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What are you drinking? Tap water versus bottled water

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Which is better: tap or bottled water? Try these activities based on simple analyses, a debate, and a blind tasting to learn about drinking water and encourage sustainable habits.

Water management is crucial to sustainable development, because clean freshwater is essential to human health and well-being. Many prefer bottled water over tap water, but this has a high environmental impact in terms of waste production and pollutants. Many beliefs are related to preconceived ideas rather than to actual experiences or product characteristics: in most EU countries, tap water is controlled, safe to drink, and usually tastes good.

These activities aim to determine students' views on the topic and influence changes in water consumption and perception. They will increase their knowledge and trust of distributed drinking water, and consider the overconsumption of plastic bottled water.

Curriculum links

Chemistry: pH, acids and basis (Lewis theory), group 2 metal ions, complexation reactions, solution preparation and concentration, titration technique and principle of the method, pH indicators;
Earth sciences: composition of limestone sedimentary rocks;
Biology: water as a source of mineral salts, physiological effects, osmotic pressure in cells.

We devised the following activities for students aged 16–19. They are also suitable for ages 14–16 if there is less emphasis on titration methods and chemical reactions.

Image: Bluewater Sweden/Unsplash

Activity 1: Introduction to drinking water

Firstly, students are given some background information on types of drinking water and invited to do some research on the drinking water in their area.

This activity involves 1 hour of introduction and 2 hours of homework.

Materials:

- Introduction on water management (Drinking water infosheet)
- Internet access for research
- Information on/plan of the local water system and water quality (guided visits to water plants are strongly recommended to acquire on-site knowledge of distributed water)
- To-do list (Local water task sheet)
- Presentation evaluation rubric

Procedure:

1. After an introduction on water management and uses (1 h), the students are divided, depending on where they live, into groups of two to four.
2. Based on water certificates of analysis (available from the local water utility website) and school science texts, they should prepare a short PowerPoint presentation, following the to-do list on the Local water task sheet. This should include a plan of the area, with a description of the water origin (spring, ground water, or surface water) and its path from source to tap.
3. A comparison of the hardness values in different areas influenced by geological features can be made, if applicable.
4. The students should assess the values indicated on a water certificate of analysis (e.g., pH, nitrogen content, hardness, etc.) and describe the possible health risks associated with noncompliance.
5. The presentations can be marked based on the presentation evaluation rubric.

Activity 2: A debate on tap water versus bottled water

To explore different types of drinking waters and the consequences of our consumption habits, students conduct research and then run a class debate on tap water versus bottled water.

As an alternative, the debate can be left until after Activities 3 and 4, as a consolidating activity at the end.

This activity takes about 3 hours: 1 hour of introduction and research, 1 hour to prepare arguments, and 1 hour for the debate.

Image: engin akyurt/Unsplash

Materials

- Internet access for research
- Materials from reliable resources
- Parameters for discussion and debate rules (Debate task sheet)
- Debate evaluation rubric
- 1 computer
- 1 projector or digital board
- 2 lecterns

Procedure

1. Students should be provided with articles and web materials from official sites or publications (e.g., WHO guidelines, Ministry of Health guidelines, data published on the local water company's website, medical and research associations, articles on environmental issues) that they can integrate with other sources considered to be reliable. See the supporting material for suggested parameters to consider.
2. The class is divided into two teams (chosen at random), each supporting one of the motions (tap water or bottled water). Each student should take one parameter (see the Debate task sheet; make sure all are covered), examine the sources, do their own research, and prepare two sentences to argue their case and one sentence to argue against possible points made by the opposition.
3. In the classroom, each team should prepare a list of arguments and counterarguments to ensure that all participants can provide a contribution to the discussion.
4. Before the debate, the teacher checks that every argument is based on reliable sources and includes significant and well-documented data or scientific information.
5. In the debate, the sides speak in turn. All participants must make a statement. Each speaker has a specified amount of time to speak (approx. 2 minutes) and present arguments and counterarguments (e.g., tap water can taste (smell) like chlorine – to remove chlorine, place a jug of water in the fridge for a few hours before drinking it).

Discussion

The argumentation skills of each participant, in terms of presentation and content, can be evaluated using the debate evaluation rubric.

After the debate, the class can discuss what they've learned. Invite students to share things they didn't know before or found surprising. Will this affect their drinking habits?

Activity 3: Determination of total hardness in water

Students can analyze their home/school tap water or marketed bottled waters.

For tap water, they should compare the analytical results with the certificates of analysis provided by the local water company; for bottled water, they should compare them with those shown on the labels.

The determination of the total hardness in water is made by titration with ethylenediamine tetraacetic acid (EDTA), which forms colourless stable complexes with Ca^{2+} and Mg^{2+} ions at pH = 9–10. These ions are naturally present in water due to minerals that dissolve as water passes through soil and rocks.

To maintain the pH of the solution at 9–10, a buffer solution (NH_4Cl + NH_4OH) is used. The indicator Eriochrome Black T (EBT) changes colour when these two ions are completely complexed by EDTA.

In addition to the hardness test described here, other tests can be proposed, depending on time and instrument availability, such as:

- calcium and magnesium ion concentrations (atomic absorption)
- calcium salts (flame test)
- bicarbonate concentration (water alkalinity titration)
- microbial analysis of total coliforms (faecal contaminants – reference value: 0 colony forming units (CFU) per ml)

Image courtesy of the authors

This activity takes about 2 hours. Time is also needed for preparing solutions and equipment (1 h; this can be done by the teacher or technician).

Safety notes

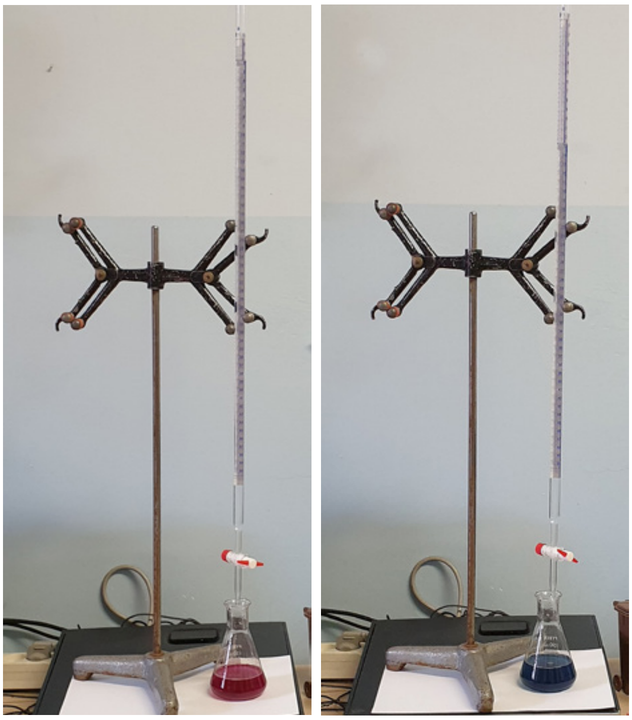
Wear lab coat and gloves

Materials (per group)

- 50 ml burette (+ support)
- 100 ml graduated cylinder
- 250 ml conical flask
- 100 ml beaker
- Glass funnel
- 0.01 M sodium EDTA solution
- EBT powder
- Stainless-steel spatula
- Buffer solution, pH 10 (NH_4Cl + NH_4OH)
- The provided Water-hardness scale

Procedures

1. Split students into groups of two to four. Assign each group a water sample (tap, distilled, filtered, bottled).
2. Fill the burette with 0.01 M EDTA sodium solution (titrant).
3. Measure 100 ml of water (sample) into a 250 ml conical flask.
4. Add a small amount (a few crystals) of EBT powder (indicator): the solution in the conical flask will turn a rose–violet colour.
5. Titrate with sodium EDTA solution until the colour changes to light blue without violet shades.



Images courtesy of the authors

6. Measure the volume of titrant added and take note of it.
7. Repeat at least three times and calculate the average volume of titrant.

Results

- What do you observe when the indicator is added to the water + buffer solution?
- What do you observe when a small amount of EDTA is added to the solution? (The colour does not change; it forms colourless stable complexes with Ca^{2+} and Mg^{2+} ions, which are naturally present in water.)
- Why does the solution turn blue when an extra volume of EDTA is added? (Because all Ca^{2+} and Mg^{2+} ions have been complexed by EDTA.)
- Calculate the total hardness in French degrees (F°; not to be confused with degrees Fahrenheit!) as mg/l of calcium carbonate ($CaCO_3$) according to the following formula:
  1 ml sodium EDTA solution (0.01 M) = 1F° = 10 mg/l $CaCO_3$
- Classify water as very hard, hard, moderately hard, medium, soft, or very soft: values can change according to local laws, but should be between 10 and 50F°.
- Compare the value with that shown on the label (bottled water) or certificate of analysis from the local water company (tap water).

Units of water hardness

There are a number of different common official measurement units for hardness:[1]

- **Parts per million (ppm)** is usually defined as 1 mg/l $CaCO_3$. It is equivalent to mg/l without a specified chemical compound.
- **French degree (°F or f):** 10 ppm or mg/l $CaCO_3$. Lowercase f is often used to prevent confusion with degrees Fahrenheit.
- **Degree of general hardness (dGH)** or German degree (°dH, deutsche Härte): 10 mg/l CaO, equivalent to 17.85 ppm or mg/L $CaCO_3$.
- **Clark degree (°Clark)** or English degrees (°e or e): one grain (64.8 mg) of $CaCO_3$ per imperial gallon (4.54609 litres) of water, equivalent to 14.254 ppm or mg/l $CaCO_3$.
- **US degree (gr/gal):** a grain $CaCO_3$/gal (US gallon = 3.78541 litres), equivalent to 17.118 ppm or mg/L $CaCO_3$.

Discussion

- Does your result match with theoretical values?
- If not, what could be the reasons (e.g., old or ill-maintained pipes, presence of a water softener)?
- If yes, could you form a hypothesis about the origin of water under survey (bottled or distributed water, surface or groundwater, geological characteristics of the catchment area)?
- How do you measure hardness in French degrees? (By measuring the volume in ml of EDTA added under the method conditions.)
- How do you measure hardness in mg/l expressed as $CaCO_3$? (By multiplying the value in French degrees by 10.)

Activity 4: Blind tasting of water

Research shows that tap water is just as safe as bottled water and is often not significantly different in taste. Tap water is generally a better option, since it has a much lower environmental impact and costs considerably less.

This activity is useful to work out common perceptions around the topic and discuss water-drinking habits. The duration depends on the number of participants in the blind-tasting session (at least 50 are required for statistically significant results). Bottled waters should be selected to include a highly advertised luxury brand, to show how price and advertising do not have a significant impact on taste preferences. If the tap water is very hard and/or does not taste so good, it can be replaced with filtered tap water.

Materials

- 3 glass bottles/jugs
- Paper or compostable coffee cups
- Tap water
- 2 types of bottled water (hardness: 4–8 °F and 20–25 °F)
- Paper for labelling each bottle/jug
- Blind-tasting questionnaire

Procedure

1. Encourage the students to come up with their own questions for the questionnaire. The provided questionnaire can be used as a template.
2. Fill up the bottles: each bottle should be filled with a different type of water.
3. Line up the bottles and arrange the cups on a table.
4. Place a numbered/coloured slip of paper next to each bottle.
5. Have someone who is not participating in the test pour the different types of water into three separate cups for each participant. Ideally the cups should be labelled with the same number/colour as the corresponding bottle.
6. The participants should take a sip from each cup and fill in the questionnaire to express their perceptions of the three waters included in the taste test, answering the following possible questions: What type of water do you think it is? How would you describe its taste? Do you like it? Can you taste any flavourings? What was your favourite water? Why?

Image courtesy of the authors

Results

The tasting results can be statistically processed (e.g., test results in terms of number of voters, % assigned to each type of water (pie chart), and choice motivations) and collected in a poster or digital presentation. They can be shared and made public through the school website, social media, and/or a poster exhibition encouraging the benefits of sustainable drinking habits. In many blind taste tests, participants find bottled water to be indistinguishable from tap water, and tap water is often the favourite one, showing that many beliefs are related to preconceived ideas rather than to actual experiences or product characteristics.

THE MULTIPLIERS PROJECT

This teaching and learning activity was developed as part of the MULTIPLIERS Horizon 2020 project by Iren, an Italian multiutility company and one of the MULTIPLIERS partners, through its educational department Eduiren and in cooperation with the Pascal upper secondary school in Reggio Emilia.

MULTIPLIERS promotes open schooling across Europe to make science more meaningful and directly relevant to real-world challenges. By connecting students with universities, informal education providers, museums, local associations, industry, civil society, policymakers, media, and other actors in authentic learning settings, the project promotes competence development in socioscientific issues that have a direct impact at the local level and beyond. The ultimate goal is to foster social transformation by enabling students to act as “knowledge multipliers”, sharing their learnings and findings with their wider communities.

MULTIPLIERS has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement No. 101006255.

Learn more about the project:
https://multipliers-project.org/

References

[1] The Wikipedia entry on how to measure hard water: https://en.wikipedia.org/wiki/Hard_water

Resources

- Learn how to spot pseudoscientific fake news in the media: Domenici V (2022) Fake news in chemistry and how to deal with it. *Science in School* **59**.
- Read about the impacts of meat consumption and the development of lab-grown substitutes: Noble M (2023) From Petri dish to plate: the journey of cultivated meat. *Science in School* **63**.
- Read an article about the environmental effects of food packaging: Barlow C (2022) Plastic food packaging: simply awful, or is it more complicated? *Science in School* **56**.
- Explore the water footprints of the foods we eat: Kelly S (2020) Do you know your water footprint? *Science in School* **50**.
- Teach about freshwater with these low-cost experiments: Realdon G et al. (2021) Watery world – hands-on experiments from Earthlearningidea. *Science in School* **54**.
- Investigate the properties of so-called superfoods: Frerichs N, Ahmad S (2020) Are 'superfoods' really so super? *Science in School* **49**: 38–42.
- Teach about water quality and analysis: Al-Benna S (2014) Become a water quality analyst. *Science in School* **29**: 35–40.

Cutting-edge science: related EIROforum research

Seed extracts from the Moringa tree have been used for centuries to help purify water in regions where clean water is not available. Researchers at the Institut Laue–Langevin (ILL) and the European Synchrotron Radiation Facility (ESRF) have used neutrons and X-rays, respectively, to identify and characterize key proteins underlying the unique water purification properties of Moringa seeds. This information may allow better use of this abundant resource for sustainable water purification.

AUTHOR BIOGRAPHY

Paola Semeghini graduated with a degree in pharmaceutical chemistry from Modena University and worked for several years in the pharmaceutical industry. Since 2011, Paola has been a chemistry and scientific laboratory teacher at IIS Pascal, an applied science upper secondary school in Reggio Emilia, Italy, focusing on competence-based education and experiential learning.

Daniela Bergamotti manages the educational activities and projects promoted by Iren, a multiutility company operating in the waste, water, and energy sectors, in the Italian region of Liguria. Eduiren, the company's educational division, is committed to building relationships with schools and communities, using a creative and inclusive approach to spread a culture of sustainability and achieve concrete changes.