself before doing this activity with students.

Image Credit: Great Lakes Now

Give students time to build their models with their partner(s). Like the example seen below, there are many ways to build a model to explain the phenomenon of coal ash pollution and how it affects human health and the environment. Encourage students to model both the airborne and waterborne threats posed by coal ash, and remind them to write descriptions under each connection step to explain the thinking behind the model they developed.

When students are finished making their models, have them export their models into a PowerPoint file that they can use to present their model to others. Have groups pair up with other groups in the class to look at their models together. They should compare and connect the way that each of them modeled the situation. After each group has had the chance to see 1-2 other groups' models, engage the whole group in a discussion of what features are essential to a good model of the coal ash problem.

Generate a class list of the most important parts of the coal ash pollution model before concluding this activity.

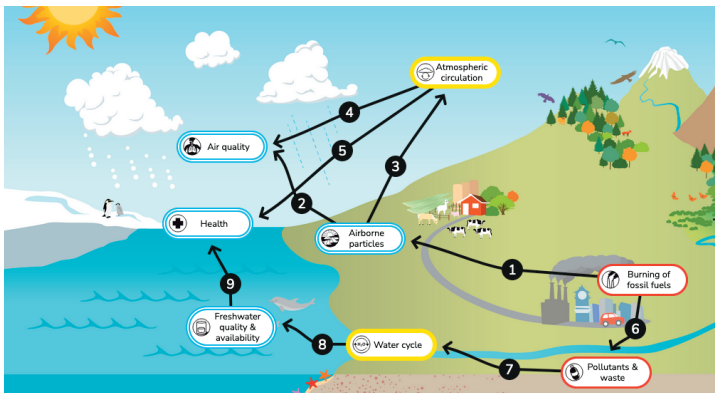


Image Credit: Gary Abud, Jr., Courtesy: University of California Berkeley

LESSON CLOSURE

After the conclusion of all the activities, help students to make connections* between everything they did in the lesson and what they learned overall.

A. Free Recall

Group students in pairs or triads (e.g., in groups of 2-3 partners) and distribute the **Free Recall Protocol handout**, Alternatively, you can have students do this in their notebooks. Set a 3-min timer and have students generate a list of everything they can remember learning about in this lesson related to the central topic of the lesson. This doesn't have to be in depth, just whatever each group can call to mind. Have them draw lines between any terms that relate to one another. After the timer finishes, give groups a chance to volunteer to share aloud 2-3 things from their free recall lists and any of the connections that they made with those. Jot down any ideas that come up multiple times during the shareout for the whole group to see.

B. Lesson Synthesis

Give students individual thinking and writing time in their notebooks to synthesize their learning, by jotting down their own reflections using the **Word, Phrase, Sentence Protocol.**

In the Word-Phrase-Sentence Protocol, students write:

- A **word** that they thought was most important from the lesson
- A **phrase** that they would like to remember
- A **sentence** that sums up what they learned in the lesson

Image Credit: Great Lakes Now

C. Cool Down

After the individual synthesis is complete, students should share their synthesis with a partner.

After sharing their syntheses, have students complete a **3, 2, 1 Review** for the lesson with their partner, recording in their notebooks or, optionally, on exit ticket slips to submit, each of the following:

- **3 things** that they liked or learned
- **2 ideas** that make more sense now
- **1 question** that they were left with

Invite several students to share aloud what they wrote in either the synthesis or 3, 2, 1 Review.

Lastly, ask one student volunteer to summarize what has been heard from the students as a final summary of student learning.

**Optionally here, the teacher can revisit the learning objectives and make connections more explicit for students.*

Teaching Tip: Use the Student Handouts to help students organize their thinking in writing around each of the lesson protocols.

NAME: _____

A Word, Phrase, Sentence Protocol

What is a **word** that you thought was most important from this lesson?

What is a **phrase** that you would like to remember from this lesson?

What is a **sentence** that sums up what you learned in this lesson?

3, 2, 1 Review Protocol

What are **3 things that you liked or learned** from this lesson's activities?

-
-
-

What are **2 ideas that make more sense** now to you?

-
-

What is **1 question that you were left with** after this lesson?

-

NAME: _____

Free Recall Protocol

With 1-2 partners, generate a list of everything you can remember learning about in this lesson related to the central topic of the lesson. Draw lines between any terms that relate to one another.

NAME: _____

4 Notes Summary Protocol

OOOH!

Something that was interesting to you

AAAH!

Something that became clearer; an "ah-ha" moment

HMMM...

Something that left you wanting to learn more

HUH?

Something you questioned or wondered

Sum It Up Statement:

Summarize your group discussion about your 4 Notes Summaries below:

NAME: _____

Think Pair Square Protocol

THINK

Write down your own individual ideas

PAIR

Summarize what you and your partner discussed

SQUARE

Summarize what your group discussed

NAME: _____

Rose, Thorn, Bud Protocol

ROSE

Something that "blossomed" for you in your learning

THORN

Something that challenged your thinking or was difficult to understand

BUD

Something that's new and growing in your mind — a "budding" idea