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WELCOME, ENVIRONMENTAL ENGINEER!

ARE YOU READY TO ENGINEER A CLEANER FUTURE?

Plan → Build → Test → Measure → Improve



The environment includes the air we breathe, the water we drink, the soil beneath our feet, and the materials and resources we use every day.

Sometimes oil spills into water. Tiny particles make water cloudy. Gases released into the air can contribute to pollution and climate change. Useful materials are often thrown away instead of recovered and reused.

But how can we stop pollution from spreading? How can we clean water and treat harmful emissions? How can we capture carbon dioxide and recover useful resources from waste?

These are the kinds of problems that environmental engineers solve.

In this book, you will not simply read about environmental problems. You will build systems that model real engineering solutions. You will:

🌊 **Contain and clean up a model oil spill.**
💧 **Design and compare water-filtration systems.**
🏭 **Build model scrubbers that reduce acidic pollution.**
🌎 **Capture carbon dioxide through mineralization.**
♻️ **Operate a model Materials Recovery Facility and transform recovered materials into useful products**.

YOUR ENVIRONMENTAL ENGINEERING MISSION

Complete all five engineering projects and discover how engineers protect natural resources, control pollution, and recover useful materials. During your mission, you will:

1. Contain Pollution
Design barriers and cleanup methods that help prevent a model oil spill from spreading through water.

2. Clean Water
Compare filtration materials and design a system that improves water clarity while maintaining flow and water recovery.

🚧 Build an Oil Spill Containment System



Get ready to think like an environmental engineer and build your own **oil spill containment system**! In this activity, you will design and build a system that helps stop oil pollution from spreading across water.

You will create a model oil spill using a tray of water and a small amount of oil. Then, you will build a floating barrier, called a **boom**, to keep the oil in one area. After the oil is contained, you will test different **sorbent materials** to remove the oil from the water.

A good oil spill cleanup system does more than remove oil. It also protects as much clean water as possible. That means your goal is not just to collect the most liquid — your goal is to remove the most oil while removing the least clean water.

❓ What problem are we solving?

Imagine an oil spill happens in a river, lake, or ocean. If the oil spreads too far, it can:

- 🚫 Cover the surface of the water
- 🚫 Harm fish, birds, and other wildlife
- 🚫 Damage wetlands and shorelines
- 🚫 Make cleanup much harder
- 🚫 Spread pollution to new areas

👉 **Environmental engineers design systems that help stop pollution before it causes more damage.**

💡 Challenge

How can we design a system that: contains an oil spill → stops the oil from spreading → removes oil from the water → protects as much clean water as possible → and creates the most effective cleanup system?

Your system should work in two stages:

🔍 Test and Record Your Results

📊 Record Your Results

Starting oil amount: 10 mL per tray

Cleanup Material	Total Liquid Collected (mL)	Oil Collected (mL)	Water Collected (mL)	Oil Recovery (%)
Cotton balls				
Sponge pieces				
Coffee filter				

$$\textbf{Oil Recovery (\%)} = \frac{\text{Oil Collected}}{\text{Starting Oil Amount in That Tray}} \times 100$$

Compare Your Results

Which material recovered the most oil while removing the least clean water?

Best overall cleanup material: _____

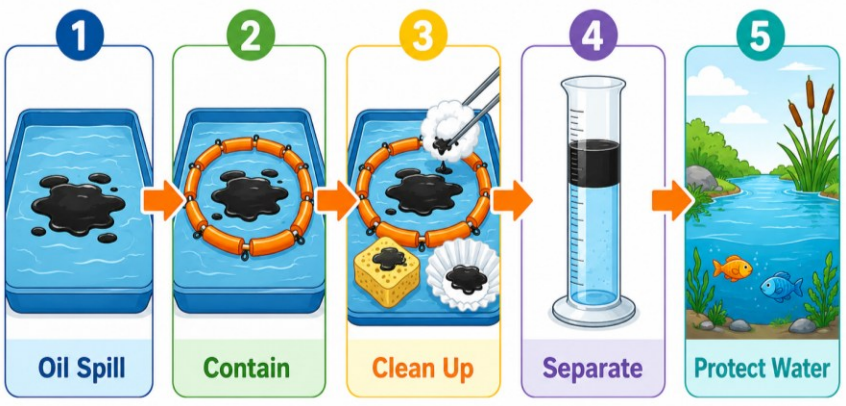
Evidence from your results: _____

🔬 How It Works (Science Background)

Now that you have tested your oil spill containment system, let's explore the science behind it.

🌎 An Environmental Engineering System

Your model includes a **pollution source**, a **water environment**, a floating **containment boom**, several **cleanup materials**, and a way to **measure the results**. These parts work together to contain the spill, remove oil, reduce clean-water loss, and protect the water system.



💧 Build a Water Filtration System

Get ready to think like an environmental engineer! In this activity, you will design, build, and compare three model water filters that help clean polluted water. Your engineering question is:

Which filter design removes visible pollution while recovering as much filtered water as possible?

You will create a model of polluted water using water, cocoa powder, and a small amount of soil. Then, you will build three filter systems.

A good filter does more than make water look clear. It should also allow water to flow through, prevent clogging, and recover sufficient filtered water.



❓ What problem are we solving?

Polluted water can enter rivers, streams, ponds, storm drains, and ecosystems. If pollution is not reduced, it can:

- 🚫 make water cloudy or dirty
- 🚫 carry soil and particles into ecosystems
- 🚫 harm plants and animals that depend on clean water
- 🚫 make water harder to treat later
- 🚫 reduce the quality of natural water resources

Environmental engineers design filtration systems to remove visible particles, improve water clarity, keep water flowing, and protect water resources.

💡 Challenge

How can we design a filtration system that: **removes visible pollution → improves water clarity → allows water to flow through → recovers enough filtered water → creates the best overall filtration system?**

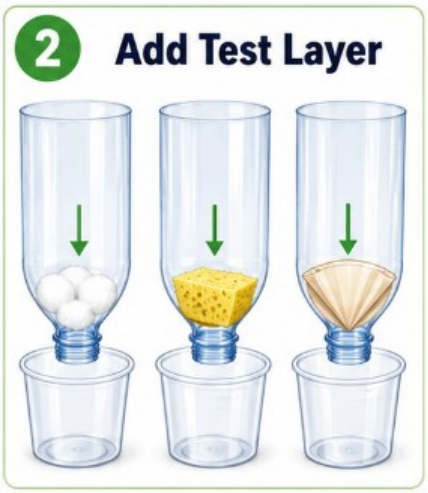
👉 Environmental engineers design filtration systems to remove visible particles, improve water clarity, keep water flowing, and protect water resources.

🟠 Step 2 — Add the Test Layer First

Because the bottle is upside down, the test layer goes near the **bottle's mouth** first. This keeps sand and gravel from falling out and helps catch fine particles.

Filter 1 — Cotton Layer

→ Place cotton near the bottle mouth inside Filter 1
→ Spread it gently so it covers the opening
→ Do not pack it too tightly



Filter 2 — Sponge Layer

→ Place a sponge piece at the bottle mouth inside Filter 2
→ Make sure it covers the opening
→ Do not block the opening completely

Filter 3 — Coffee Filter Layer

→ Fold one coffee filter so it fits inside the bottle
→ Place it near the bottle mouth inside Filter 3
→ Press it gently so it lines the lower part of the bottle

👉 **This is the layer you are testing and comparing.**

🟡 Step 3 — Add the Same Base Layers

→ Rinse the gravel and sand with clean water until the rinse water is mostly clear. Use the same measured amount in every filter.



→ Add the same base layers to all three bottle filters.

→ Add a layer of **sand** on top of the test layer in each bottle
→ Add a layer of **gravel** on top of the sand in each bottle
→ Try to make the sand and gravel layers have the same measured volume of sand and gravel in all three filters
→ Do not press the layers down too tightly

The layer order from top to bottom should be:

Gravel → Sand → Test Layer → Bottle Mouth → Collection Cup

👉 **Gravel is on top because polluted water enters from the wide cut opening.**

🟢 Step 4 — Create the Model Polluted Water

→ Measure **300 mL of water** into a cup or container
→ Add **1½ teaspoons of cocoa powder**

📊 Why Engineers Measure Several Results

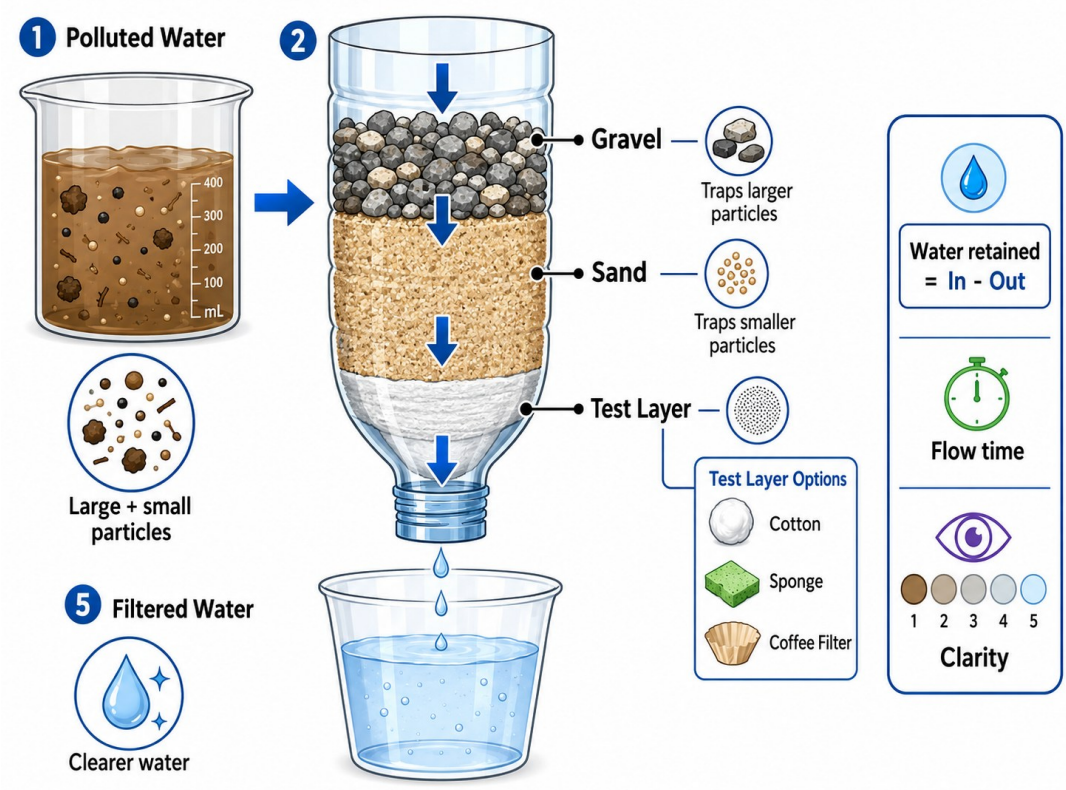
A strong filter must balance more than clarity. You measured:

✓ **Filtered water out** — how much water was recovered;
✓ **Water retained** — how much remained in the filter;
✓ **Flow time** — how quickly the water passed through;
✓ **Clarity score** — how clear the output appeared.

Water Retained = Polluted Water In – Filtered Water Out

Water retained is water held in the filter materials. It does **not** mean the same thing as pollution removed.

A filter may produce very clear water but work too slowly or retain too much water. Another may recover more water but allow more particles through. Engineers use all the measurements to select the best overall design.



🌊 Real-World Connection

Real water-treatment systems may use screening, settling, sand filtration, activated carbon, chemical treatment, and disinfection. They also monitor water quality throughout the process. Your filter models only the removal of visible particles.

⚠️ **Clearer-looking water is not necessarily safe water. The filtered water may still contain microorganisms or dissolved substances and must not be consumed.**

Troubleshooting

Problem	What You Can Do
Filter tips over or water misses the cup	Stabilize the bottle with tape or a stand, center the bottle mouth over the cup, and pour slowly.
Sand or gravel falls into the cup	Make sure the test layer fully covers the bottle mouth and is secure before adding sand.
Filter clogs or flows too slowly	Loosen packed layers, use less sand or fine-filter material, and check that the bottle mouth is not blocked.
Water flows too quickly	Add slightly more sand or a thicker test layer, and check for gaps or shifted layers.
Filtered water remains cloudy	Check the layer order, pour more slowly, and try a thicker sand or fine-filter layer.
Too much water stays in the filter	Reduce the amount of cotton, sponge, or sand and avoid packing the layers tightly.
Cotton or sponge blocks the opening	Use a smaller amount and spread it lightly so water can still pass through.
Coffee filter tears or folds	Fit it carefully against the bottle wall and replace it if damaged.
Layers shift during pouring	Pour slowly along the side of the bottle and keep the gravel layer stable.
Results differ too much between filters	Use the same water mixture, input volume, gravel and sand amounts, and testing time. Stir before measuring each sample.
Clarity is difficult to compare	Use clear cups on white paper and apply the same clarity scale or black “X” test.
Measurements are hard to read	Place the measuring cup on a flat surface and read the liquid level from the side.

REFLECT & EXPLAIN

① **Filtration Pathway**: Which pathway best describes the water-filtration system?

☐ A. Clean Water → Pollution → Gravel → Storage
☐ B. Polluted Water → Filter Layers → Collected Water → Measurement
☐ C. Sand → Clean Water → Pollution → Gravel
☐ D. Polluted Water → Heating → Evaporation → Drinking Water

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② **Match Each Layer to Its Main Function**: Write the correct letter beside each part.

Filter Part	Answer	Function
1. Gravel	___	A. Traps smaller visible particles
2. Sand	___	B. Collects the filtered-water output
3. Test layer	___	C. Catches larger particles and supports flow
4. Collection cup	___	D. Catches finer particles and keeps sand from escaping

---

③ **Fair Testing**: Why did all three filters use the same amount of gravel and sand?

☐ A. To make every filter look identical
☐ B. To make the filters heavier
☐ C. So only the test-layer material changed
☐ D. So the water would stop flowing

---

④ **Calculate Water Retained**

A filter received **100 mL** of polluted water and produced **72 mL** of filtered water. How much water was retained?

☐ A. 18 mL ☐ B. 28 mL ☐ C. 72 mL ☐ D. 172 mL

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⑤ **What Does Water Retained Mean?**

☐ A. The amount of pollution removed
☐ B. The water held inside the filter materials
☐ C. The amount of clean water added afterward
☐ D. The water that evaporated during testing

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⑥ **Analyze the Results:** Which conclusion is best supported?

Filter	Water Out	Water Retained	Flow Time	Clarity
Cotton	68 mL	32 mL	95 sec	5/5
Sponge	84 mL	16 mL	48 sec	3/5
Coffee filter	76 mL	24 mL	70 sec	4/5

🏭 Build a Smokestack Scrubber System



Get ready to think like an environmental engineer! In this activity, you will design, build, and compare three model smokestack scrubbers that help reduce acidic pollution before it reaches the environment. Your engineering question is:

Which scrubber moves the acidic input closest to neutral while maintaining steady, safe, and reliable flow?

You will create an acidic input model using vinegar and water. Then, you will pour equal amounts through three scrubber systems:

Scrubber 1 — Control Scrubber
Support filter only — no neutralizing material

Scrubber 2 — Baking Soda Scrubber
Uses baking soda as a fast neutralizing material

Scrubber 3 — Chalk / Antacid Scrubber
Uses crushed chalk, Tums, or antacid tablets as a calcium carbonate neutralizer

---

❓ What problem are we solving?

Some emissions can lead to acidic pollution and acid rain. If acidic pollution spreads, it can affect air, water, soil, plants, buildings, and ecosystems. Environmental engineers design scrubber systems to treat pollution near the source. A scrubber should:

✓ reduce acidic output
✓ keep flow moving
✓ compare materials fairly
✓ raise pH
✓ prevent clogging or overflow
✓ use evidence to improve the design

💡 Challenge

How can we design a smokestack scrubber system that:

makes acidic input less acidic → raises the output pH → allows steady flow → avoids clogging and overflow → stays open and safe → gives the best overall performance?

All three scrubbers must use the same bottle setup and the same amount of acidic input. This makes your test fair because only one part changes: **the scrubber material.**

🌿 Build a Carbon Capture Mineralization System

Get ready to think like a climate engineer! In this activity, you will build a model carbon capture mineralization system that moves carbon dioxide through two capture stages. Your system will follow this path:

Reaction Bottle → Capture Bottle 1 → Capture Bottle 2

The reaction bottle produces CO_2 gas using vinegar and baking soda. The gas travels through straws into limewater. When CO_2 reacts with limewater, the clear liquid can turn cloudy or milky white as a solid mineral called calcium carbonate forms. Your challenge is to answer:



Can a two-stage system show stronger evidence of CO_2 capture?

❓ What problem are we solving?

Carbon dioxide, or CO_2, can be released from human-made sources such as factories, power plants, transportation, and energy use. Too much CO_2 in the atmosphere is connected to climate change. Climate engineers design systems that help:

✓ reduce CO_2 emissions
✓ capture CO_2 before it spreads
✓ move CO_2 into capture materials
✓ measure system performance
✓ improve environmental protection technologies

💡 Challenge

How can we build a carbon capture mineralization system that:

👉 captures CO_2 evidence
👉 forms visible calcium carbonate
👉 reduces leaks
👉 turns limewater cloudy
👉 uses two capture stages
👉 stays safe, open, and measurable?

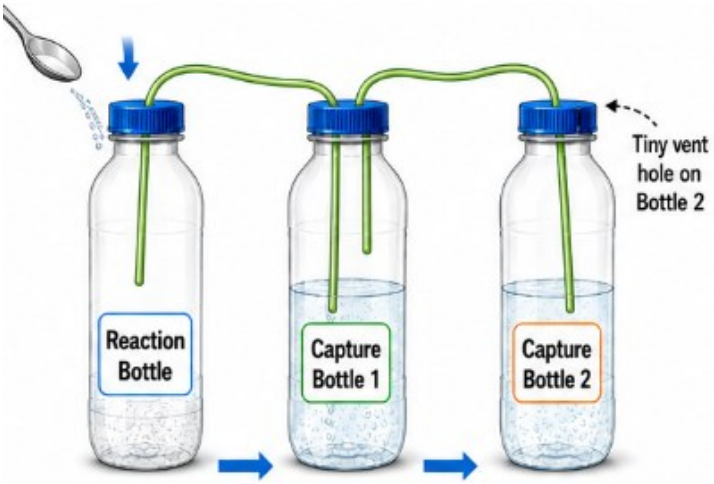
Your goal is to guide CO_2 through two capture stages and look for evidence that mineralization happened.

🔍 Test and Record Your Results

Start the CO_2 Reaction and Test the System

Now test the complete system.

→ Add 1 teaspoon of baking soda to the vinegar in the Reaction Bottle
→ Quickly place the lid with Straw 1 onto the Reaction Bottle
→ Start the timer when fizzing or bubbling begins
→ Watch for bubbles entering Capture Bottles 1 and 2
→ Keep the bottles still during the test. Do not shake, squeeze, or block the vent opening in Capture Bottle 2
→ Continue testing for 2 minutes



Record:

Time when Capture Bottle 1 first becomes cloudy: _____ seconds
Time when Capture Bottle 2 first becomes cloudy: _____ seconds

Bubbling in Capture Bottle 1: ☐ weak ☐ medium ☐ strong
Bubbling in Capture Bottle 2: ☐ none ☐ weak ☐ medium ☐ strong
Leaks noticed? ☐ yes ☐ no

Where? _____

👉 If Capture Bottle 1 turns cloudy, CO_2 reacted in the first capture stage.
👉 If Capture Bottle 2 turns cloudy, some CO_2 escaped the first stage and reacted in the second stage.

Observe Cloudiness

After the test time ends, compare Capture Bottle 1 and Capture Bottle 2. Look closely at the limewater in each bottle. Use this cloudiness scale:

Score	1	2	3	4	5
Appearance	Clear	Slightly cloudy	Cloudy	Very cloudy	Milky white

♻️ Build a Recycling Recovery System



Get ready to think like a circular economy engineer! In this activity, you will build and test a mini–Materials Recovery Facility (MRF). Your system will follow this path: **Mixed Input Waste → Sorting → Contamination Audit → Material Processing → Circular Economy Outputs**

You will prepare a mixed waste input made from safe household materials and separate it into three useful material streams: **Fibers**, **Synthetics** and **Biomass**. After sorting, you will process each material stream into a useful output. Fibers will become a **Pressed Recycled Fiber Tile**. Synthetics will be compacted into a **High-Density Eco-Brick**. Biomass will be tested for two-minute water absorption to model how organic material can help hold moisture. Your challenge is to answer: **How well can your recycling recovery system recover useful materials and reduce waste?**

❓ What problem are we solving?

Communities produce waste every day. Some materials can be recovered and reused, but only if they are sorted and processed correctly.

Environmental engineers design recycling recovery systems that help:

✓ separate mixed materials
✓ reduce contamination
✓ recover useful resources
✓ reduce landfill waste
✓ create new products from discarded materials
✓ support a circular economy

💡 Challenge

How can we build a recycling recovery system that:

👉 separates mixed waste into useful material streams
👉 reduces contamination
👉 recovers fibers, synthetics, and biomass
👉 creates useful outputs

💡 System Model

👉 **Mixed Input → Sort → Weigh → Audit → Process → Measure Results**

🧺 Mixed Waste Input

Material Stream	Use These Materials	Starting Amount
Fibers	clean paper scraps and thin cardboard	10 pieces
Synthetics	soft plastic strips from clean bags or soft packaging	10 pieces
Biomass	dry leaves, wood shavings, or clean cellulose sponge pieces	10 pieces

🔍 Sorting Key

Use this key to decide where each material belongs.

Category	What Goes Here?	What Does NOT Go Here?
Fibers	paper, cardboard, paper towel pieces	plastic, foam, cellulose sponge, leaves
Synthetics	soft plastic strips, soft packaging pieces	paper, cardboard, leaves, cellulose sponge
Biomass	dry leaves, wood shavings, cellulose sponge pieces	plastic, paper, cardboard
Landfill / Contamination	materials that are incorrectly sorted, unclear, mixed, damaged, or not represented by the three recovery categories	clean materials that clearly fit one of the three useful streams

🔧 Step-by-Step Instructions

🔵 Step 1 — Set Up the MRF Sorting Station

Place four trays or food containers on your workspace. Label them clearly:

✓ Fibers ✓ Synthetics ✓ Biomass ✓ Landfill / Contamination

Place your mixed waste input in one central starting pile.

Use a scale to weigh the full starting pile before sorting.

Starting Mixed Waste Mass: _____ g



👉 **Your system has three recoverable streams and one extra container for materials that cannot be recovered or were sorted incorrectly.**

🟠 Step 2 — Inspect the Mixed Waste

Use the sorting key to decide where each item belongs.

REFLECT & EXPLAIN — ANSWER KEY

ACTIVITY 1 — OIL SPILL CONTAINMENT

① **B** ② **A** ③ **C** ④ **Matching:** 1–B 2–C 3–D 4–A

⑤ **B** — **60%** (18 ÷ 30 × 100 = 60%) ⑥ **A**. The sponge collected the most oil (8 mL), but it also removed the cleanest water (9 mL).

⑦ **C** (Use equal-sized sorbent materials and the same starting amount of oil).

⑧ **Design B** (Evidence: no oil escaped, its containment score was **5/5**, and the spill area remained small).

⑨ **Correct changes:** ✓ Close gaps between the boom sections. ✓ Dab gently with a smaller sorbent piece.

⑩ **Suggested Response**: The floating boom surrounds the oil spill and provides containment, so the pollution does not spread. A sorbent collects oil from the surface, but it may also remove clean water. Measuring oil recovery and water loss helps identify the most efficient cleanup material.

ACTIVITY 2 — WATER FILTRATION

① **B** ② **Matching:** 1–C 2–A 3–D 4–B

③ **C** ④ **B** — **28 mL** ⑤ **B** 1(00 mL − 72 mL = 28 mL retained).

⑥ **A**. Cotton produced the clearest water, **5/5**, but retained the most water, **32 mL**, and had the slowest flow time, **95 seconds**.

⑦ **A**. A clear sample may have taken too long to produce or may have left too much water trapped inside the filter.

⑧ **B** — **Improved Filter**. It recovered **78 mL instead of 70 mL**, flowed in **74 seconds instead of 90 seconds**, and improved clarity from **3/5 to 4/5**.

⑨ **Correct changes:** ✓ Check for gaps or shifted layers. ✓ Add slightly more sand or fine-filter material.

⑩ **Suggested Response**: Polluted water moves through gravel, sand, and the test layer. Gravel catches larger particles, sand traps smaller visible particles, and the test layer catches finer material. The filtered water is collected below. Engineers compare clarity, flow time, and water recovery to evaluate the design.

ACTIVITY 3 — SMOKESTACK SCRUBBER

① **A** ② **B** ③ **B** ④ **Matching:** 1–C 2–D 3–A 4–B

⑤ **B** — **pH improvement of 3** (6 − 3 = 3)

⑥ **A**. Baking soda raised the output from pH 3 to **pH 7**, but it also had the longest flow time, strongest fizzing, and overflow.