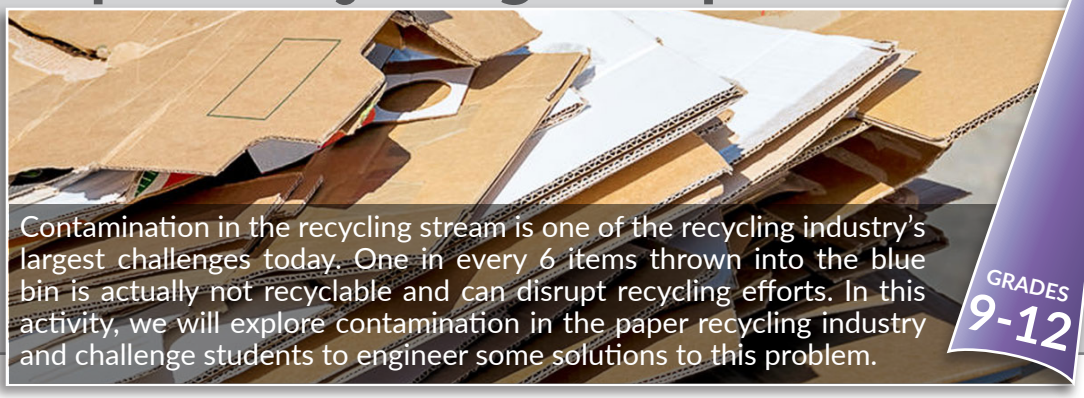
Paper Recycling: Keep It Clean!



Contamination in the recycling stream is one of the recycling industry's largest challenges today. One in every 6 items thrown into the blue bin is actually not recyclable and can disrupt recycling efforts. In this activity, we will explore contamination in the paper recycling industry and challenge students to engineer some solutions to this problem.

GRADES 9-12

ISRI Voice of the Recycling Industry

JASON Learning

NEXT GENERATION SCIENCE STANDARDS

- Science and Engineering Practices: Asking Questions and Defining Problems
- Science and Engineering Practices: Constructing Explanations and Designing Solutions
- Science and Engineering Practices: Developing and Using Models
- Crosscutting Concepts: Systems and System Models
- Crosscutting Concept: Scale, Proportion, and Quantity
- Disciplinary Core Ideas: ETS1: Engineering Design
- Disciplinary Core Ideas: HS-ESS3.A: Natural Resources
- Disciplinary Core Ideas: HS-ESS3.C: Human Impacts on Earth Systems

PREPARE:

Time Required: 4 to 6 class periods (180-270 minutes)

- Make copies of the Paper Making and Paper Engineering handouts.
- Gather the materials (see activity pages). Students may ask for additional materials. Recommended items include, but are not limited to:
  - Strainers and/or screen material with different sized holes
  - Dishwashing detergent
  - Vinegar
  - Nail polish remover
  - Bleach (be sure to supervise its use carefully)
  - Rubbing alcohol
  - Magnets
  - Safety goggles
  - Smaller bowls or container like large yogurt container for students to experiment with smaller batches of their pulp
- Paper-making can be messy. Plan to do this activity in a setting free from carpet and that can be easily cleaned. Students will also need easy access to water for this activity.
- If possible, make a piece of paper yourself before teaching this lesson.

MOTIVATE:

- Ask students to work with the person sitting next to them to create a list of things that can and cannot be recycled. Ask them to categorize their lists, and have a few students share with the class. Have students use a T-chart.
- Place an assortment of items that can and cannot be recycled at the front of the room. Suggested items may include: glass, plastic, mixed paper, metal recyclables, corrugated cardboard, wax-coated boxes (such as an ice cream container or fast food to-go cup), batteries, papers such as envelopes with windows, papers with staples, some containers that still has food in them, a clean pizza box, and heavily greased pizza box that may still have food in it, batteries, light bulbs, paint cans and more. Pictures also work if actual materials cannot be collected. Ask students to add to their T-chart they started in step 1.
- Have students read the following article and add to or modify their T-charts. *The American Recycling Business:* http://fortune.com/2015/09/03/waste-management-recycling-business/. Have students briefly discuss what some of the major issues in recycling are today. They can think of the entire recycling industry as a system that balances resources, economics, technology, human nature, policy . . . etc. Spend a little time asking students to rephrase what the article is saying. What is the "perfect storm"? According to the article, what are the current challenges that are impacting the way this system works? You may want to display a class list of ideas.
- Explain that they are going to focus on one of the challenges identified in the article: single-stream recycling and contamination. Explain they will examine one commodity more closely - paper - and some of the challenges associated with recycling it. Have students generate a class list of all the things students can think of that might be considered "contaminants" in paper recycling. Another way to think about this is, what kinds of things might have to be removed from paper in order to successfully recycle it and be able to make new, quality paper? List might include: staples, paper clips, inks, dirt, liquids, oils, grease from food or other dirty containers that are thrown into the same bins, colored paper . . . etc.

TEACH:

Part 1: Paper Making

- Discuss the information in the introduction with your class. Include in your discussion the idea that contaminants can limit the amount of paper that can be recycled.
- Divide students into small groups and distribute the Instructions for Making Paper handout to each student.
- Walk students through the process of making paper.
- Give students used paper to be their source for the paper they will make. Try to use paper that does not contain a lot of ink (very lightly used). Do not use newspaper for this step. Groups will use the piece of paper they make from this batch as their control so they understand the type of quality the in-classroom paper-making process is capable of producing (the paper will not look like commercial, white paper).
- Have students complete Part 1 of the activity.
- Some of the characteristics of good paper that students may identify is its strength (strong enough to write on without tearing), its thinness, and its light color, which allows writing to show up more easily.
- Note that students are likely to create imperfect paper to begin with. If time permits, allow them to experiment a bit and make several pieces of paper. They will not be able to produce paper of the same quality as paper you can buy, and that is fine. The purpose of this step is to give them practice making paper, and to give them a realistic idea of the quality of paper they can produce, which should inform the quality criteria they set for their paper in part 2.
- To prime students for the next part of the activity, discuss how the paper they were able to make differs from the printer paper they examined in the first part of the activity.

Part 2: Paper Engineering

- Make sure each group has a copy of the Instructions for Making Paper handout. Distribute a copy of the Paper Engineering handout to each group as well.
- For this part of the activity, give students some of the same source paper you used in Part 1. In addition, include paper with a contaminant. Possible contaminants include staples, paper clips, plastic windows in envelopes, ink, and oil (to mimic grease from foods or other sources).
- Have students complete Part 2 of the activity.
- Have students follow the engineering process (see activity section) closely. Sometimes they will want to jump ahead and just try things. Following a methodical, thoughtful process helps them to better identify ways to improve their idea and to be able to repeat their process aside from intentional changes. It is also important that the students have clear and realistic quality criteria they want to meet and specific ways to test for these goals. This criteria should be based on the paper they made in part 1.
- As students are developing their plans, remind them that it is not acceptable to manually remove contaminants (i.e. pick out staples). The way this actual process might work changes with scale. What we can do in our classroom may look quite different in a large-scale recycling operation, where manually removing contaminants is not practical. Have students consider this. There may be some limitations to their models, therefore, in class, but they can think about what this might look like on a much larger scale.
- Students can conduct research by looking up information or by experimenting with materials, but they should not carry out a full test of their ideas during the research phase. For example, students might test to see if staples are attracted to magnets, but they should not mix pulp and try to use a magnet to remove the staples. This is a place where students often take a shortcut, so monitor this step carefully.
- Check students' plans before allowing them to begin creating and testing their solutions. Look for safety issues and unrealistic time or materials needs. As long as students' plans are safe and feasible to carry out and follow the rules of the challenge, allow them to proceed, even if you don't think their idea will work. Avoid advising students about ways to improve their ideas. The point of the activity is to try, fail, and try again.
- Re-engineering their ideas is key to the engineering process. However, if time does not permit students to engineer and test multiple times, they can plan changes and additional testing procedures without carrying them out. Even if students' attempts were successful, they can still think of ways to improve their design to make it more efficient, less expensive, etc.
- When students have completed the project, have them reflect using the Reflect and Apply questions. Use these as the basis for discussing the process as a class. Tie the activity back to paper recycling, the importance of recycling, and the room for constant improvement in recycling methods.

Part 3

- Once students have made their second piece(s) of paper, have the class do a gallery walk. If each team experimented with a different contaminant, have students indicate what contaminant they were assigned. You might have students create labels. At this point in time, students will be able to see the effects of heavy ink (if a team was assigned this) on the quality of the paper, and will be able to consider that when looking at their own results. The gallery walk itself should be done fairly quickly.
- Have students share their methods and findings with the class. They should explain what their contaminant was, what they did to remove it, how successful they felt they were, and and if there is any evidence of the contaminant left in the paper they made. They should also describe any modifications they would make if given the opportunity to try again, and explain how this could work on a larger scale in the recycling plant.
- Have students read the article, *Contamination in Paper Recycling*: http://americanrecyclingca.com/2011/05/paper/contamination-in-paper-recycling/. Then pass out the Residential Curbside Recycling Guidelines. Have students compare their original T-charts they made at the very beginning with the lists in the guidelines note any items they may have mislabelled. Discuss what items surprised them and why? Have students focus on the first rows - paper and cardboard. Discuss that people have engineered methods for safely removing some of the contaminants, and paper recycling plants can safely remove items such as plastic windows, staples, and ink. Some of the methods students came up with in class might actually mimic the real methods found at these plants. Paper with these items can go straight into the recycling bin. Other contaminants, however, such as grease, food, and wax, can ruin batches of paper and should be kept out of the recycling bin.

REFLECT/ASSESS

Students should be able to:

- Identify some of the challenges of single-stream recycling.
- Define the problem of contamination in paper recycling, and design, test and refine an engineering solution (as time permits).
- Consider if and how their classroom model could transfer to a large scale recycling plant.
- Explain the inherent complexity of the recycling system and the relationships and trade-offs between making recycling easy for the consumer, helping the environment, producing high grade quality recyclable products, and economics.
- Identify specific ways they may be able to help reduce contamination in single-stream recycling.

EXTEND

- Have students investigate what kinds of paper and cardboard can and can't be recycled in their area. Have them make recommendations to their school for ways to reduce contaminants that are unacceptable in their paper recycling.
- Have students compare what can and can't be recycled in their area with what can and can't be recycled in other cities. Discuss why there may be differences. If glass can be recycled in one place, why might it not be recycled in another place?
- Have students compare their recycled paper with source paper under a microscope, and describe the differences they see in fibers. How will these differences affect the ability to recycle the paper they made again? Over time?

JOURNAL QUESTION

Ask students to explain the inherent complexity of the recycling system and the relationships and trade-offs between making recycling easy for the consumer, helping the environment, producing high grade quality recyclable products, and economics. Do they think single-stream recycling should be kept or eliminated? Why or why not? What could they do to help eliminate contaminants from single-stream recycling in their own community?

WEBLINKS

How to make paper (with video):
http://www.wikihow.com/Make-Paper

Everything You Need to Know about Paper Recycling:
http://earth911.com/business-policy/business/paper-recycling-details-basics/

Contamination in Paper Recycling:
http://americanrecyclingca.com/2011/05/paper/contamination-in-paper-recycling/

The American Recycling Business:
http://fortune.com/2015/09/03/waste-management-recycling-business/

TEACHER TIPS

Background

Processes exist in recycling to remove contaminants that would ruin or lessen the quality of products made from old materials. These processes are not perfect, and new, less expensive, and more efficient ways to recycle are always a possibility. This activity uses the problem with recycling soiled pizza boxes as a starting point for engineering solutions to contaminants in paper recycling. Processes currently exist in the recycling industry to remove most of the contaminants that students will work with in this lesson, such as plastic windows, staple, and ink. After students engineer their own solutions, they can compare their process with the processes used in paper recycling facilities.

Part 1

- Keep in mind that there is wait time inherent in making paper, so plan your time accordingly. In the first step of the paper-making process, the recycled paper will need to soak for at least an hour and as long as a day. The finished product will need to dry overnight. Students will be able to get an idea of what the paper will look like before it is completely dry (too thick, textures, etc.), and they can use that information to play around with making a second or third piece.
- In part 1, you will be giving some groups paper free of ink and other groups paper that is not free of ink. When students are finished making their paper, you can discuss how the ink contaminated the paper and how the color of the paper would have been different had their source paper been free of ink. This will prime the students for part 2, in which all groups will receive paper with ink on it, but groups trying to remove contaminants other than ink will need to ignore the ink in assessing the success of their final paper.
- If you intend to give students newspaper to use in part 2 of the activity, have them use newspaper in part 1, as well, even though this will result in darker paper for all groups. Newspaper will result in a significantly different paper than if office paper were used as the source, and students should have an idea of the quality of the paper they can realistically produce before they try to remove contaminants in part 2.
- The screens students use in the paper-making process should be small (about the size of a large post-card). This will require less source paper than full sheets of paper, and be easier for students to keep even as they remove the pulp from the water.

Part 2

- In part 2 of the activity, you can choose to give all groups the same contaminant, or give different contaminants to each group. However, do not assign more than one contaminant to study for each group. If much of the source paper you have has ink on it, inform groups that in addition to the contaminant they may be assigned to study, their source paper may contain some amounts of ink. Have them note relative amount of ink in their batch before they begin so they can take this into consideration. They will be able to use the paper made by the team experimenting with heavy ink, to consider to how ink affects the quality of the resulting paper.
- You can use the different contaminants to differentiate the activity. Staples are usually the easiest contaminant to remove, followed by plastic windows, ink, and then oil, which cannot be successfully removed. You need to soak the source paper in a substantial amount of oil to get the effect you need. In addition, the effect of the oil is more difficult to measure the worse the quality of the paper. Therefore, using oil as a contaminant should be reserved for groups that are up to a significant challenge.
- Below are some possible methods students may try to remove contaminants. While they may come up with other ideas, as well, this list will give you an idea of what to expect.
  - Staples: straining the paper pulp, using magnets, using centrifugal force (i.e. spinning the paper pulp).
  - Windows: straining
  - Ink: blotting the paper before it dries, using chemicals when mixing the pulp, including bleach, fingernail polish remover, vinegar, and rubbing alcohol
  - Oil: blotting, skimming oil from the water, adding dish detergent to the pulp

- Safety tips:
  - Do not let students mix chemicals.
  - Supervise any use of bleach carefully and use with proper ventilation. Be sure students are wearing gloves and safety goggles.
  - If students are working with any chemicals, have them wear gloves and safety goggles.
  - Students who are using centrifugal force should wear safety goggles. They should also place the pulp into a container with a tight lid before spinning it.
  - Other methods that students devise may present their own safety hazards, so be sure students consider safety in their plans.

Answers to Reflect and Apply

1–4. Answers will vary.

5. With single stream recycling, consumers can now throw all of their recyclables into one bin, without having to sort the metals, plastics, and paper separately. What are some the negative impacts of this practice? ***Students can discuss how containers with substances still in them - soiled with anything from food to chemicals- often end up in the bin and can leak out onto the paper. Take-out containers or pizza boxes with food still inside can make their way into the bins. Glass can also be thrown in and break, making entire batches hard to sort and separate. Students might also talk about how single-stream recycling might promote laziness and/or "ambitious" recycling, both of which results in lots of items that cannot actually be recycled ending up in the bins. This, in turn, has other implications. For example, contaminants like plastic bags can cause whole recycling facilities to shut down for workers to remove and cut away the bags off the machinery. This method does not result in the highest quality of recyclables, and so,in the long run, not as profitable.***

6. Why do you think many areas have moved toward having one curbside recycling bin despite the negatives you may have identified in question # 5? ***Students might talk about up front costs being lower. Single-stream is easier for people so they are more likely to recycle - so even though not highest quality, has increased overall recycling rate. Other answers possible.*** Are there other positive benefits and do these outweigh the negatives? Explain your reasoning. ***Accept a variety of responses as long as they are based on reasoning.***

Refer to the article ***The American Recycling Business*** for additional guidance on questions 5–6:

Paper Recycling: Keep It Clean!

Paper is one of the recycling industry's biggest success stories. If measured by weight, more paper is recycled annually than glass, metal, and plastic combined. Forty-seven million tons of paper is recycled annually in the US. However, recycling paper is not without its challenges. Contaminants can limit the amount of paper that can be successfully recycled. When paper gets mixed in with other items like foods, liquids, grease, and dirty containers, it can contaminate the entire batch of paper. An example is a heavily soiled or greased pizza box. This is because the oil cannot be separated from the paper fibers, and it can result in lower quality paper. Food and food grease is not the only contaminant found in paper recycling. Inks, glues, wax linings, even staples and paper- clips are also considered contaminants. In many cases, though, these contaminants won't ruin a whole batch of paper. Instead, methods exist to remove these contaminants during the paper-making process. These processes are not perfect, and new, less expensive, and more efficient ways to recycle are always being generated. Contaminants that can be removed without ruining the final paper product are called outhrows. Outthrows are "thrown out" as the recycled paper is being processed. Contaminants like food waste, grease, and wax that can ruin a batch of paper are considered prohibitive. They should be kept out of the recycling process entirely. There are different grades, or qualities, of paper. Some items that are outthrows in lesser-quality paper, like newsprint, are prohibitive in high-quality paper.

Engineers are always trying to come up with better ways to recycle materials. New ideas can make recycling less expensive, more efficient, safer, and more environmentally friendly. In this activity, you will be challenged to engineer a way to remove a contaminant from a batch of paper during the recycling process. You will then consider how this method might work on a larger scale in an actual recycling plant.

Materials

- Fine-meshed screen
- Large tubs
- Blender
- vinyl gloves (Rubber or latex possible but must confirm no latex allergies)
- Rolling pin and/or iron
- Felt
- Large sponge
- Liquid starch
- Large bowl
- Gloves (optional)
- Newspaper
- Paper recycling
- Used envelopes with windows
- Paper recycling with staples
- Other materials, as determined by students

Part I: Make Paper

1. Examine a few different kinds of paper. List some characteristics that good paper shares.
2. Follow the instructions on the Instructions for Making Paper handout to make a new piece of paper from the used paper your teacher supplies. You may need to make a few pieces before you get one that has some of the characteristics of good paper that you identified.

Part II: Engineer Paper

1. Again, follow the instructions on the Instructions for Making Paper handout to make a new piece of paper from the used paper your teacher supplies. This time the used paper will contain contaminants.
2. Your teacher will assign you one type of contaminant. Engineer a way to remove that contaminant at some point in the paper-making process. You may not remove the contaminant directly by hand.
3. Use the data sheet provided to follow the steps in the engineering process and to document your work and ideas.
4. Be prepared to share your results with the class. As a team, discuss how successful your methods were based on evidence (any challenges you experienced during the process, how much time it took, and the quality of the resultant paper), and what future improvements you could make.

Part III: Findings & Analysis

1. Lay out the paper you made in round 2 with a label indicating the contaminant your team experimented with. Walk around the room to view the class results. Be sure to notice the effects of heavy ink (if a team was assigned this) on the quality of the paper if your source paper also had amounts of ink.
2. Briefly share your methods and findings with the class. You should explain what your contaminant was, what you did to remove it, how successful you felt you were, and if there is any evidence of the contaminant left in the paper you made. Describe any modifications they would make if given the opportunity to try again, and how this might work in a large-scale operation.
3. Read the article, *Contamination in Paper Recycling*: http://americanrecyclingca.com/2011/05/paper/contamination-in-paper-recycling/ and the handout called *Residential Curbside Recycling Guidelines*. Compare your T-chart to the items listed on the Residential Curbside Recycling Guidelines. These guidelines are very general, and might differ from your town's guidelines. Focus on the first rows - paper and cardboard. Today, paper recycling plants can safely remove items such as plastic windows, staples, and ink. Paper with these items can go straight into the recycling bin. Other contaminants, however, such as grease, food, and wax, can ruin batches of paper and should be kept out of the recycling bin. Make final adjustments to your T-chart.

Reflect and Apply

1. Was your idea successful? Did it produce paper free of contaminants that met your criteria?
2. What would you have done differently throughout the process?
3. Do you think that your method could be fully successful given more time to develop it? Why or why not?
4. How might a recycling plant be able to replicate your methods on a much larger scale? Do you think it would work? Explain why or why not.
5. With single stream recycling, consumers can now throw all of their recyclables into one bin, without having to sort the metals, plastics, and paper separately. What are some the negative impacts of this practice?
6. Why do you think many areas have moved toward having one curbside recycling bin despite the negatives you may have identified in question # 5? Are there other positive benefits and do these outweigh the negatives? Explain your reasoning.

Extensions

- Find out more about commercial paper recycling. What is the process? What are some common ways prohibitive contaminants are introduced into the process? What methods are used to remove those contaminants? Do these methods introduce any other problems, such as paper quality or environmental impact? Investigate to find out what paper recycling items are and are not allowed in your area. After your research, make recommendations to your school for ways to reduce contamination in your paper recycling. Use information from your research to back up your recommendations.
- Research what can and cannot be included in recycling bins in your area. Then research a few other cities' recycling programs. Are there any differences in what can and can't be recycled in these places? Why might those differences exist?
- Compare the paper you made with your source paper under a microscope. What differences do you see in the fibers? You may also want to compare newsprint and printer paper under the microscope. How will the differences you see affect the quality of the paper? How will these differences affect the ability to recycle the paper again? Over time?

JOURNAL QUESTION

Discuss the inherent complexity of the recycling system and the relationships and trade-offs between making recycling easy for the consumer, helping the environment, producing high grade quality recyclable products, and economics. Do you think single-stream recycling should be kept or eliminated? Why or why not? What could you do to help eliminate contaminants from single-stream recycling in your own community?

Student Name: Period:

Instructions for Making Paper

Gather and Prepare the Materials

1. Cut the fine-mesh screen to a size that will easily fit in the large tub. You do not need to make the screen as large as the tub. The ideal size for this activity is about the size of a large post-card.
2. Cut the felt into two equal pieces, each slightly larger than your screen.

Prepare the Source Paper

3. Tear the paper into small pieces.
4. Soak the paper in warm water for at least one hour. For best results soak overnight.

Create the Paper Pulp

5. Place the soaked paper in a blender, filling it about a quarter of the way.
6. Add enough warm water to the blender to fill the blender halfway.
7. Blend the water and paper mixture on slow. Gradually increase the blender speed and blend until you have a paper pulp about the consistence of watery oatmeal. If the blender seizes, you can add a small amount of water.

Make the Paper

8. Fill the large tub halfway with water.
9. Place the fine-mesh screen at the bottom of the tub.
10. Add pulp to the tub and mix it into the water. The more pulp you add, the thicker your paper will be. Remove any large clumps of pulp.
11. Add two teaspoons of liquid starch to the tub and stir.
12. Slowly lift the screen from the basin, gently shaking it to even out the paper pulp on the screen. You may need to support the screen underneath as you lift it out of the tub.

Dry and Set the Paper

13. Hold the screen over the tub and let any excess water drip back into the tub.
14. Place a piece of felt slightly bigger than the screen on a flat surface. Lay the screen with the paper pulp still on it on top of the felt and cover it with another piece of felt.
15. Iron the top piece of felt on a low setting. Alternatively, roll over the felt with a rolling pin. This method will take significantly longer to dry.
16. When the paper is dry enough, but not completely dry, remove it from the screen and felt. Place it on a smooth, flat surface, and roll over it with a rolling pin. Flip the paper over and repeat on the other side. Note that you can skip this step, but rolling the paper in this way will make the final product smoother.
17. Allow your paper to dry completely before using it.
18. Trim the edges if desired.

Data Sheet

Paper Engineering

Define the Problem

1. Before attempting to solve a problem, you must be able to clearly state what the problem is.

   What is the problem you are trying to solve? Be sure to identify the contaminant you are trying to remove.

2. Any engineering design must work within certain constraints and considerations. Constraints are absolute limits (example: a bookshelf to go onto a specific wall cannot be larger than that wall). Considerations are other things that must be thought about in the design, but aren't absolutely necessary (example: The bookshelf is going into a blue and white room, so it would be best if it were blue and white; however, a red bookshelf could work if necessary).

   List the constraints for this problem.

   List the considerations for this problem.

3. Develop a set of criteria by which you will judge whether your paper is of acceptable quality. As you develop your criteria, keep in mind both the characteristics of good paper and the quality of paper you were able to realistically produce in part 1.

   What are the criteria you will use to judge if your paper is acceptable?

4. Come up with a method to test your paper to see if it meets the criteria you described.

   How will you test your paper to see if it meets the criteria?

Design a Solution

1. Brainstorm ideas for possible ways to remove the contaminant. Accept any ideas at this point.

   What are your best ideas?_____

2. Do some research into your ideas. This could mean looking things up online or experimenting with materials you are considering. Document your research carefully on a separate piece of paper.

   Summarize your research here. _____

3. Select one of your ideas for how to remove the contaminant during the papermaking process and develop step-by-step instructions on a separate sheet of paper. Attach your instructions to the end of this data sheet. Below, include a detailed, labelled diagram to illustrate how your idea will work.

4. Develop step-by-step instructions for how you will make your paper and remove the contaminants during the process. These instructions should be specific enough that someone else could read them and follow your process.

   Write step-by-step instructions on how you will make the paper and remove the contaminants.

Test and Refine Your Solution

1. Follow the instructions you wrote carefully to make a small batch of paper.
2. Test your paper as you described in step 4 of the Define Your Problem section to see if it meets the criteria you described in step 3. Take detailed notes on any problems you see when testing the paper. You will need these notes when you improve your solution, so be very specific.

   Record your notes here.
3. Evaluate the results of your test. Think about these questions: Was the contaminant successfully removed? Does the paper meet your criteria for acceptable quality? Which criteria were not met? What specific issues did you have?

   Write your evaluation here.
4. Develop a plan for how you will re-engineer your idea to improve it. If you found problems in your testing, be sure your plan addresses each problem.

   Summarize your plan.
5. Follow steps in the Design Your Solution and Test and Refine Your Solution sections again, using your new plan. Repeat this process as many times as you can or until you are satisfied with your results.

Engineering Process