B4 We produce drinking water – Methods of purifying water

There are various separation methods that can be used for water treatment. This unit will familiarize you with some of those methods.
You will work in teams of two or three for all experiments. Before you start, you should gather all materials for the experiments. In addition, you will need a log sheet for recording your observations and the results of your experiments.

1 Rough purification of contaminated water with silica sand, activated carbon, and filter paper

1.1 Apparatus and materials

- 1 accumulator, 9 V
- Activated carbon
- Clay (“bentonite”)
- 3 connecting cables, alligator clip to alligator clip
- Filter paper (round filter), 12.5 cm
- 1 funnel
- Ink, blue (“aquatint”)
- 1 LED, red (red case), 5 V
- 2 nails (steel, “iron”) as electrodes
- 2 plastic cups (clear), 500 ml
- 2 plastic cups, 100 ml
- 2 screw-on lids (for 100-ml cups)
- Silica sand (“filter sand”)
- Table salt
- 1 teaspoon
- Water

Attention: After you have completed the experiment, return the materials or dispose of them properly as instructed by your teacher.

1.2 Safety information

The materials may be used only as instructed by your teacher or as described in the experimentation instructions.
For this experiment, be aware of the following risks:

- Do not ever short-circuit the accumulator! This results in a risk of explosion and fire.
- Remove all water-sensitive materials from your workspace.

1.3 Conducting the experiment

For the following separation methods, you need to first create a suitable mixture of contaminated water. To do so, pour 90 ml of water into a 100-ml cup, and then add:

- One drop of ink (represents undesirable dyes, fragrances, and flavorings)
- A small amount of bentonite (measure using just the tip of the spoon handle; represents insoluble substances)
- A small amount of table salt (measure using just the tip of the spoon handle; represents dissolved salts)

Screw the lid onto the cup and shake to mix.

Fig. 1: Making “contaminated” water.

- Afterwards, fold a paper filter (follow the folding instructions in the appendix), moisten it, and place it in the funnel.
- Pour silica sand into the filter to a height of approx. 3 cm.
- Place the funnel on top of the 500-ml cup.
- Thoroughly shake the mixture of “contaminated water” again and pour about half into the funnel.
- Occasionally lift the funnel out of the filtrate to allow the filtrate to flow out better.
- Once the contaminated water has passed through the sand and all the filtrate has been captured in the cup, dispose of the “sand filter” in the household waste.

Fig. 2: Filtering through sand and filter paper.

- Pour the solution, now a clear blue, into a screw-top cup containing 1 spoonful of activated carbon. Screw on the lid and shake for about 30 seconds.
- Then pour the contents through the funnel with a new piece of folded filter paper, filtering it again into a 500-ml cup.
- How does the filtrate look?
- Afterwards, dispose of the used filter in the household waste.

Fig. 3: Removing the dye using activated carbon.

- Now check the conductivity of the filtrate.
- First pour the filtrate into a clean 100-ml cup.
- Using the two nails as electrodes, immerse them in the filtrate.

- Using the connecting cable, connect the two nails to the accumulator and the LED (see Fig. 4). Pay attention to the polarity of the LED: Connect the positive pole of the LED (long terminal pin) to the positive pole of the accumulator.
- Also test the conductivity of the contaminated water for comparison.
  Are there significant differences?

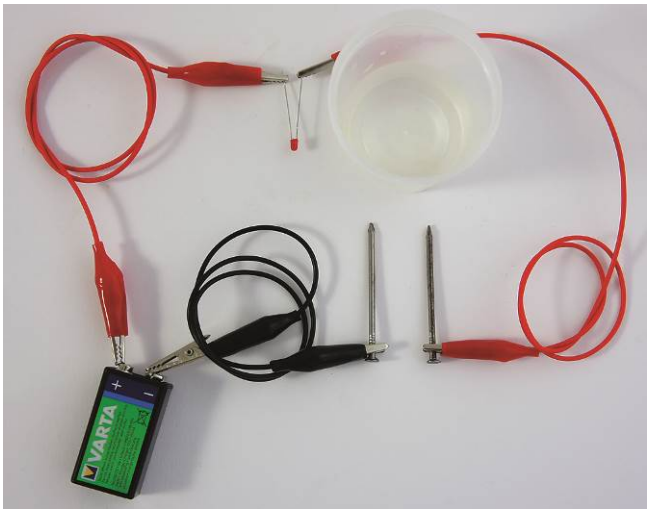


Fig. 4: Measurement setup to determine the conductivity.

1.4 Observation

Write down a summary of your observations.

1.5 Analysis

a) How does the solution change after each filtration procedure?
b) Were you able to remove the dissolved table salt using the sand/paper filter and activated carbon?

2 Fine purification of water with membrane filter

2.1 Apparatus and materials

- 1 accumulator, 9 V
- Clay (“bentonite”)
- 6 connecting cables, alligator clip to alligator clip
- 1 filter cartridge (membrane filter) with Luer lock
- 1 LED, red (red case), 5 V
- 2 nails (steel, “iron”) as electrodes
- 4 plastic cups, 100 ml
- 4 screw-on lids (for 100-ml cups)
- 1 syringe, Luer lock, 50 ml
- Table salt
- 1 teaspoon
- Water

Attention: After you have completed the experiment, return the materials or dispose of them properly as instructed by your teacher.

2.2 Safety information

The materials may be used only as instructed by your teacher or as described in the experimentation instructions.
For this experiment, be aware of the following risks:

- Do not ever short-circuit the accumulator! This results in a risk of explosion and fire.
- Remove all water-sensitive materials from your workspace.

2.3 Conducting the experiment

For this experiment, you again need to create “contaminated water” using around 50 ml of water and a small amount each of bentonite and table salt (measure using just the tip of the spoon handle).

Just like when you get an injection at the doctor’s office, we cannot have air bubbles in the syringe. So we need to carefully fill the syringe and filter cartridge assembly with water to avoid any air bubbles. To do so, follow these steps:

- Fill the 50-ml syringe with approx. 10 ml of pure water.
- To remove the air bubbles, hold the syringe so that the connector tip points up (see Fig. 5) and squeeze the air out by pushing the plunger until water begins to come out the tip.

Fig. 5: Squeezing out the air.

- Carefully screw the membrane filter cartridge on to the tip of the syringe.
- Squeeze out enough of the remaining water through the filter cartridge until only the connector tip of the syringe and the filter cartridge are filled with water. This ensures that all the air bubbles have been expelled. Our filter system is now ready to use.

Fig. 6: Syringe with membrane filter screwed on before squeezing out the rest of the water.

Now you can begin the actual experiment:

- Submerge the tip of the filter cartridge into the contaminated water and draw approx. 20 ml of filtrated water into the barrel of the syringe. When drawing fluid into the syringe, pull the plunger back with gentle, even pressure, because the water needs time to run through the filter (around 1 – 2 minutes).
- Unscrew the cartridge and squirt the filtrated water out of the syringe and into a clean 100-ml cup. Set the cup aside.

Fig. 7: Syringe with filtrated water.

- To prevent air bubbles from forming or dirt from drying in the filter cartridge, you need to immediately clean the syringe and the filter cartridge.
- To do so, fill the syringe completely with clear water and squeeze it back out. (The syringe is now clean.)
- Fill the syringe completely a second time and follow the procedure described above to remove the air from the syringe. Screw on the filter cartridge and squeeze the water out until the syringe is empty. (This procedure ensures that the bentonite you filtered out of the contaminated water and which was retained in the cartridge is flushed back out of the filter membrane.)
- Now it is time to check the conductivity of the filtrate you set aside. Does the value differ from that of the filtrate you obtained with the sand filter and activated carbon in subexperiment 1?

2.4 Observation

Write down a summary of your observations.

2.5 Analysis

a) What can you say about the result after filtering?
b) Were you able to remove the dissolved table salt using the membrane filter?

3 Fine purification of water with hollow fiber membrane filter

Since this kit has only one hollow fiber membrane filter, all groups will need to take turns performing this experiment, or one group can perform the experiment for the entire class. Please ask your teacher how you should proceed.

3.1 Apparatus and materials

- 1 accumulator, 9 V
- Clay (“bentonite”)
- 6 connecting cables, alligator clip to alligator clip
- 1 hollow fiber membrane for all groups
- 1 LED, red (red case), 5 V
- 2 nails (steel, “iron”) as electrodes
- 4 plastic cups, 100 ml
- 1 one-way cock (to fit 7mm/4mm tube and Luer lock)
- 4 screw-on lids (for 100-ml cups)
- 1 syringe, Luer Lock,10 ml (only one for all groups, belongs to hollow fiber membrane)
- Table salt
- Water

Attention: After you have completed the experiment, return the materials or dispose of them properly as instructed by your teacher.

3.2 Safety information

The materials may be used only as instructed by your teacher or as described in the experimentation instructions.
For this experiment, be aware of the following risks:

- Do not ever short-circuit the accumulator! This results in a risk of explosion and fire.
- Remove all water-sensitive materials from your workspace.

3.3 Conducting the experiment

For this subexperiment, you can use the contaminated water from the last subexperiment; otherwise, you should prepare more contaminated water following the instructions for the previous subexperiment.

- First screw the one-way cock to one end of the membrane tube (see Fig. 8). The cock is closed, i.e., the handle is crossways, or perpendicular, to the tube.

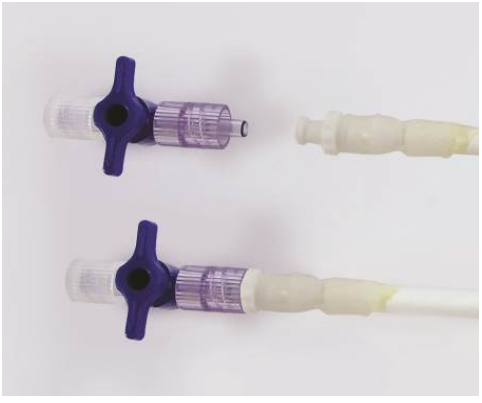


Fig. 8: Attaching the one-way cock to the membrane tube.

- Using the 10-ml syringe, draw about 5 cm of contaminated water into the barrel and screw the syringe to the other end of the membrane tube.

- Dangle the membrane tube into a 100-ml cup and slowly push the syringe's plunger until you see the filtrated water forming beads along the surface of the tube and dropping into the cup. Set the filtrate aside.

Fig. 9: Filtrate appearing along the surface of the membrane tube.

- Now immediately clean the hollow fiber membrane filter. To do so, unscrew the syringe, rinse it out, fill it with clean water, and reattach it to the hollow fiber membrane tube.
- Now open the one-way cock (turn the handle parallel to the tube) and hold the opening over another cup. Squeeze the water out of the syringe slowly to flush the bentonite out of the filter.
- Repeat this cleaning procedure several times until only clear water comes out of the membrane tube.
- Now check the conductivity of the filtrate you set aside (see subexperiment 1).

3.4 Observation

Write down a summary of your observations.

3.5 Analysis

a) Which of the filtration methods used was most effective? Please explain.
b) Explain the degree to which the pore size of the filter or the particle size of the contaminants affects the use and the result of the different filtration methods.
c) Ask yourself whether all contaminants can be removed from the water using mechanical filtration.
d) Describe how the conductivity of the filtrate changed after the individual separation methods and explain the result.
e) Suggest an additional separation method that you could use to turn salt water into drinking water.

4 Questions (summary for all subexperiments)

a) Why is clean drinking water so important for humans? How many people do not have access to clean drinking water?
b) The quality of drinking water is deteriorating around the world. How can you explain that?

If you have Internet access:

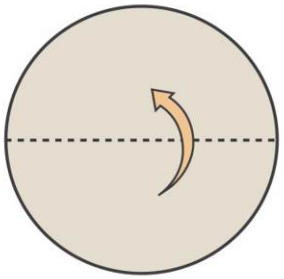
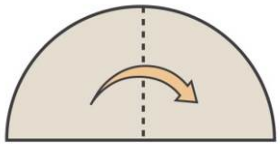
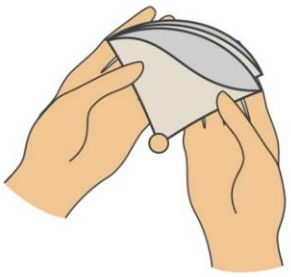
c) Which filtration methods are best suited for different sizes of contaminant particles? What are these methods called? What technology do they require?
d) What other options are available for the purification of drinking water?
e) How does reverse osmosis work? What it is used for? Are there any advantages or disadvantages of the process?
f) What is meant by “biodegradable” contaminants? Can you name some examples? How does biodegradation work?
g) How does the government of your country regulate the protection of drinking water? What institutions oversee compliance with those laws?

Appendix: How to fold the round filter so it will fit into the funnel

The material:

Round filter:

Funnel:

1. Fold the round filter in half.	
2. Place the resulting semicircle in front of you so that the flat edge is closest to you. Take the left corner and fold the filter in half again, from left to right.	
3. Hold the folded filter by the tip (marked by a dot in the figure to the right). Gently squeeze the filter so that a cone-shaped opening appears.	
4. Insert the filter into the funnel.