Magnetic Nanoparticles: A Solution to Pollution

Day 2: Functionalized GO vs Non-functionalized GO?

Group Members Names: ____

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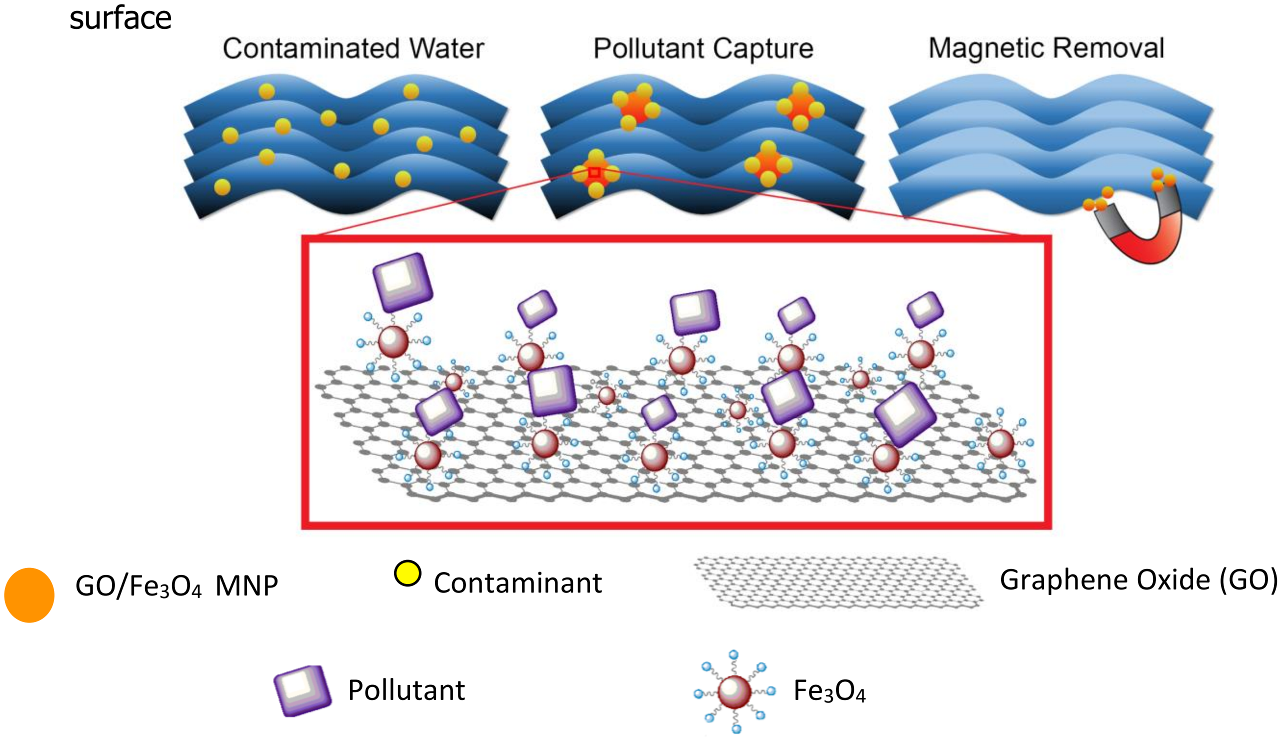
The Nanosystems Engineering Research Center for Nanotechnology-Enabled Water Treatment (NEWT) is facilitating access to clean water with their Magnetic Nanoparticle (MNP) research. NEWT chemical engineers and researchers are functionalizing (organizing particles into units to preform specialized tasks) graphene oxide (GO) with magnetite (Fe_3O_4) to make the nanoparticles magnetic, more resourceful, reusable, and cost-efficient with regards to water footprints. The future of water sanitation and purification lies in the research of MNPs. MNPs are organic polar compounds that adsorb (trap atoms, ions, molecules to the surface of the particle in layers) pollutants from water and removes them through the aid of a magnet.

Methylene Blue (MB) is a common dye used for clothing, medication, and biological staining. Because of its universal usage, it is a common pollutant found in many freshwater sources. Research has found that GO quickly and easily adsorbs MB onto its surface



Day 2: Functionalized GO vs Non-functionalized GO?

The image above demonstrates how GO/Fe_3O_4 adsorbs the MB to the top of the nanoparticle and how easily the pollutant is removed from the water via a magnet.

Materials

- Scale
- 2 Weigh Boats
- 0.100 g Graphene Oxide (GO)
- 0.100 g Functionalized Graphene Oxide (GO/Fe_3O_4) -
- 200 mL (.200 L) of "Polluted" water
- Three (3) 150 mL beakers
- 2 Stirring magnetic rods
- Stirring plate
- Neodymium Magnet
- Waste container
- Distilled water (for rinsing)

Safety Procedures

- DO NOT bring any electronic devices to the lab tables!! The neodymium magnets are EXTREMELY powerful and will delete all data from your devices.
- If you have a metal plate/rod or pacemaker, stay AWAY from the magnet. Stand on the opposite side of the magnet. The magnets have a 12pound force and will cause irreparable damage.
- Always place the magnet down **carefully.** KEEP your hands AWAY from the path of the magnet.
- Wear goggles and aprons/lab coats. MB is a permanent dye and will stain clothing and skin. Gloves are optional, however are recommended.

Procedures (record all answers to the nearest hundredths places)

- Place the neodymium magnet **AWAY** from all metallic lab equipment
- Carefully measure out 100 mg of GO ________________mg
- Carefully measure out 100 mg of GO/Fe_3O_4 ________________mg
- Label one beaker "GO/Fe_3O_4" and the other "GO"
- Add the GO/Fe_3O_4 to the beaker labeled GO/Fe_3O_4
- Add the GO to the beaker labeled GO

Place the exact amount of material you measured out in the lines provided.

Day 2: Functionalized GO vs Non-functionalized GO?

- Add 100 mL of "polluted" water to two (2) of the 150 mL beakers. Leave one beaker empty
- Place both beakers on the stirring plate.
- Add one (1) magnetic stirring rod to each beaker
- Turn the stirring plate on to high. **<u>DO NOT TURN ON HEAT!!!</u>**
- Leave the beakers stirring for 1:30 minutes.
- Turn off the stirring plate.
- Move the neodymium magnet to the center of the table AWAY from all metallic items
- Place the GO beaker about 5 cm away from the neodymium magnet.
    - Time set down_____________
- Place the GO/Fe_3O_4 on top of the neodymium magnet
    - Time set down_____________
- For each beaker, record the TOTAL time it took to clean out the water.
    - Total time for GO ___________
    - Total time for GO/Fe_3O_4 ___________
- Holding the magnet and the GO/Fe_3O_4 beaker together, carefully pick them up and pour out the water.
    - Record your observations:

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- What happened?

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- What evidence do you have?

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- Using your knowledge of polarity, elemental properties, and chemistry, would GO be useful to clean out other material besides MB?

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- What **major** water pollutant would be ideal to have adsorbed and removed via magnetic nanoparticles? What could be the results of such efforts?

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- How are MNP more beneficial than non-magnetic?

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- Are these particles reusable? How do you know?

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The correct amount of MB is crucial in testing how effective the nanoparticles are. Current chemical engineers are conducting this experiment at concentrations of 12.5 ppm (parts per million), 25 ppm, 50 ppm, and 100 ppm. This means that they add 12.5/25/50/100 mg of MB for every ***liter*** in their sample. The liters needed in a sample comes from the number of samples of polluted water multiplied by the number of trials they will conduct. This value is then multiplied by 10 to get the correct amount of water needed (in mL) to conduct the experiment based off the total number of trials. To get an accurate value of how well these nanoparticles clean out the water samples, scientists use three (3) trials to get a reliable range of efficiency. Once the chemical engineers determine the amount of water necessary, they can then calculate the exact amount of MB needed to test the efficiency of the nanoparticle. They do this by multiplying the ppm by the amount of liters needed.

- If you were the chemical engineer working in the lab, how many liters of water would be needed to test 15 samples?

  ____

- How much MB would be needed to each separate concentration of MB and water?

  12.5 ppm ________________________________

  25 ppm ________________________________

  50 ppm ________________________________

  100 ppm ________________________________

Magnetic Nanoparticles: A Solution to Pollution

Chemistry

Solutions, Chemical Reactions, Data Analysis and Probability, Measurements and Technology, Chemical Engineering

Magnetic Nanoparticles: A Solution to Pollution

Figure 1

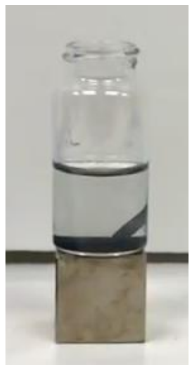

Figure 2

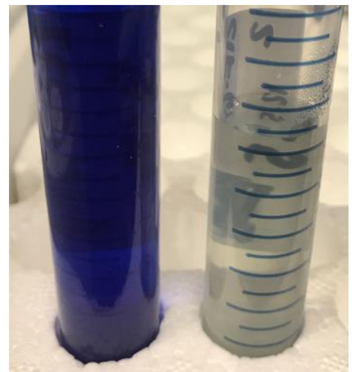

Figure 3

Figures 1, 2, and 3

Contaminated Water Sample vs Clean Water Sample

ADA Description: Fig 1: Small clear vial with black turbid water filled half way sitting on a flat surface.

Fig 2 Vial filled half way with clear, clean water and a stirring rod sitting on top of a square neodymium metallic magnet. The vial has dark mass sitting on the bottom of the vial.

Fig 3: Side by side comparison of blue polluted water (left) and clean and clear water (right). Both samples are inside of centrifuge tubes sitting on top of a styrofoam centrifuge rack

Source/Rights: Michelle Gomez

Caption: Water contaminated with Methyl Blue is treated with magnetic nanoparticles to purify and produce crystal clear water

Grade Level 10 (High School 9-12)

Activity Dependency

Time Required _90__ minutes (2 class periods)

Group Size 8 individual groups of 4-6 students (Smaller size groups are acceptable too)

Expendable Cost per Group US $14.32 (**All items are only available to schools, labs, or for commercial use. Items will only be able to be purchased in bulk through a school purchase order) Teacher should not make any out-of-pocket expenses. All materials should be ordered at the beginning of the school year to ensure delivery for lab. See attached “Purchase Order”

Summary

Students are introduced to the newly developed research-currently being conducted- of using magnetic nanoparticles to clean water. Students evaluate how they can completely clean out a “dirty” water sample using only the materials provided; then they are prompted to compare functionalized graphene oxide (magnetic graphene oxide) and nonfunctionalized graphene oxide (non-magnetic) to clean out their water sample given to them. The lesson promotes higher order thinking coupled with advanced problem solving skills.

Engineering Connection

Chemical and environmental engineers are constantly creating new ways to keep natural resources abundant on our planet. Chemical engineers are responsible for bullet proof fabrics, smaller computer chips, treatments for disease, recycling, and cleaning water. Environmental engineers use the materials created by the chemical engineers to sample the quality of the water, the effectiveness of their computer chips, etc. The Nanosystems Engineering Research Center for Nanotechnology-Enabled Water Treatment (NEWT) is facilitating access to clean water with their Magnetic Nanoparticle research. NEWT chemical engineers and researchers are functionalizing graphene oxide with magnetite to make the nanoparticles magnetic, more resourceful, reusable, and cost-efficient with regards to water footprints (www.newtcenter.org).

Engineering Category =

1. Relating science and/or math concept(s) to engineering

Keywords

Magnetic Nanoparticles, Turbidity, Water Treatment Analysis, Chemical Engineering, Environmental Engineering

Educational Standards

Texas (TEKS) Standards

§112.35. Chemistry

(8) Science concepts. The student can quantify the changes that occur during chemical reactions. The student is expected to:
- (C) calculate percent composition and empirical and molecular formulas;
- (D) use the law of conservation of mass to write and balance chemical equations; and
- (E) perform stoichiometric calculations, including determination of mass relationships between reactants and products, calculation of limiting reagents, and percent yield.

(10) Science concepts. The student understands and can apply the factors that influence the behavior of solutions. The student is expected to:
- (A) describe the unique role of water in chemical and biological systems;
- (B) develop and use general rules regarding solubility through investigations with aqueous solutions;
- (C) calculate the concentration of solutions in units of molarity;
- (D) use molarity to calculate the dilutions of solutions;

(E) distinguish between types of solutions such as electrolytes and nonelectrolytes and unsaturated, saturated, and supersaturated solutions;
(F) investigate factors that influence solubilities and rates of dissolution such as temperature, agitation, and surface area;
(G) define acids and bases and distinguish between Arrhenius and Bronsted-Lowry definitions and predict products in acid base reactions that form water;
(H) understand and differentiate among acid-base reactions, precipitation reactions, and oxidation-reduction reactions;
(I) define pH and use the hydrogen or hydroxide ion concentrations to calculate the pH of a solution; and
(J) distinguish between degrees of dissociation for strong and weak acids and bases.

ITEEA Standards

Students will develop an understanding of Design. This includes knowing about:

The attributes of design.

Engineering design.

The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

NGSS Standards

HS-PS1-5.
Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
HS-PS1-6.
Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. *
HS-PS1-7.
Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Pre-Requisite Knowledge
A basic understanding of mixtures, solutions, chemical properties (metallic properties), chemical reactions, algebra, and states of matter. Students should be able to safely and correctly measure out quantities of chemicals, mix chemicals, and dispose of chemicals.

Learning Objectives
After this lesson, students should be able to:
- Define magnetic nanoparticels
- Understand how magnetic nanoparticles are currently being used in modern-day research
- Properly apply algebra concepts to material given
- Identify properties of magnetic metals

Materials List

Teacher Material List

- Solid Methyl Blue (MB) (.100 g) or RIT clothing Dye (5-10 drops)
- 3-gallon water jug with lid
- Small vials with lids (20 mL)
- Graphene Oxide (5g package)
- Magnetite (Fe_3O_4) (10 lbs package)
- Büchner Flask (filtration flask) 200mL
- Büchner Funnel
- Rubber/plastic tubing
- Filter paper
- Hot Plate/Stirring Plate
- 150 mL beaker
- Magnetic stirring rods

- Each group needs - Day 1 (45 minutes)
    - A sample of "dirty, polluted" water - prepared a night before prior to the activity. Preparation is done by the teacher (see Before Activity Section)
    - A regular magnet (do not use the neodymium)
    - Student Handout A (Attached)

  To share with the entire class:
    - NEWT 2.0 Video
    - Magnetic Nanoparticle Preliminary Handout

- Each group needs - Day 2 (45 minutes) - can be done as a demonstration if need be.
    - Scale
    - Weigh Boats
    - Graphene Oxide (GO) (.100g—students measure out)
    - Functionalized Graphene Oxide (GO/Fe_3O_4) - prepared two to three days prior to the activity. Preparation is done by the teacher (see Before Activity Section) (.100g—students measure out)
    - 200 mL (.200 L) of "Polluted" water with Methyl Blue (or RIT dye) - prepared a night before or morning prior to the activity. Preparation is done by the teacher (see Before Activity Section) (students should obtain this amount from what the teacher previously made)
    - 2 (two) 150 mL beakers
    - Stirring magnetic rods
    - Stirring plate
    - Neodymium Magnet
    - Waste container
    - Distilled water (for rinsing)
    - Student Handout B (Attached)

Introduction / Motivation

Day 1:

(Have attached video ready to show (NEWT 2.0) to introduce magnetic nanoparticles to the students. Video will be displayed AFTER their activity)

Have a sample of "dirty water" ready at each lab station - dirty water can easily be made with dirt, food coloring, oil, and water - and a magnet (a regular magnet is fine. Do not use a neodymium magnet for this activity). As the students come in, have them leave their bags at their desks and ask them to go to their lab stations. It is important that you DO NOT give the students any information about magnetic nanoparticles before the lesson. You do not want your students answers to automatically reflect what they will be learning without first exhausting all other "possible" options. Tell the students "At your lab stations, you have a sample of polluted, non-potable water and a magnet. You have ten (10) minutes to come up with two different methods that can be used to clean the water sample given to you. Your methods can be anything you feel would work so long as the magnet is used. Discuss within your groups how a magnet could make this water safe to drink. Go!" Start timing the students. Walk around to ensure meaningful and purposeful talk is being exchanged within the students. Students will ask some of the following questions or make similar statements to the following:

- "Are you sure this is possible?"
- "How is a magnet going to clean the water?"
- "Magnets only attach to metals, so the pollution has to be a metal in order for this to work."
- "Is this a trick question?"

The students are to collaborate and come up with two unique methods in which a magnet can be used to clean the water. Each group must come up with two completely different methods they can use the magnet to clean the water.

Once the ten minutes are up, say to your students, "Each group will share one method on how they can use the magnet to clean the water. No group can repeat what another group has already said, this is why you have two methods. If another group comes up with the same method you chose, have your second method ready to share." Listen to each group give their method. Some answers to expect may include:

- "Magnets have to have a metal for it to work. So we think that a large metal basket will trap all of the pollution, then they take a huge metal held up by a construction crane and pull everything out."
    - With answers like this, be sure you ask something like this: "How will the basket trap the pollution?" This helps set up the magnetic nanoparticle lesson and how the pollutant adsorbs to the nanoparticle. All questions asked by you should start framing the lesson without giving them much information. You are "planting the seed".
- "You can put the magnet at the bottom of the water and electrocute the water with the magnet and all of the water will be shocked clean"
    - You can ask questions such as "How does 'electrocuting' the water clean the water? What properties of water allow you to believe this would work?"
- "A magnet cannot clean the water because none of the properties of a magnet allow for such actions"
    - Do not discredit answers that state it is not possible. Remember, the students do not have any background knowledge of the matter therefore they may or may not know if it is possible.

To keep all other groups engaged, give groups one to two (1 to 2) minutes (collaboratively) to explain why or why not that method could or could not work. As they are discussing, you-the teacher-should be writing down all of the methods mentioned on a poster board to display to the class. Allow time for questions from groups to groups.

After all groups have discussed their methods, ask them to go back to their desks to proceed with the lesson. Ask all students "Has anyone ever heard of a magnetic nanoparticles (MNP)?" Most students probably have not. If there happens to be students that are familiar with MNPs, allow the student(s) to explain their definition or understanding of MNPs and fill in any missing information or clear up any misconceptions.

Play the NEWT 2.0 video (found in the PowerPoint, first slide) for the students. Tell your students, "In the video you see a polluted water sample. The water is polluted with Methylene Blue, a common organic dye found in the majority of all of our clothing. This dye is toxic to people and animals in high amounts. It is a common pollutant found in many large bodies of water that surround clothing factories. The demonstrator took a small amount of a black 'powder' or better known as magnetic nanoparticles, and placed it inside of the polluted water sample. After a minute of constant stirring, the methylene blue attaches itself to the magnetic nanoparticle through a process known as adsorption. Once the pollutant and the magnetic nanoparticle have adsorbed together, the magnet can easily pull all of the pollutant out from the water. This is why we see the water crystal clear when the demonstrator poured the water out of the magnetized vial." Continue with the PowerPoint provided to show and explain to students what MNPs are and how they are the future of water purification. Be sure to answer any questions during the lessons to help students better understand. The PowerPoint does explain the difference between adsorption and absorption. At this point tell the students "on the back of your handout, please draw your interpretation of the differences of adsorption and absorption and explain the differences."

After the PowerPoint, have students give you at least 5 other instances (besides the ones shown on the slide) where MNPs would be beneficial. Ask the students to go back to their stations and say "You now have the remainder of the period to come up with 5 innovative ways that magnetic nanoparticles could be used. (You can even go a step further and ask them "How can these magnetic nanoparticles be further engineered to provide universal functionality?" This really triggers advanced thinking and forces students to think outside the box.) Some examples should include military, camping, power outages, etc. Students should write their ideas on a piece of butcher paper with markers to display.

<u>Day 2:</u>

Students will need to compare the cleaning efficiency of the functionalized Graphene Oxide (GO/Fe_3O_4 - magnetic) and non-functionalized graphene oxide (GO non-magnetic). Allows students to engage in current scientific research using magnetic nanoparticles, and correlate their findings with those of the professionals.

As students walk into the classroom, have them sit down at their desks before you release them to their lab stations. Be sure to inspect each student's attire and that it is in compliance to lab safety. Say to the students "Today you are going to be functionalizing the nanoparticle Graphene Oxide. To functionalize a nanoparticle means to make your nanoparticle have a specialized task. In today's lab, you will functionalize your nanoparticle into being magnetic. Your instructions for today are found at each of your lab stations. You have only today to complete the hands on portion of the activity. You will need to read ALL of the information regarding magnetic nanoparticles as a group prior to starting your activity. The reflection questions are to be answered after your lab stations have been cleaned. Everyone must wear lab aprons and goggles. Gloves are available for those who feel they need them. Your goal is to compare which nanoparticle works best in cleaning out water. Do not skip any steps and work with mindfulness and extreme caution. At your stations there is a neodymium magnet. This magnet is VERY powerful and will destroy electronic devices. DO NOT take anything of value to the lab stations, only your pencil, notebook, and assignment are needed. The magnets are not a toy. Only use them when prompted to do so in the assignment." Expect your students to have a lot of questions about the magnet at this time. Ensure them that as long as they exercise caution with the magnet, no accidents should occur. If you have a student with metal inside their bodies, advise them to stay away from the magnet as it will be attracted to them.

Continue by saying to your students "In the areas that ask you to measure out certain amounts of material, record the EXACT amount you measured out to the nearest hundredths place. For example, if the instructions say to measure out 100 grams of something, and I can only get the scale to 99.98 grams without going over the 100 grams required, then I would record the 99.98 grams in the space provided. I will be walking from station to station if you should have any questions regarding this step. Remember! The weigh boats that you will be using to measure out the materials have a mass as well!! Be sure to measure out the mass of the weigh boat before you mass the material! Does anyone have any questions or concerns before I release you to your stations?" At this time expect most students to not have questions. If a student does have a question it will be to clarify something you said earlier. Most, if not all, questions will be asked during the activity itself. Say to your students "OK, you may now go to your stations and begin your lab."

Walk around and watch all students work on the activity. Keep them on task and make sure they are not playing with the neodymium magnet. Answer any questions the students may have. Some questions to expect will be:

- "Is this correct:
    - Answer these types of questions with "What did you do to come up with this answer?' If the students can explain with full detail how they came up with an answer, then the student is on the right track, if not, redirect the student to where they need to be to get the correct answer.
- "Is 100.3 mg ok for us to measure out?"
    - As long as the amount measured can be rounded to 100 mg then the amount is acceptable. If it is rounded to more or less such as 98.99 mg or 101.24 mg, then ask them to either add or remove material from their scales.
- "Is this the correct placement of the magnet"
    - As long as the magnet is away from the students when not in use, and is under the vial when in use, the placement is correct.
- "Which button is for stirring?"
    - Usually the buttons are labeled "heat" and "stir". Guide the students to the correct button or switch
- "What is the difference between the neodymium magnet and a regular magnet"
    - "A neodymium magnet is a rare earth metal magnet that is extremely powerful. A one-inch neodymium magnet can hold 12 lbs. in weight."

During the lab, students' answers will vary. Time answers will change depending on the time of the day that the activity was done. Other answers to the activity can include:

- What Happened?
    - The magnetized nanoparticle cleaned the water better than the non-magnetized particles because the magnet pulled all of the pollution to the bottom of the vial while the other one had to settle
- What evidence do you have?
    - We saw the water clear up a lot faster (within seconds of exposing it to the magnet) with the magnet than without the magnet. We had to let it set, which took about 10 minutes before we noticed anything.
- Using your knowledge of polarity, elemental properties, and chemistry, would GO be useful to clean out other material besides MB?
    - So long as the materials were organic hydrophilic material, these nanoparticles should be able to clean out that material.
- What MAJOR water pollutant would be ideal to have adsorbed and removed via magnetic nanoparticles?
    - The answer you are looking for here is oil. Students may or may not make the connection especially since oil is hydrophobic. For those students struggling explain how chemical engineers are still developing magnetic nanoparticles that can adsorb hydrophobic material including non-organic material.
- How are MNP more beneficial than non-magnetic?
    - Students should immediately refer back to their results.
    - The MNP reduces the cleanup time to seconds since we do not have to wait for the particles to settle
- Are these particles reusable?
    - Students can come up with a variety of answers with a variety of explanations. You are looking for:
        - Yes, because the material is stuck to the top of the magnetic nanoparticle. You should be able to clean off the pollutant and discard of it properly.

Vocabulary / Definitions

Word	Definition
Adsorption	The adhesion of atoms, ions, or molecules from a gas, liquid, or dissolved solid to the surface of the adsorbent (the substance adsorbing the material).
Functionalize	To cause to be functional; to organize into units performing specialized tasks
Graphene Oxide	Formally called graphitic oxide, is a compound of carbon, oxygen, and hydrogen in variable rations. Obtained by treating graphite with strong oxidizers.

Magnetic Nanoparticle (MNP)	a class of nanoparticle that can be manipulated using magnetic fields. They consist of two components: a magnetic component (iron) and a chemical component with functionality (graphene oxide)
Magnetite	A mineral and one of the main iron ores. Chemical formula Fe_3O_4. It is ferromagnetic (attracted to a magnet).
Magnetism	A class of physical phenomena that are mediated by a magnetic field.
Metallic Properties	Physical properties associated with metallic character.
Nanoparticle	Particles between 1 and 100 nanometers in size with a surrounding interfacial layer.
Water Pollution	Contamination of water bodies

Procedure

Day 1:

- Separate students into small groups of 4-6 students. At each lab station there will be a "dirty water sample" and a magnet.
- Have students collaborate within each other for 10 minutes on how they can achieve clean, potable water with the materials given. Show them an example of a clean glass of drinking water.
    - Be prepared to hear comments such as "this is not possible", "a magnet does not purify water" etc.
    - Students should come up with two different ways that they can purify the water and write their ideas on the handout provided (see attached).
- Students will share their group's ideas with the class. Ideas cannot be repeated (hence the two ideas). If two groups have the same idea, then one group will need to share their second idea to avoid repetitiveness and keep students engaged. Give all groups a 1-minute timeframe to share their idea.
- After all ideas have been shared, begin talking about magnetic nanoparticles (MNPs) and let students explain their understanding of what a MNP is.
- Once MNP definitions have been clarified, show the NEWT 2.0 video (https://www.youtube.com/watch?v=mkUqRUdOLds) to illustrate just how the MNP adsorbs the pollutant and how [this] is a possible way to clean and purify water.
- Go through the quick PowerPoint presentation (attached) to help students fully comprehend what the role of a MNP is and how it adsorbs pollutants to clean and purify water.
- After the presentation, have students collaborate and write down - on butcher paper with markers- 5 other uses where MNP purification would be beneficial. This could be used as their "Exit Ticket"
- Explain to students that tomorrow, they will be comparing functionalized graphene (GO/Fe_3O_4) and comparing it with non-functionalized GO. They will need to make inferences to determine which is most conducive and for what specific reasons.

Day 2 (done as group activities):

- Students already have the introductory background to MNP's and should have minimal questions during the activity. **However, be prepared for higher learning questions after the activity.**

- Students should be separated into their groups from the previous activity. This allows for less error since students are familiar with each other.
- At each lab station there should be a scale, a small amount of GO, a small amount of GO/Fe_3O_4, 200 mL (.200 L) of Methyl Blue (MB) contaminated water, the student handout (see attached), two weigh boats (one for each nanoparticle sample), two 150 mL beakers, stirring rods, a neodymium magnet, distilled water, and a waste container.
- Make sure students do not have their electronics at the lab stations. Explain that the magnet is very powerful and will erase all contents from their devices.
- Ensure all students are dressed appropriately for their lab (lab coats/aprons, goggles and gloves (optional).
- Have students follow the instructions on the handout.
- Walk around to monitor students are using the right amounts, proper handling techniques, and are on task.
- Once completed, have students dispose of ALL materials in the waste container provided, and thoroughly wash and dry their lab-ware.
- Have a discussion with students (as a whole) about what they observed and what they concluded. Have them explain how MNP's are more beneficial than non-functionalized nanoparticles. Ensure that all students are engaged in the small purposeful talk.

<u>Day 2 (done as a demo)</u>

- Students already have the introductory background to MNP's and should have minimal questions during the demo. **However, be prepared for higher learning questions after the demo.**
- Depending on the class size, either have students stand around the demo station, or have students in their seats with a clear view of the demo station.
- At the demo station there should be a scale, a small amount of GO, a small amount of GO/Fe_3O_4, 200 mL (.200 L) of Methyl Blue (MB) contaminated water, the teacher demo guide (see attached), two weigh boats (one for each nanoparticle sample), two 150 mL beakers, stirring rods, a neodymium magnet, distilled water, and a waste container.
- As you follow the teacher demo guide, be sure to explain everything that is being done and why (found on teacher demo guide). Check for understanding and/or questions with students periodically and consistently. This demo has a lot of basic lab techniques that many students may not be learned in.
    - At the discretion of the teacher, student helpers are encouraged. This keeps the class more engaged and focused at what is being taught.
- Once the demo is complete, your beakers should demonstrate similar results as Figures 1 and 2 (found at the beginning of this activity). Answer any questions that the students may have, and offer clarifications for any uncertainties.
- Have a discussion with students (as a whole) about what they observed and what they concluded. Have them explain how MNP's are more beneficial than non-functionalized nanoparticles. Ensure that all students are engaged in the small purposeful talk.

Background

Magnetic nanoparticles (MNPs) are a new and important class of functional materials. Their magnetic properties are caused by the functionalization of graphene oxide (GO) and magnetite (Fe_3O_4) - GO/Fe_3O_4. Their minuscule size (below 100 nm) gives them the potential to be used in unconventional ways such as water treatments (Willard, 2013). The MNP's currently in research are synthesized (created) by functionalizing (adding additional properties to) graphene oxide (a nanoparticle known for its ability to adsorb materials) with magnetite -Fe_3O_4 (a mineral and main iron ore). The graphene oxide and magnetite combine to produce a MNP. The future of water filtration and purification lies within MNPs. Since they are so small in size, they can easily be transported making them ideal for use in military and remote water sanitation projects. These prepared MNPs are currently being used to remove Methyl Blue (MB) as a model for common organic pollutants and ions found in fresh water sources. These newly developed MNPs can effectively remove organic pollutants from contaminated water. Findings like this make MNPs suitable for water and wastewater treatments. Best of all, these MNPs are reusable!

Before the Activity

- Teacher preparation **IS** required!
  - Preparation of "dirty" water samples—should be completed at least one day before the activity
    - Obtain small vials with lids (recycled baby food jars work perfectly) enough for each lab group to have one (1)
    - Fill each vial half way with water
    - Add food coloring (color and intensity to be left up to preference of teacher)
    - Add a few drops of oil (type or kind of oil is of non-importance; this is just to illustrate contamination)
    - Dirt or sand are optional but a great way to demonstrate turbidity—which most polluted water is.
    - Secure lids tightly and set aside.
      - Separation is natural. Don't be afraid to let the students shake the samples
  - Preparation of MB polluted water—should be completed the day before. Can also be done in class as part of the demo.
    - Obtain an empty 3 gallon (minimum) water jug with a lid. Many can be found at Walmart. For this lesson, a 5-gallon water jug and lid was readily available and used.
    - Fill the jug with 8.5 L (2.25 gallons) of tap water.
    - Carefully measure out 100 mL (0.100 L) of MB ** Be extra careful to not get MB on your hands or clothing. It permanently stains!
      - If MB is not something you were able to obtain, RIT clothing dyes are an excellent alternative. These are easily found at Walmart in the laundry section, costing about $2.00 each.
        - Use between 5-10 drops of RIT dye only.
    - Add the MB to the 8.5 L of water in the jug.
      - The MB will slowly travel down to the bottom
    - Place the lid on the jug and shake vigorously until all MB is dissolved.
    - Set aside
  - Preparation of the functionalized GO/Fe_3O_4 — should be prepared at least three (3) days prior to the activity
    - Carefully measure out 1.8 g of GO
    - Carefully measure out 100 mg (.100g) Fe_3O_4
    - Combine both the GO and Fe_3O_4 in 10 mL of distilled water in a 150 mL beaker
    - Add a magnetic stirring bar to the mixture
    - Leave stirring - overnight - on a stirring plate. DO NOT TURN ON HEAT!
    - Obtain a Büchner flask, Büchner funnel, rubber/plastic tubing, and filter paper

        - Connect one end of the tubing to the arm of the flask, the other to the faucet tap (the one that looks like the gas adapter)
        - Add the funnel to the mouth of the flask
        - Add the filter paper to the funnel ensuring all sides are covered and nothing can escape from the sides
        - Turn on the water from the faucet — this creates suction within the flask
        - Remove the beaker from the stirring plate
        - Pour all contents from the beaker onto the fixated filter paper in the funnel.
        - Use distilled water to rinse out any remaining residue from the beaker into the funnel
        - Rinse the material on the filter paper three (3) times with distilled water.
            - Be careful that NONE of the material seeps to the sides of the filter paper and into the funnel. KEEP ALL SOLID MATERIAL ON THE FILTER PAPER
            - If ethanol is available, you can rinse the material three (3) times with ethanol AFTER you have rinsed with water to help the material dry faster
        - Carefully remove the filter paper without letting any of the solid material fall
        - Leave material to dry for at least 24 hours to ensure it is completely dry
        - Scrape up the remaining solid (MNP) and place in a dry, clean, container with a lid.
- <u>With the Students</u>
    - Review metallic properties
        - students need to understand the different physical properties of magnetic metals
    - Review chemical nomenclature
        - A lot of the vocabulary is uses IUPAC naming instead of the common names.
    - Complete day one of the activity before starting on the Day two. This activity cannot be done without the prior knowledge (even if minimal) of MNPs.

<u>Attachments</u>

- Day 1 Student Handout (Handout A) with teacher guide
- MNP Reference Materials
- Day 2 Student Handout (Handout B) with teacher guide
- MNP Powerpoint Presentation
- Teacher Demo Guide

<u>Safety Issues</u>

- MB is an organic compound but can cause skin irritation. Keep away from skin and clothes as it does permanently stain
- The neodymium magnet is EXTREMELY powerful. Advise students to NOT have ANY electronics around the magnet—all information from the electronic devise will be completely deleted and the device will be destroyed. Students with metal plates or rods SHOULD not come in close contact with the magnet.
- Goggles and lab coats/aprons are a must in this lab. Gloves are not required but are recommended.
- Ensure students are careful with the glassware
- Do not dispose of any materials down the drain. All needs to be placed in an appropriate waste bin or trash.

Troubleshooting Tips

- If you notice that the water is not completely clear after treating it with the MNP, add more water to the "MB polluted water sample" to dilute the concentrations. Add in increments of 100 mL at a time only. Test a small amount of the water sample with the MNP to see if that concentration is correct.
- If there is not enough pressure in the flask when rinsing out the GO/Fe_3O_4, turn the water on all the way (on high). This will create more pressure within the flask and will filter out the water from the particles more efficiently. If your fume hood is equipped with an air valve (orange valve), use this instead. Set up is done the same.
- All values can be halved or doubled if need be.

Investigating Questions

- Why does graphene oxide adsorb the MB so easily?
    - GO is an organic compound that is highly oxidized which causes the presence of more hydrophilic (water loving) functional groups. This then enhances the adsorption of the organic dye since the dye is a polar substance.
-

Assessment

Pre-Activity Assessment
Descriptive Title: How is Water Cleaned and Purified?

Activity Embedded Assessment
Descriptive Title: How Are Magnetic Nanoparticles the Future of Water Sanitation?

Post-Activity Assessment
Descriptive Title: Exit Ticket: 5 Unique Ways that MNP could be beneficial in the real world?

Activity Extensions

- Magnetic Nanoparticles: A Solution to Pollution Independent Research
    - In this extension (to be released in June 2018), students functionalize their own MNPs and test their own "polluted" water samples. Student groups will undergo the same synthesis process as the scientists in the NEWT Labs to create MNP and test the efficiency of what they created. This is a perfect way to bring the chemistry course to an end as it encompasses every lesson taught in high school chemistry.

References

1. Powder Technology, volume 257, pages 141-148, Sakthivel Thangavel, May 2014

2. Chemically Prepared Magnetic Nanoparticles, pages 125-170, M.A. Willard, July 18, 2013

URLs

https://www.youtube.com/watch?v=mkUqRUdOLds

www.newtcenter.org

Contributors

RET NEWT
University of Texas El Paso (UTEP)

Dr. Jorge Gardea-Torresdeyp
Dr. Dino Villagran
Dr. Karen Ventura
Edgar Aldama

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Classroom Testing Information

This lesson proved to be engaging and fun for the students. It was a great way to introduce MNPs to the students and get them thinking about what they are, what they could be used for, and what the possible benefits to this research could be. A lot of higher learning questions were generated and the students gained more interest in the subject matter after Day 2 activity. Students were very curious about the Neodymium magnet and all followed the safety procedures carefully. Ensure that you do not "sugar coat" the effects of the magnets. It is better to over exaggerate what can happen than to underestimate. At this age, students prefer rules, procedures, and consequences given to them straight forward.

Many students did not quite grasp the difference between adsorb and absorb. In future classes, a hands on activity to demonstrate the differences would be beneficial. These two properties are best learned if they are visual rather than written.

This lab could be done at later times of the year to incorporate stoichiometry. Students would find the molar ratios to determine the amounts needed.