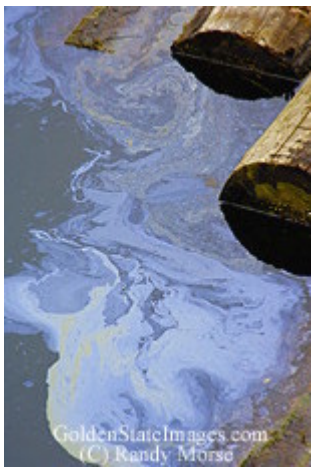
PETROL POLLUTION
Reducing petrol residues in water



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Languages available
English, Slovenian

Summary
The environmental impacts of spilt petrol or paraffin on groundwater resources are severe and long-term. Students are asked to find out if polluted water could be cleaned by using two proposed methods:
1. Adsorption on activated charcoal to remove petrol and paraffin from drinking water.
2. Multiple dilutions by adding clean water to restore drinking water quality.
Smell is used in both methods to check the water after each treatment to detect the presence of petrol or paraffin.

Activity type **A**
Use of scientific knowledge and understanding to solve problems
Working in teams to solve problems

Techniques
Adsorption

Field
Water pollution
Environment

Time
Practical lessons: 90 minutes
Theory lessons: 90 minutes
Out of class time: 90 minutes

StandardBase procedures
None

StandardBase techniques
None

Other resources
http://www.ec.gc.ca/water/en/info/pubs/FS/e_FSA3.htm (Canadian basic text on the need for clean water and about pollution)
http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=6283736 (Abstract of a paper on petroleum pollution)
http://www.limnos.si/english/erm.html (On ecoremediation possibilities)
http://www.ecological-engineering.nl/presentaties/Ecoremediation.ppt (On ecoremediation systems, pictures)
http://www.goldenstateimages.com/GSI_search.php?f=0&i=24&srch=water (Images of polluted water, the upper image is taken from this site)
http://en.wikipedia.org/wiki/Activated_carbon (Describing activated carbon)
http://www.emedicinehealth.com/activated_charcoal/page2_em.htm (Describing activated charcoal for medicinal use, with basic terms explained)
http://en.wikipedia.org/wiki/Absorption (Explanation of absorption)

Student's document

PETROL POLLUTION: Reducing petrol residues in water

Petroleum or paraffin spilt on groundwater resources usually endangers sources of drinking water. Also, their presence in surface waters is harmful to life in rivers, lakes and other water courses.
When petroleum or paraffin pollutes water, we need to know how to reduce its presence and to try to clean the water.

Your brief
You are asked to test two qualitative methods to clean up water (reduce the pollutant) that has been polluted by petrol or paraffin. For separate samples of water contaminated with a. petrol and b. paraffin, try to remove the contaminant using:
1. activated charcoal
2. a dilution technique, using clean water.

Smell is used in both methods to check the water for the presence of petrol or paraffin, after each treatment.
The method of using smell is described under *Odour concentration* (about odour, smell and adsorption) on the website http://en.wikipedia.org/wiki/Odor
The method of dilution to the threshold odour is also described there.

Your investigation
With the other members of your group, plan your work together to carry out the research and the practical tasks.

Discuss your results with other members of your group before you write your final report.

Task 1
Use **Student sheet***: Water pollution − some aspects* to find out about pollution and the remediation of water. As well as the links given on the sheet, there are some more in **Other resources**. Discuss your findings with your group and present the short reports to your teacher.

Task 2
Prepare materials and set up the apparatus for the practical work on **Student sheet**: *Petrol or paraffin pollution*.

Task 3
Conduct the experiments, determine and record your results following the procedures on **Student sheet**: *Petrol or paraffin pollution*.

Task 4
Answer the following questions and discuss your answers with your group.

Is it possible to get drinking-quality water from polluted water by dilution with clean water only?
Do we mind if some petrol is spilt on the ground? Why?

How would you test for the presence of petrol or paraffin in water?
How would you determine quantitatively both pollutants in water?
How would you clean the water polluted by petrol or paraffin?
How do you calculate the dilution factor for multiple (serial) dilutions?

Task 5
Find and briefly describe methods for the quantitative determination of hydrocarbons, like petrol and paraffin, in water (see links below).

http://en.wikipedia.org/wiki/Water_purification (Techniques of water treatment)
http://pubs.acs.org/doi/abs/10.1021/ac0340197 (Quantitative analysis of hydrocarbons in water – mass spectrometry)
http://pubs.acs.org/doi/abs/10.1021/ac950862w (Quantitative analysis of fuel-related hydrocarbons in water by microextraction)
http://cat.inist.fr/?aModele=afficheN&cpsidt=13891288 (Identification of trace petroleum-related hydrocarbons in water using several instrument techniques, e.g. gas chromatography)

For safety reasons there should be no open flame for a minimum of 2 m around the location where you are handling petrol or paraffin. Petrol and paraffin bottles should be kept in a hood or in a safety container.
For information on the safe handling of petroleum, see
http://www.hanford.gov/rl/?page=458&parent=436

A risk assessment must be carried out before starting practical work.

Your findings
1. Summarise your findings in a short report. Your report should contain information on other techniques for water treatment and the quantitative analyses of hydrocarbons in water that are available.
2. Compare the two methods you investigated in the practical work.
3. Include the questions and their answers in your report.

Student self assessment
In 50–100 words describe

- what scientific skills and knowledge you used and how effectively you used them.
- how you worked as a team, giving examples of how you supported others in your group or were supported by them. What is the advantage of working in a team?

Student sheet: Water pollution – some aspects

Step 1

Define the problem of clean water and water pollution

Water pollution is still one of the greatest problems in the World. We are talking about overload of ecosystems which previously had the capacity to render fresh water suitable for drinking. Now they may no longer have the capacity to clean the water into which our wastes are penetrating or chemicals we use are spilled.

Write a report about the problem of water pollution. Give a basic overview about water resources, quality, and pollution. For data, see websites such as
http://www.ec.gc.ca/water/en/info/pubs/FS/e_FSA3.htm (Canadian basic text on a need for clean water and about pollution)
and (also for the Task 2)
http://www.umich.edu/~gs265/society/waterpollution.htm

Step 2

Define the problem of water pollution by petrol and paraffin

This activity ***Petrol pollution*** is about trying out two aspects of treating water polluted with petrol or paraffin.

The environmental impacts of petrol spills on groundwater resources are severe and long-term.
So that you can describe the problem, try looking at the following websites:
http://www.earthworksaction.org/oilgaspollution.cfm (Oil and gas pollution)
http://www.earthworksaction.org/contaminantpathways.cfm#SPILLS (Data and pathways of oil spills and similar pollution)
http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=6283736 (Abstract of a paper on petrol pollution)

One drop of oil can render up to 25 litres of water unfit for drinking, as estimated in the Canadian text listed in step 1.

Step 3

Ecoremediation (phytoremediation) as another technique for cleaning up pollution from petroleum hydrocarbons

Use the links below and the ones listed under **Other resources** to write a short report about other cleaning techniques, besides adsorption with charcoal.
http://www.ebi.calpoly.edu/about/ecoremediation.pdf (Phytoremediation - one of the other techniques for cleaning water)
http://ces.iisc.ernet.in/hpg/envis/doc98html/journews99718.html (Bioremediation is the field of using biological entities, including microbes for degrading environmental harms. This includes the use of microbes for breaking down petroleum products, toxic wastes, waste materials, and other environmental pollutants.)

Student sheet: Petrol or paraffin pollution

1. Removing petrol or paraffin from tap water by adsorption

Step 1
Mixing (polluting) tap water with petrol or paraffin:
1. Fill a conical flask (300 mL) with 250 mL tap water and add 0.25 mL petrol or paraffin. If possible, use a syringe for small volumes (1–3 mL) to deliver the petrol or paraffin.
2. Stopper the flask and shake vigorously. Water and petrol do not dissolve in each other (an emulsion is produced). Water is typically a polar liquid, petrol is non-polar.
3. Calculate the dispersion factor for petrol or paraffin. Dispersion factor f by volume is calculated as volume after mixing V_a divided by volume before mixing V_b:

$$f = \frac{V_a}{V_b}$$

Hint: 250 mL is used in the calculation as V_a instead of 250.25 mL. We ignore the small error (0.1 %). V_b in a 1st mixing step is 0.25 mL of petrol or paraffin.

Step 2
Put two teaspoonsful of activated charcoal into the flask and mix a couple of times. After 15–20 minutes rest, filter. Find out if the tap water still has a smell.

2. 'Removing' petrol or paraffin from tap water by multiple dilutions

Step 1
1. Mix tap water with petrol or paraffin as in *Step 1*, above.
2. Stopper the flask and shake vigorously.
3. Calculate the dispersion factor f_1.

Step 2
Multiple (serial) dilutions:
1. Transfer 25 mL of water/petrol (or paraffin) mixture (emulsion) from *Step 1* immediately after the shaking to another Erlenmeyer flask (300 mL), fill to 250 mL with tap water and shake vigorously.
2. Open the flask and examine for petrol or paraffin by smelling.
3. Calculate dispersion factor f_2.

Step 3
The procedure is repeated until no smell is detected.
1. Transfer 25 mL of water/petrol (or paraffin) mixture from *Step 2* to another Erlenmeyer flask (300 mL), fill to 250 mL with tap water and thoroughly shake.
2. Open the flask and examine for petrol or paraffin by smelling.
3. Calculate the dispersion factor f_3 in each of the dilution steps.

Step 4
After the final mixing, dispersion factor f_m is calculated for multiple steps.
For multiple steps, the dispersion factor f_m is the product of the dispersion factors for each individual mixing:

$f_m = f_1 \times f_2 \times f_3 \times f_4 \times f_5 \times ...$

Note 1: If the dispersion factor f_1 in *Step 1* is 1000 and the dispersion factor f_2 in *Step 2* is 10, then the multiple dispersion factor for both steps in series is f_m = 10.000

Note 2: When eventually multiple dispersion factor of 1 000 000 is reached, we sometimes speak of dispersion in terms of ppm (parts per million).

Note 3: Irrespective of multiple mixings, petrol or paraffin and water are still a mixture (emulsion).

3. Cleaning glassware after use

Method 1
The method of cleaning by dissolving hydrocarbons uses the 'like dissolves like' rule of thumb. Read about this rule and a table of common solvents at http://usm.maine.edu/~newton/Chy251_253/Lectures/Solvents/Solvents.html

For hydrocarbons such as petrol and paraffin (non-polar liquids) this means using, for example, hexane – a lower hydrocarbon, also a non-polar liquid (see characteristics of hexane at http://msds.chem.ox.ac.uk/HE/hexane.html).

Classification of solvents can be found at http://en.wikipedia.org/wiki/Solvent

This technique is not recommended because problems with dissolved petrol and paraffin still persist. The solvent itself is dangerous both as a waste and when it evaporates and leaves both solutes in the environment.

Method 2
This involves cleaning by using surface active agents (SAA). Detergent, which is a mixture of SAAs dissolved in water, can be used. The principle is different from *Method 1*. Molecules of the SAA surround molecules of petrol and paraffin, keeping them dispersed and easily washable from a glass surface.

Teacher's document

Overview
The experiments are designed to develop competency for technicians working in industry as technologists through a problem-based activity that imitates a real life situation.

It would be worthwhile to use the topic of water pollution for an entire module. This could be worked up using case studies and field tests. This activity is only one of many possibilities in the broad area of water pollution.

Competencies/skills to be developed during this activity:
- using knowledge and understanding to tackle scientific problems
- observing, measuring, analysing and evaluating scientific data
- working in teams to solve problems.

Principal areas concerned:
- Chemistry: cleaning of water, to differentiate between adsorption and absorption:
  http://www.thefreedictionary.com/adsorption
  http://www.thefreedictionary.com/absorption
- Ecology: water pollution and its effect on the human body
- Public relations: communicating the results to clients

Developing students' skills
1. Water pollution by petrol or paraffin needs some explanation regarding liquid/liquid mixtures, partial solubility, density and surface tension. Petrol and paraffin are spread in a nearly monomolecular layer (also the optical effect can be mentioned). So, a small quantity of it will spread over a large surface area.

2. Big petrol, paraffin and oil spills should also be mentioned (see **Other sources**).

3. Smell is introduced. How it works needs to be described and the possibility of substituting electronic sensors can be discussed. On the Internet, the key words 'odour' or 'smell' will help students. Odour is one of the most specific and difficult to measure to determine environmental pollution. However, our nose is still an official instrument in detecting odours.

4. Let the students explain the difference between adsorption and absorption (see Internet links). Adsorption is a process that uses special solids (called adsorbents) to remove substances from either gaseous or liquid mixtures. The term 'adsorption' was first coined in the late 19th century, but the process itself was not widely used until the 1940s and 1950s when activated carbon was first used for municipal water treatment.

http://adsorption.com/publications/AdsorbentSel1B.pdf (Adsorbent selection)
http://adsorption.com/publications/AdsorberDes2.pdf (Adsorbent design)
http://en.wikipedia.org/wiki/Adsorption (Explanation of adsorption process)

5. Calculations and the definition of dilution factor are described in the **Student sheet**: *Petrol or paraffin pollution*

Organising and managing the class

1. At least two groups should be arranged and a minimum two participants per group is suggested.

2. For safety reasons, sufficient time should be allowed to introduce the hazards posed by petrol and paraffin. For information on safe handling, use: http://www.hanford.gov/rl/?page=458&parent=436

Session plan for teachers

A suggested approach:

- Introducing the topic, checking prior knowledge, arranging students into groups. Students discuss and allocate the work. (90 minutes)
  - Teacher's introduction to water pollution may include using an analysis of local tap water to exemplify the criteria for clean water (local websites search) and a short video on a water distribution plant. (45 minutes)
  - Students gather Internet information, using key words, and share their findings with their group. (45 minutes)
- Carrying out practical work, writing a report and comparing results. (90 minutes)
- Out of school activity including research to find local water courses, ponds or lakes that may be polluted by releases from industry or from sewage outfalls. (90 minutes)

Technical notes

1. For safety reasons there should be no open flame for a minimum of 2 m around the location where petrol (gasoline) or paraffin (fuel oil) is being handled. Bottles of petrol and paraffin should be kept in a hood or in a safety container. Refer to your national guidelines on the safe handling of these hydrocarbons.

2. Cleaning glassware after use

- Cleaning by using surface active agents (SAA) is suggested. Detergents are a mixture of SAAs, dissolved in water. Molecules of the SAA surround molecules of petrol and paraffin, keeping them dispersed and easily washable from a glass surface. For more information, see http://www.extension.umn.edu/distribution/naturalresources/DD6620.html (Surface active agents)

The method of cleaning by dissolving both hydrocarbons using the 'like dissolves like' rule of the thumb involves a different principle. Details and a table of common solvents can be found at http://usm.maine.edu/~newton/Chy251_253/Lectures/Solvents/Solvents.html

For hydrocarbons such as petrol and paraffin (non-polar liquids) this means using, for example, hexane – a lower hydrocarbon, also a non-polar liquid (see characteristics of hexane at ttp://msds.chem.ox.ac.uk/HE/hexane.html). Classification of solvents can be found at http://en.wikipedia.org/wiki/Solvent

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Equipment and materials

Materials and their CAS numbers

tap water
petrol from filling station
paraffin from filling station
activated charcoal

The table gives a comparison of terminology in different languages.

UK	USA	Slovenia	Hungary	The Netherlands
petrol	gasoline	bencin	benzin	benzine
paraffin	kerosene	petrolej	petróleum	petroleum
diesel	diesel oil	diesel	gázolaj/ (dízelolaj)	diesel
heating oil	heating oil	kurilno olje	fűtőolaj	huisbrandolie/ rode diesel
aviation fuel	aviation fuel	kerozin	kerozin	kerosine

The explanation of the UK expressions:

petrol
generally used by cars
paraffin
used in lamps and small domestic heaters

diesel
fuel for trucks and some cars
heating oil
similar to diesel, condenses at higher temperature than paraffin; dyed red or yellow to ensure that it is not used in vehicles (to evade taxes); used in central heating systems
aviation fuel
unleaded paraffin or naphtha/kerosene mix; higher quality than road fuels

Glassware
- 300 mL conical flasks (Erlenmeyer flask)
- pipettes for pipetting petrol or a syringe 3 mL or less
- stopper
- 50 mL measuring cylinders

Preparation
No special preparation needed.

TESTING PRIOR KNOWLEDGE

Select the correct answer.

1. Which of the following is another word for pollution?
   a. containment
   b. contamination
   c. pollination
   d. polonium

2. Which of the following is a most probable source of pollution of drinking water?
   a. rotting leaves from trees
   b. poisonous mushrooms in forests
   c. pesticides on fields
   d. cows pastured on grassland

3. Why does petrol *not* mix with water?
   Because of a difference in:
   a. density
   b. polarity
   c. odour
   d. colour

4. Why does paraffin remain on the surface of water?
   Because paraffin has:
   a. lower polarity
   b. an odour
   c. lower density
   d. colour

5. What does the term adsorption mean?
   a. adsorption means absorption
   b. adsorption means dissolving in a liquid
   c. adsorption means evaporating from a surface
   d. adsorption means binding on a surface

6. 5 mL of pure alcohol was made up to 250 mL with water. What is the dilution factor?
   a. 25
   b. 75
   c. 50
   d. 255

Note: answers are given in red. These need to be removed before test is used.

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