# POLLUTION INCIDENT
# Measuring pollutant concentrations in river water

**Author**
Ken Gadd and Roger Ellis, 4science, Stratford sub Castle, SP1 3YP, UK;
ken@4science.org.uk, roger@4science.org.uk.
**Languages available**
English, Slovenian

**Summary**
As a member of a team of environmental scientists working for a national water quality monitoring agency, you would need to respond to pollution incidents. How can you work effectively with the other members of your team to protect the environment from further damage? You are asked to investigate a river pollution incident. It appears that manure, slurry or fertiliser is getting into the river. A farm is the suspected source.

**Activity type C**
Use of scientific knowledge and understanding to solve problems
Working in teams to solve problems
Time and workload management

**Techniques**
Colour matching

**Field**
Environmental science

**Time**
Practical lessons: 120 minutes
Theory lessons: 90 minutes
Out of class time: 60minutes

**StandardBase procedures**
None

**StandardBase techniques**
None

**Other resources**
Rolf C. Hagen (UK) Ltd. www.hagen.com
(http://www.lagunaponds.com/lagunaengeu/index.php)
DVD ROM from *Scientists at work* www.4science.org.uk
Environment Agency http://www.environment-agency.gov.uk
(follow the *Water quality link* in the left hand menu)
Others are found in the activity.

# Student's document

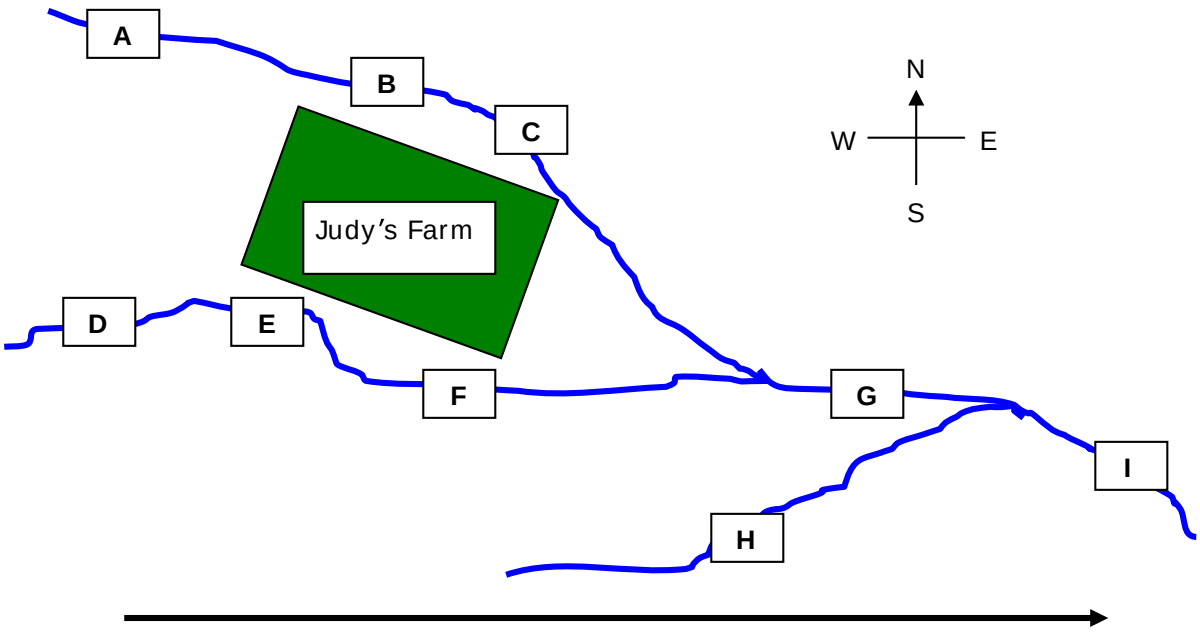
## POLLUTION INCIDENT: Measuring pollutant concentrations in river water

6 am in the morning. It's been raining heavily all night. The river is high, but the clouds are clearing. In the calmer water above the weir and glistening in the early morning sun, fish are floating on the surface of the water, dead. It's another pollution incident and another job for environmental scientists, like those who work for the UK Environment Agency. As a member of the team, you would want to act with speed and efficiency to resolve the problem. Symptoms of pollution are not always so obvious. However, the sooner you can identify the pollutant and its source, the sooner action can be taken to prevent further environmental damage.

### Your brief

You are a member of a team of environmental scientists that monitors and responds to water pollution incidents. Your work is vital to keeping your country's environment safe and clean. You also play an essential role in helping your government uphold the legal requirements of the EU Water Framework Directive.

A possible water pollution incident has been reported. It seems likely that it is caused by fertilisers (natural or man-made) from a farm being washed into the river. Quick and easy to use test kits are taken to the site to check the quality of the water. To minimise damage to the environment, your team needs to work quickly and without error to resolve the problem.
This sketch map was prepared by the chief field officer. It shows the sites from which water samples are to be collected.




direction of flow of the rivers

The land slopes gently down from the north-west to the south-east. Upstream of sampling points A and D both rivers are 'white water' rivers. In other words, they run rapidly through rocks and boulders where they bubble and froth.
In this simulation, you will be provided with samples that represent the water obtained from various parts of the river (A to I). You need to gather evidence of the pollution. The pollutants and their source must be identified and action to control the situation recommended. You may also need to supply valid evidence to support a prosecution if the law has been broken.

**Your investigation**
Work as a team. Your teacher will decide who is in your team. You will need to read **Your investigation** so that you can decide what tasks need to be done and who is to do them. Your teacher will act as your manager or supervisor to whom you report your findings and from whom you may ask for technical advice.

*Planning*
This activity is about time and workload management. Your teacher will tell you what lesson and laboratory time you will have to work on this assignment. The team will be given access to commercial test kits. There are various makes. Not all use tests identical to one another. You will need to find out what is available for you to use.
You have 3 hours of laboratory time available and a further 11 hours outside the laboratory. No more time is available. There are many samples to test. Your team needs to collect sufficient reliable data to have confidence in your analytical results and be able to draw valid conclusions about the pollutants and their source. Your recommendations for action depend on these valid conclusions.
Remember reliable data are:

- repeatable (the same person gets the same results when the analysis is repeated)

and

- reproducible (two or more people get the same results using the same method).

Your level of confidence will also depend on the measurement precision allowed by the test kits.
Plan the team's work carefully before starting the analyses. Decide who is going to do what. Check the plans with your teacher before you proceed to carrying out your investigations. Some things to think about:

- How long will each test take?
- How many times should each test be carried out on a sample?
- Who should carry out the tests?
- What is the best way to share the workload and maximise the team's chances of getting reliable data in the time available?

*Practical activity*
Your teacher will tell you when your laboratory time and materials are available. Collect the apparatus and materials you need and set out your working area.

Remember that a risk assessment must have been carried out for each activity before you start work.

*Datasheets*
As you can see, there are nine sampling sites (A-I). Each member of your team will be given three further **datasheets**:

- *Analyst's recording sheet*
- *Summary analysis sheet*
- *Classification of river quality*.

Collect these before starting work.

*Expert panel*
If available, get some further background information from the *Scientists at work* DVD ROM (available from www.4science.org.uk ). Watch the short video showing scientists from the UK Environment Agency at work, investigating a water pollution incident. They have equipment to be able to carry out preliminary tests in the field.

*Tips for finding information*
Each test kit has instructions on how to use it. Read these carefully before starting. Your teacher may give you other suggestions or instructions.
You might find it interesting to visit these websites:

- UK Environment Agency http://www.environment-agency.gov.uk/ (follow the 'Water quality' link in the left-hand menu)
- European Environment Agency http://www.eea.europa.eu/

There are various commercial test kits. Here are just four examples:
http://www.lagunaponds.com/lagunaengeu/testkits/testkits.php?link=110
http://www.palintest.com/)
http://www.kittiwake.com/Default.aspx/ProductSection/90/ProductSubSection/106/ProductSubSubSection/293
http://www.wagtech.co.uk/ShowCat.php?catid=1
You may want to find out how the various tests work.

*Procedures*
Your teacher will advise you which test kits are available to you. Each test kit comes with instructions for its use. You will be testing water from various sampling sites on the river. You will be checking on: pH, dissolved oxygen and the concentration of ammonia, nitrite, nitrate and phosphate in the water.

**Your findings**

- Do you consider your results to be reliable (repeatable and reproducible)?
- Do you consider your conclusions to be valid (reliable data have been correctly interpreted)?
- What evidence do you have to support your decisions? Discuss this with your team.

Write your results on the *Analyst's recording sheet* and summarise the team's results on *Summary analysis sheet*. Include these with your report.

Write a brief report for your manager (i.e. your teacher). It should:

- summarise your key findings
- indicate your level of confidence in your results
- recommend what further action should be taken (this could include further testing).

**Student self assessment**

In 50-100 words say:

- what scientific skills and knowledge you used and how effectively you used them.
- how you worked as a team and give examples of how you supported others in your group or were supported by them.
- what the advantage is of working in a team.
- how the group managed its time and workload.

## Student datasheet: Classification of river quality

The tables below are based on the classification system for rivers used by the UK Environment Agency.

| **Chemical grade** | **A** | **B** | **C** | **D** | **E** | **F** |
|---|---|---|---|---|---|---|
| **Description** | Very good | Good | Fairly good | Fair | Poor | Bad |
| **Oxygen / mg dm$^{-3}$** | 7.3 | 6.4 | 5.5 | 4.6 | 1.8 | <1.8 |
| **Ammonia / mg dm$^{-3}$** | 0.3 | 0.7 | 1.6 | 3 | 10.9 | >10.9 |

| **Phosphate grade** | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|
| **Description** | Very low | low | moderate | high | Very high | Excessively high |
| **Phosphate / mg dm$^{-3}$** | <0.06 | 0.06 to 0.17 | 0.18 to 0.30 | 0.31 to 0.60 | 0.61 to 3.0 | >3.0 |

| **Nitrate grade** | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|
| **Description** | Very low | low | moderate | high | Very high | Excessively high |
| **Nitrate / mg dm$^{-3}$** | <5 | 6 to 10 | 11 to 20 | 21 to 30 | 31 to 40 | >40 |

Information in the following two tables are from Laguna Test kits

| **Nitrite level** | | | |
|---|---|---|---|
| **Description** | Safe | Lethal to fish long term | Toxic to fish |
| **Nitrite / mg dm$^{-3}$** | 0 | 0.3 | >0.3 |

| **pH level** | | | |
|---|---|---|---|
| **Description** | Too acidic for most fish and plants | Safe | Reduced plant growth and increased algae growth |
| **pH** | <6 | 6.6 to 7.2 | >7.4 |

Note:
- ammonia and nitrite are toxic to fish
- high pH levels can indicate high levels of ammonia
- dissolved oxygen is essential to fish
- nitrite is formed when bacteria oxidise ammonia.

## Student datasheet: Analyst's recording sheet

Add data from your measurements. Record repeated measurements side by side in neighbouring columns.

| Name: | | | Date: | | | |
|---|---|---|---|---|---|---|
| | **Measurements** | | | | | |
| **Sampling location** | **pH** | **oxygen** | **ammonia** | **nitrate** | **nitrite** | **phosphate** |
| **A** | | | | | | |
| **B** | | | | | | |
| **C** | | | | | | |
| **D** | | | | | | |
| **E** | | | | | | |
| **F** | | | | | | |
| **G** | | | | | | |
| **H** | | | | | | |
| **I** | | | | | | |

## Student datasheet: Summary analysis sheet

Record results from all team members. Record mean values in a different colour in the shaded boxes.

| Team members: | | | | | | | | | | | | | Date: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Measurements** | | | | | | | | | | | | |
| | **pH** | | **oxygen** | | **ammonia** | | **nitrate** | | **nitrite** | | **phosphate** | | **Conclusions** |
| **A** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **B** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **C** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **D** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **E** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **F** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **G** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **H** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **I** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

# Teacher's document

**Overview**
This simulation is designed to give the students the opportunity to develop and practise the skills associated with effective time management and teamwork through a problem based activity that relates to a real life situation.

Students:
- manage relationships to work effectively with others to solve problems
- manage time and workloads effectively
- use scientific knowledge and understanding to solve problems
- observe, measure, analyse and evaluate scientific data
- communicate precisely both verbally, in writing and using ICT.

*Context*
Students work as environmental scientists testing water samples to establish the possible cause of a pollution incident. The incident is a suspected contamination of a river by fertiliser from a nearby farm.

Students work in teams to discuss, plan and complete a set of analytical tests. Working to a tight schedule, members of the team share ideas and information to solve the problem. After discussion, team members write reports to summarise their results, draw conclusions and recommend action.

The main goal is to encourage the development of time and workload management and teamwork skills. The commercial water testing kits available are ideal sources of simple procedures and reasonably priced materials. The kits are based on simple colour matching analyses. They can be used for rapid multiple testing and so produce lots of varied data quickly. Interested students might be encouraged to find out the chemical basis of each analysis.

A pollution scenario is described: two rivers flow past a farm (see the map in the student brief). Pollution is suspected. Students must identify the pollutants and their source and recommend action to prevent further pollution. They analyse simulated 'samples' from the sampling sites. (Details are provided in the technical notes for preparing the 'samples' for each of the nine sampling sites.) UK Environment Agency river classification tables provided for the students in Datasheet: Classification of water quality may be used to form conclusions on water quality at each site.

**Developing students' skills**
The amount of help depends on the nature of the students and their prior experience. If this is their first exercise in time management and teamwork, they may need considerable help and guidance.
Groups with successful experience of working together can be left more to their own resources. Whether students are inexperienced or experienced, a sharp eye should be kept on the clock and it may be necessary to bring the whole class together at some point to facilitate progress.

It is the nature of this task that it cannot be completed successfully in the time available without teamwork and setting targets with deadlines. At the beginning, the teacher may need to elicit team working strategies through appropriate

questioning and to set clear targets and deadlines. Encourage students to take care and pride in their work whilst working to deadlines.
Short reviews at the end of sessions can be based on teacher observations of progress and will help to set up the following sessions.

Trouble shooting vigilance may be needed with:
- technical aspects, including manipulative skills and correct handling of chemicals and equipment
- health and safety issues
- working relationships with others.

www.presentingscience.com/aflchem/key/groupwork.htm has ideas for setting up student groups.

**Organisation and managing the class**
Students work in groups of six or more. Smaller groups will struggle to complete the analyses in the time.

Questions provided to check prior knowledge may be used as a short test and followed by a class discussion of the answers. This should be done as quickly as possible, spending time only to clarify areas of ignorance or confusion. The task itself can be completed with a minimum of prior knowledge.

The introduction to the task should emphasise the need to work collaboratively with other members of a team. The analysis is complex:
- 9 samples
- 6 tests per each sample (so a total of 54 tests, with some tests taking a little longer than others)
- Results need to be checked for reliability (repeatability and reproducibility), which means that each test will be done more than once.

There is potentially a huge amount of work for a group to carry out. It is important that a group is challenged by the work to be done, but has a realistic chance of completing it and coming to sensible conclusions. The number and type of analyses carried out by a group can be varied (this might mean reducing the number of sampling sites and/or reducing the number of tests to be carried out on water from any one site).

Planning is essential to ensure sufficient data are collected. Students working in groups of six or more must decide how to share the workload. For example:
- Students might work individually or in pairs within the team
- One student (or pair) may be responsible for testing just one substance in all samples
- One student (or pair) may be responsible for the full analysis of one sample from a given sampling site
- Two pairs of hands and a third for recording results may be an advantage
- A single unaided investigator may be able to collect data rapidly.

There are, of course, many possibilities.

During the planning stage, ask students what their reasoning was when allocating workloads. Prompt them to consider alternatives. No matter how the

groups are organised, make sure all students carry out a variety of tests (though not necessarily all of them).

A typical approach might involve asking teams to plan in three stages:

- Discuss the scenario
  - How many samples need to be tested?
  - What tests will be carried out?
- Look at the test methods
  - How long will a test take? (Estimates could be indicated in procedures.)
  - How many times should one water sample be tested for one substance?
  - How many different people need to carry out the test?
- Plan effective use of the available time
  - How can the team be organised to share the tasks and optimise data collection?

To optimise data collection, teams must coordinate activities and share data. Tests should be repeated to check repeatability and carried out by more than one person to check reproducibility (repeatability + reproducibility = reliability). Ideally, if two results fail to agree, a third measurement should be taken.

**Session plan for teachers**

Exact timing depends on many factors, but the following is suggested:

- Introduction and checking of prior knowledge 30 minutes
- Arrange students in groups to discuss and plan the work 40 minutes
- Carry out the practical work and analyse the data 120 minutes
- Discussion of conclusions (teams then class) 20 minutes
- Completion of reports and evaluation 60 minutes

## Technical notes

### Preparation

The necessary equipment and reagents are supplied in commercial water testing kits. Students should follow the instructions provided with the kit. The *Laguna Master Test Kit* for ponds is available from aquatics suppliers (L16.99 - L24.99, 30/05/07) and contains test materials for pH, hardness, ammonia, nitrite and nitrate (though high nitrite interferes with the nitrate test). Other kits are readily available for oxygen and phosphate.

*Palintest* at www.palintest.com/ offer a wide range of water test kits and apparatus. Their *Pocket Test Kits*, each for 50 tests of an individual substance, retail at L17.15 (30/05/07).

Other procedures are available. For example, pH may be measured using narrow range indicator paper or strips, or by using a pH probe and meter. Oxygen probes are also available. As change in temperature may have a significant effect on pH or oxygen concentration, for accurate results a temperature compensating device should be used.

Sample solutions can be devised to suit the analytic procedures available to the students. To make samples that can be tested for pH, oxygen, ammonia, nitrite and nitrate, make five stock solutions (measuring cylinder accuracy) as below.

### Stock solutions (denoted by 1-5)

**1.** 0.0125 mol $dm^{-3}$ ammonium nitrate:
$[NH_4^+]$ = 0.225 g $dm^{-3}$; $[NO_3^-]$ = 0.775 g $dm^{-3}$
**2.** 0.0941 mol $dm^{-3}$ sodium nitrate: $[NO_3^-]$ = 5.834 g $dm^{-3}$
**3.** 0.00435 mol $dm^{-3}$ sodium nitrite: $[NO_2^-]$ = 0.200 g $dm^{-3}$
**4.** 0.00128 mol $dm^{-3}$ sodium dihydrogen phosphate-2-water:
$[H_2PO_4^-]$ = 0.122 g $dm^{-3}$
**5.** 0.476 mol $dm^{-3}$ sodium hydrogen carbonate: $[NaHCO_3]$ = 40 g $dm^{-3}$. This is to adjust pH and the total salt content close to that of real river water (pH about 8.1; total salt content expressed by specific conductivity 400 µS $cm^{-1}$).

### Sample preparation

| Location | Stock 1 / $cm^3$ | Stock 2 / $cm^3$ | Stock 3 / $cm^3$ | Stock 4 / $cm^3$ | Stock 5 / $cm^3$ |
|---|---|---|---|---|---|
| **A** | 2.0 | 1.0 | 0.5 | 0.5 | 10 |
| **B** | 2.0 | 1.0 | 0.5 | 0.5 | 10 |
| **C** | 15 | 1.5 | 8.0 | 10 | 10 |
| **D** | 2.0 | 0.5 | 0 | 0 | 10 |
| **E** | 20 | 2.0 | 10 | 15 | 10 |
| **F** | 35 | 2.5 | 15 | 25 | 10 |
| **G** | 25 | 2.2 | 10 | 15 | 10 |
| **H** | 2.0 | 0.5 | 0 | 0 | 10 |
| **I** | 15 | 1.5 | 8.0 | 12 | 10 |

Oxygen levels can normally only be measured at the sampling sites, since their values change rapidly. You should make students aware of this fact.

Immediately before use, raise the oxygen levels in samples A and D by bubbling air through or shaking vigorously in a partially filled bottle for several minutes. Although test kits will give only approximate values, relative results should show:

**Sample concentrations**

| Location | $[NH_4^+]$ / mg $dm^{-3}$ | $[NO_3^-]$ / mg $dm^{-3}$ | $[NO_2^-]$ / mg $dm^{-3}$ | $[H_2PO_4^-]$ / mg $dm^{-3}$ | $[NaHCO_3]$ / mg $dm^{-3}$ |
|---|---|---|---|---|---|
| **A** | 0.45 | 7.40 | 0.10 | 0.06 | 400 |
| **B** | 0.45 | 7.40 | 0.10 | 0.06 | 400 |
| **C** | 3.38 | 20.4 | 1.60 | 0.12 | 400 |
| **D** | 0.45 | 4.50 | * | * | 400 |
| **E** | 4.50 | 31.3 | 2.00 | 1.82 | 400 |
| **F** | 7.88 | 41.7 | 3.00 | 3.04 | 400 |
| **G** | 5.63 | 32.2 | 2.00 | 1.82 | 400 |
| **H** | 0.45 | 4.50 | * | * | 400 |
| **I** | 3.38 | 20.4 | 1.60 | 1.47 | 400 |

* not detectable - concentration is below 0.01 mg/ $dm^{-3}$

Higher oxygen levels found at locations A and D may be due to upstream rapids or waterfalls.

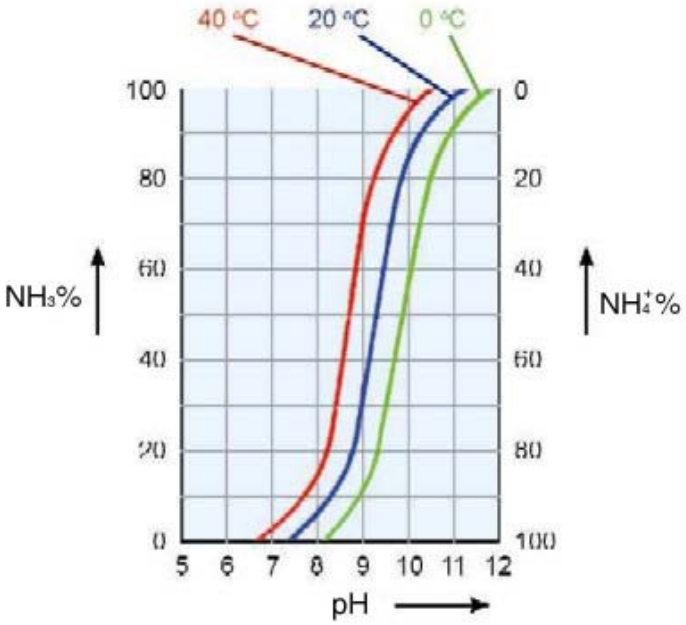
By giving concentrations in mg $dm^{-3}$, water quality at each location may be assessed using the UK Environment Agency tables provided to the students.

The farm is the clear candidate as the source of the pollution, probably due to run-off of manure, slurry or fertiliser. Furthermore, the data suggest that more pollution comes from the southwest side of the farm than the northeast side. This would make sense because of the sloping location of the farm.

Recommended action should include ensuring the fertiliser is stored securely and locating it where it is the optimum distance from the rivers.

More information and data can be found at
www.environment-agency.gov.uk/subjects/waterquality/
and www.environment-agency.gov.uk/maps/960669/
See also:
www.bristol.gov.uk/ccm/portal/
(type *living rivers introduction* in search)
http://www.defra.gov.uk/environment/water/index.htm
http://www.pca.state.mn.us/water/milestone.html
http://www.yptenc.org.uk/docs/factsheets/env_facts/river_pollution.html
http://europa.eu/scadplus/leg/en/s15005.htm
http://www.environmentcareers.org.uk/

**A note about ammonia and ammonium ions**
Ammonium ion is the pollutant of natural waters, and the $[NH_3]:[NH_4^+]$ ratio depends on pH and temperature (see graph below). Colour matching tests generally measure ammonia-based colour, but this does not mean that nitrogen was present originally in that form. Rather, it is formed during the test.




However, water test kits often provide a chart for calculating [$NH_3$] based on the measured [$NH_4^+$] and pH. By adjusting the pH of all samples to about 8, about 4% of the total nitrogen content is in the form of ammonia. The lethal concentration of total nitrogen at this pH is about 0.5 mg $dm^{-3}$.

**Equipment and materials**

Each team of students will need sufficient volumes of each water sample to carry out a minimum of three sets of tests.

Students need access to water test kits and the instructions. It may be wise to take the instructions from the test kit packaging and mount them on a laminated board. They will last longer this way.

Reagents should be made up in advance by a technician.

| | |
|---|---|
| ammonium nitrate | CAS number 6484-52-2 |
| sodium nitrate(V) | CAS number 7631-99-4 |
| sodium nitrate(III) (sodium nitrite) | CAS number 7632-00-0 |
| sodium dihydrogen phosphate-2-water | CAS number 13472-35-0 |
| sodium hydrogen carbonate | CAS number 144-55-8 |

# TESTING PRIOR KNOWLEDGE

1 Some test kits allow rapid analysis of substances in water or soil. Often a substance gives a distinctive colour when certain chemicals are added. The intensity of this colour can be matched against a standard test card (just like Universal indicator for pH). Which of the following best describes these tests?
a) qualitative colorimetric analyses
b) accurate quantitative volumetric analyses
c) approximate quantitative colorimetric analyses correct
d) approximate quantitative volumetric analyses

2 Here are four sources of pollution. Which one is most likely to cause heavy metal ion pollution of water?
a) burning fossil fuels, e.g. in an electricity power station
b) drainage ('run-off') from a farm
c) drainage from copper and tin mines or slag heaps most likely cause
d) discharge from an oil refinery

3 Which two of the following are inorganic pollutants?
a) ammonium sulfate from compound fertilisers inorganic
b) diesel oil from farm tractors
c) phosphate from washing powders inorganic
d) farmyard manure.

4 Match the correct ion:
A nitrite ion
B nitrate ion
C phosphate ion
to these statements about ions that may be found in river water:
a) essential for plant growth, this ion is formed by the action of bacteria on manure or is directly applied in fertilisers B, nitrate ion
b) toxic to fish and can be formed from ammonia by bacteria A, nitrite ion
c) often found in fertilisers, sewage effluent or detergents, it is normally so low in concentration in freshwater that it limits plant and algal growth
C, phosphate ion

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

## TESTING PRIOR KNOWLEDGE

5 Some test kits allow rapid analysis of substances in water or soil. Often a substance gives a distinctive colour when certain chemicals are added. The intensity of this colour can be matched against a standard test card (just like Universal indicator for pH). Which of the following best describes these tests?
a) qualitative colorimetric analyses
b) accurate quantitative volumetric analyses
c) approximate quantitative colorimetric analyses
d) approximate quantitative volumetric analyses

6 Here are four sources of pollution. Which one is most likely to cause heavy metal ion pollution of water?
a) burning fossil fuels, e.g. in an electricity power station
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to these statements about ions that may be found in river water:
a) essential for plant growth, this ion is formed by the action of bacteria on manure or is directly applied in fertilisers
b) toxic to fish and can be formed from ammonia by bacteria
c) often found in fertilisers, sewage effluent or detergents, it is normally so low in concentration in freshwater that it limits plant and algal growth