environmental clean up

GOAL:

Visitors will understand how the size and chemistry of nano-iron enables it to be used for groundwater detoxification.

MATERIALS:

Real Product: Iron Filtration

- Graphic of industrial site
- Nano-iron hourglass
- Macro-iron hourglass
- Magnet wand

Real Product: Iron Reaction

- Plastic pipet
- Strips of paper
- Beaker of iodine working solution
- Beaker of water
- Beaker of nano-iron working solution
- 2 stir rods/spatulas
- White plastic square
- 16 oz. squirt bottle of water
- Waste bucket
- Paper towels

Macro-scale

- Plinko board and wooden dowel supports
- “Macro-iron” and “nano-iron” Plinko pieces

PROCEDURE:

Set-up:

1. Iron Filtration: Lay out graphic of industrial site and magnet wand. Set up hourglasses in rack.

2. Iron Reaction: In one beaker, make fresh iodine working solution by adding ¾ tsp iodine stock solution to 50 ml water and stir. In second beaker, use the plastic pipet to add 5 drops nano-iron stock solution (NOT powder!) to 50 ml water. In third beaker, add 50 ml water. Cut thin strips (about ¾” x 4 ¼”) of plain white printer paper and lay out all other supplies. Have paper towels on hand to wipe up any excess water.

3. Macro-scale: Prop up Plinko board with dowels and have Plinko pieces ready.

Doing the demonstration:

1. Show visitors the graphic of the industrial site. Explain how industrial pollutants can seep into the ground and contaminate groundwater, from which many people obtain their drinking water. (You can use the Plinko board to explain soil layers and groundwater.) Tell visitors that nano-iron can be used to clean up the groundwater.

<u>Iron Filtration</u>

2. For iron to detoxify pollutants in the ground and groundwater, it first needs to penetrate through the soil to reach them. Show visitors the macro-iron hourglass with the iron on the bottom and explain that the sand in the middle represents the soil. Have a visitor use the magnet wand to see that there is iron inside. Invert the hourglass to show that macro-iron is too large to filter through (the macro-iron may not even allow water to flow through the contraption).

3. Show visitors the nano-iron hourglass with the iron on the bottom and again have a visitor use the magnet wand to see that there is iron inside. Invert the hourglass – the nano-iron is small enough to filter through the sand. Likewise, nano-iron is able to filter through the ground to reach the pollutants. Place both hourglasses back in the racks with the iron on the bottom and set aside out of visitors' reach, if possible.

<u>Iron Reaction</u>

4. Once iron penetrates through the ground, it reacts with pollutants to make them less harmful. Dip two paper strips into the beaker of iodine working solution. Shake excess liquid off the strips, allowing iodine to soak in for a few seconds. Ask visitors for observations – the blue color is due to the complex formed between the iodine and the starch that is already in the paper. The starch/iodine represents pollutants.

5. Place one paper strip into the beaker of nano-iron working solution and the other strip into the beaker of water. Have two visitors use the stir rods to simultaneously stir each of the solutions for about 30 seconds.

6. Remove the paper strips from the beakers and squirt water onto each to rinse over the waste bucket. Place the rinsed strips on the white plastic square and ask visitors for observations. The paper strip from the nano-iron beaker looks cleaner than the one from the water because the nano-iron reacted with the starch/iodine. This reaction is similar to how nano-iron reacts with pollutants.

<u>Macro-scale</u>

7. The Plinko board represents a slice through the ground with soil particles at different levels. This model shows how iron travels through the ground and traps pollutants at a scale that is easy to see. Have a visitor drop a "macro-iron" Plinko piece from the top of the board. The "macro-iron" is too large to fit through the soil particles and gets stuck, just as the macro-iron in the hourglass cannot filter through sand.

8. Have a visitor drop a "nano-iron" Plinko piece from the top of the board. The "nano-iron" pieces are small enough to fit between the soil particles and can fall

through. When they encounter magnetic "pollutants", the "nano-iron" pieces will stick, representing the reaction between nano-iron and toxic compounds.

Clean-up:

1. Use the magnet wand to remove as much of the iron from the sand as possible. The hourglasses should be stored in the rack vertically with the iron/water suspension at the bottom. Store in a safe place.

2. Pour iodine working solution, water, and nano-iron working solution down the drain. Rinse the beakers and stir rods. Throw the used paper strips in the trash.

3. Gather Plinko board, Plinko pieces, and all other supplies and return to storage.

EXPLANATION:

Treating polluted areas with nano-iron is a new method of environmental remediation based on nanotechnology. Nano-iron is made up of particles of zero valent iron (iron in its metallic state, Fe^0) that are approximately 100 nm in size. The iron is treated with a noble metal catalyst that speeds up its ability to reduce, or donate electrons to, other compounds. Iron's reducing power is shown in this demonstration through its reaction with the deep blue colored starch/iodine. When starch/iodine is reduced by iron, the color disappears.

Several classes of compounds, such as chlorinated organic molecules and soluble forms of lead and chromium, are transformed into much less toxic or less mobile forms by gaining electrons when they are reduced by nano-iron. Nano-iron can neutralize many different pollutants, including herbicides, pesticides, PCBs, toxic metals (like chromium) and other industrial chemical wastes. Remediation with nano-iron works both *in situ* (at the original location of pollution) and *ex situ* (when pollutants are removed from the original location and then treated.

When used for *in situ* treatment, nano-iron is typically injected into the ground and then travels downward due to gravity. Due to its small size, nano-iron can fit between particles of sediment to reach pollutants at depths of ten meters or more. Nano-iron can travel through a variety of media, including sand, silt, fractured rock, landfill, fill materials and sediment. Since nano-iron is made up of smaller particles than macro-iron, nano-iron is also more efficient because of the greater surface area available to react with pollutants.

In commercial applications, nano-iron particles are often encapsulated in a polymer such as sodium polyacrylate. This enhances the transport of nano-iron through the ground but does not interfere with the chemical reaction, as spaces in the polymer encapsulation leave enough room for the iron to be exposed to the pollutants. (Polyacrylate is also found in laundry detergents where it has a similar function; it adsorbs to particles attached to clothing, making them negatively charged and thereby lowering their attraction for the surface of the cloth.)

Remediation with nano-iron has recently been used in various locations across the U.S., including New Jersey, Pennsylvania, New York, Ohio, Maryland and Florida. It costs significantly less than other remedial approaches such as pumping out and treating pollutants or installing a reactive barrier.

WHAT COULD GO WRONG?

Over time, the iron in the hourglasses will rust and the sand may clog. The old sand will have to be replaced with new sand (see Maintenance section for instructions). Ions in tap water accelerate rusting, so use distilled or deionized water to refill hourglasses. The macro-iron hourglass will need to be changed more often than the nano-iron hourglass.

GENERAL MAINTENANCE:

Iron Filtration

Materials:

- Wire
- 1 piece of nylon
- Funnel
- Sand
- Stir rod/spatula
- Beaker
- Nano-iron powder (NOT stock solution!)
- Polyacrylic acid (PAA)
- Dish detergent
- Scissors

To remove clogged sand in the hourglasses, use the wire provided to remove the nylon holding the sand in place. Running water through the hourglass while simultaneously poking the sand with the wire aids in the removal of the nylon and packed sand.

To repack, cut one of the provided pieces of nylon in half. Tie each piece into a loose knot and cut off the excess nylon. Place one nylon knot into the top of the hourglass and use the wire to squeeze it through the indentation. Once the nylon knot is in place, add the sand using the funnel. While adding the sand, run water through the hourglass in order to wash the sides of the hourglass and to pack the sand lightly. Pack the sand just until there is enough room for the second nylon knot. Use the wire to squeeze the second nylon knot through the indentation. Run water through both ends of the hourglass to ensure that water drains well and there is no loose sand. **Pack the nylon and sand as lightly as possible. If packed too densely, water may not drain through.**

Mix the nano-iron or macro-iron solutions in a separate beaker, then add to hourglasses:

Nano-iron: 1 spatula tip of nano-iron POWDER
2 spatula tips of PAA
1 drop of dish detergent
20 ml distilled water

Macro iron: 4 spatula tips of macro-iron
20 ml ethanol

Iron Reaction

Refrigerate the nano-iron stock solution to minimize rusting. Remake the working solution (5 drops stock solution to 50 ml tap water) at the beginning of each day that you are doing the demo. The solution should last for the day and then be disposed.