Bib Numbers

One commonality in many sports is the need to distinguish between individual participants during the race. Bib numbers have been used for decades to label the individual racer during track, skiing, swimming and other events. What should the bib number be made of? Considerations include strength, water resistance, and the ability to move with the racer. Three choices include paper, polyethylene, and Tyvek®, a fabric made from polyethylene. This activity explores the relevant features of each of these materials.

Comparison of Paper, Polyethylene, and Tyvek®

How do different kinds of polymers compare in terms of strength, flexibility, and water resistance? In this activity students compare the properties of three polymers: cellulose, a natural polymer that is used to make paper; polyethylene film, a synthetic polymer; and Tyvek ®, a nonwoven fabric made from polyethylene fibers.

Recommended Grade Level……………………………4-12
Group Size………………………………………………1-4 students
Time for Preparation……………………………………none
Time for Procedure……………………………………Part 1: 10 minutes
Part 2: 15 minutes (+ 5 minutes per day for 3-5 days)

Materials

Procedure, Part 1

- Per Group
  - Container of water
  - Sharp pen or pencil
  - 10-cm x 10-cm (4-in x 4-in) square of each of the following:
    - Paper
    - Low-density polyethylene film (sandwich bag or dry-cleaning bag)
    - Tyvek® (computer-disk sleeve or express-mail envelope)

Procedure, Part 2

- 3 transparent plastic cups
- Modeling clay
- Permanent marker or grease pencil
- Sharp scissors
- Graduated cylinder or tablespoon
- 10-cm x 10-cm (4-in x 4-in) square of the following:
  - Paper
  - Low-density polyethylene film
  - Tyvek®

Procedure

Part 1: Comparing Strength

Conduct each of the following tests on the squares of paper, polyethylene film, and Tyvek® and record your results.

1. Determine the comparative strengths of each polymer by trying to tear each sample.
2. Determine the flexibility of each polymer by bending each sample in the same place repeatedly.
3. Determine the puncture resistance of each polymer by pushing the tip of a pen or sharp pencil through each sample.
4. Determine the water resistance of each polymer by soaking a piece of each sample in water and shaking off the excess water.

Part 2: Comparing Permeability

Perform the following procedure with a new sample of each material.

1. Trace the cup rim into each polymer sample. Use sharp scissors to cut out the circle.

2. Pour exactly 30 mL (2 Tbsp) water into the cup.
3. Use rings of modeling clay to seal the polymer circle over the cup.
4. Mark the water levels on the cups with a marker or grease pencil, and then place them in a warm spot.
5. Observe and record the water level in each glass over a period of several days. Compare the rate of evaporation of water through the different materials and record these observations.

Material	Strength	Flexibility	Puncture Resistance	Water Resistance	Evaporation of Water
Paper					Day 1- 2- 3- 4- 5-
Low-density polyethylene					Day 1- 2- 3- 4- 5-
Tyvek®					Day 1- 2- 3- 4- 5-

Additional Observations:

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Sample Data:

Material	Strength	Flexibility	Puncture Resistance	Water Resistance	Evaporation of Water
Paper	Easily torn	Flexible	Can be punctured	Not water-resistant	Noticeable to substantial
Low-density polyethylene	Tears with effort	Flexible	Can be punctured	Water-resistant	Little to none
Tyvek®	Does not tear	Flexible	Can be punctured	Water-resistant	Noticeable to substantial

Discussion

- Discuss the results performed in Part 1 for the three polymers used in this activity.
- Ask students which of the three polymers permitted the greatest permeability of water and which of the three allowed the least permeability of water.
- Discuss reasons for these findings.

Explanation

In Part 1, it was shown that Tyvek® is exceptionally strong as compared to paper and low-density polyethylene film. The Tyvek® can be flexed thousands of times without breaking. Water will run off of Tyvek® and polyethylene films or lie in drops on the surface, but paper absorbs water. Tyvek® is water-resistant because although there are air spaces in it, these spaces wind around and between the tiny fibers and keep the water from penetrating the film. Polyethylene film is water-resistant due to the close packing of the polymer chains-no water molecules can penetrate this barrier.

In Part 2 of the activity, polyethylene film had the smallest amount of water loss. Again, this is due to the close packing of the polymer chains which does not allow the water to penetrate the film. Tyvek® and paper both allowed about the same amount of water evaporation; the polyethylene allowed the least amount of evaporation. Some reasons for these observations are that the polyethylene polymer chains are packed closely together in the film and will not allow water vapor to escape; Tyvek® and paper have openings in the molecular structure which allow the water vapor to escape. Unlike polyethylene, Tyvek® and paper will allow water vapor and other gases to slowly pass through.

The properties of a polymer determine its uses. Cellulose, a natural polymer and the most abundant organic substance on earth, is the main ingredient in paper. It is a polysaccharide (complex carbohydrate) formed from repeating glucose units.

Polyethylene is a synthetic polymer made up of long carbon chains. It is a very stable plastic, unreactive to acids and bases, and is waterproof. It is used to make plastic bags, frozen food packaging, shrink wrapping, meat packaging, and liquid food and chemical containers, as well as other molded items. Depending on the degree of branching of the chain that results during its preparation, polyethylene can be made in different densities which can be broadly defined as low-density polyethylene (LDPE) and high-density polyethylene (HDPE). The more branching within the polymer structure, the more flexible the plastic is. LDPE, which is a highly branched form of polyethylene, is used mainly in plastic films and bags where flexibility is more important than strength. HDPE, a form of polyethylene with little to no branching is used for containers such as milk jugs which must remain fairly rigid.

Tyvek® is a special form of HDPE. The polyethylene used in Tyvek® is first formed into extremely fine fibers. These fibers are then allowed to fall randomly onto a flat moving belt. The resulting web of fibers is exposed to heat and pressure, and the fibers are melted together. If most of the fibers are fused, the material is stiff and paper-like. If only a few are joined, a softer, more cloth-like material is formed. Some of the current uses for Tyvek® are mailing envelopes, computer disk sleeves, tags, labels, signs, banners, and draft-proof wrapping for houses (under siding).

Sarquis, Mickey, Chain Gang-The Chemistry of Polymers, 1999, Terrific Science Press, pp 85-88.