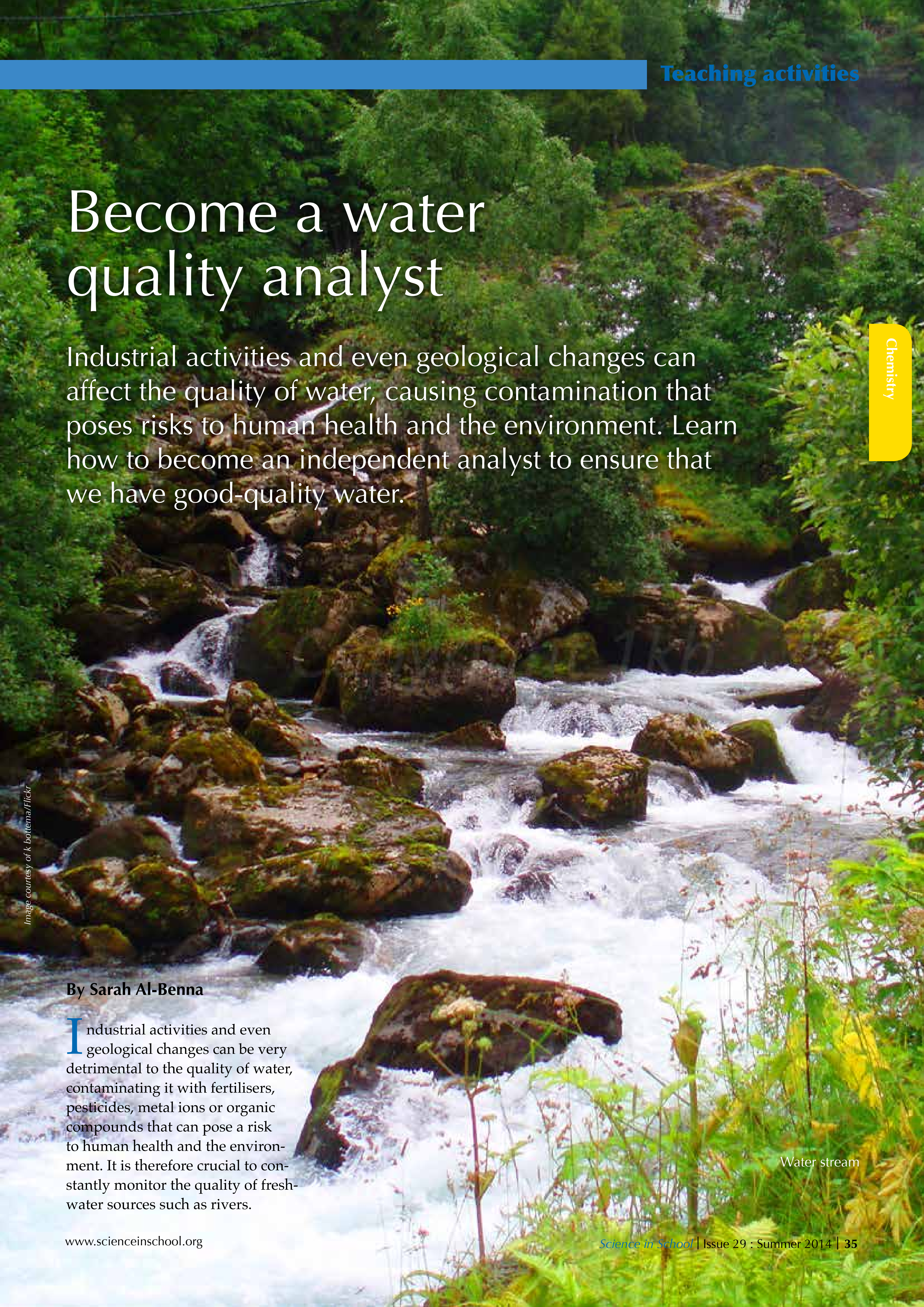

Chemistry

Become a water quality analyst

Industrial activities and even geological changes can affect the quality of water, causing contamination that poses risks to human health and the environment. Learn how to become an independent analyst to ensure that we have good-quality water.

By Sarah Al-Benna

Industrial activities and even geological changes can be very detrimental to the quality of water, contaminating it with fertilisers, pesticides, metal ions or organic compounds that can pose a risk to human health and the environment. It is therefore crucial to constantly monitor the quality of freshwater sources such as rivers.

Water stream

Image courtesy of k bottema/Flickr

Quality analysts are a key part of the process to keep us safe from polluted water. They regularly check water quality by performing quantitative analyses (such as determining the amount of an ion in a solution) on collected samples at various sites before, during and after water treatment.

In the following activity, students put themselves in the shoes of a water-quality analyst working next to a manufacturing plant similar to the Tata Steel site in Scunthorpe, UK. They will have to react to a specific scenario, perform the appropriate analyses, and determine whether the plant is removing thiocyanate from its waste water efficiently.

Image courtesy of the Royal Society of Chemistry

Coal is converted to coke in coke ovens. Thiocyanate ions are a by-product.

Thiocyanates: a ubiquitous poison

Thiocyanate ions (SCN^-) are toxic to aquatic organisms and are known to affect the thyroid gland in humans, reducing the ability of the gland to produce the hormones necessary for the normal function of the body.

Thiocyanates can have many different origins. Coal gasification and the production of industrially useful chemicals from coal, for example, produce large quantities of thiocyanate ions, together with a large number of other toxic compounds such as phenols and ammonium. These by-products are therefore constituents of the plant's waste water.

Thiocyanates can also be found where cyanide is used in the mining of precious metals. The cyanide is converted to thiocyanate by the reaction with sulfur, which is naturally found in ores:

$$8\,CN^- + S^8 \rightarrow 8\,SCN^-$$

Some pesticides also contain thiocyanate ions as their active, poisonous, compound.

Traces of thiocyanate are found naturally in the human body as a by-product of the metabolism of cysteine and detoxification of cyanide – it is then excreted in the urine. It can be taken into the human body through smoking and is a by-product of the metabolism of some drugs used to treat hypertension.

Microbes vs poison

The process of removing thiocyanate ions from waste water takes place in huge open-air concrete tanks that contain activated sludge, a biologically active material comprising a range of micro-organisms that can break down thiocyanate ions and other contaminants into less dangerous compounds. The chemical reaction that takes place to neutralise thiocyanate is:

REVIEW

✔ Chemistry
✔ Ages 16–18

Educational research has shown the value of placing theoretical ideas in 'live' project scenarios – or in real-world contexts. This practical activity is a good example of placing classical analytical chemistry in a real-world context. It also offers the opportunity to develop transferable skills in data processing and communication.

Marie Walsh, Limerick Institute of Technology, Ireland

$$SCN^- + 3H_2O + 2O_2 \rightarrow$$
$$HCO_3^- + NH^{4+} + SO_4^{2-} + H^+$$

This reaction is an example of bioremediation[w1], a process in which microbes are used to clean up contaminated soil and groundwater. Plants may also be used to clean up

Image courtesy of jetsandzeppelins/Flickr

Pesticide sign in Manito Park in Spokane, WA, USA contaminated land, in a process called phytoremediation[w2].

Before and after treatment, water can easily be tested for the presence of thiocyanate ions. If the solution turns blood red upon the addition of iron(III) chloride, then thiocyanate ions are present, as per this equation:

$$Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightarrow [FeSCN]^{2+}_{(aq)}$$

or, more fully,

$$[Fe(H_2O)_6]^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightarrow [Fe(H_2O)_5SCN]^{2+}_{(aq)} + H_2O_{(l)}$$

This reaction can be used for the quantitative analysis of low concentrations of thiocyanate ions. By using a colorimeter, you can measure the absorbance at 480 nm of the $[Fe(H_2O)_5SCN]^{2+}$ complex and deduce the precise concentration of thiocyanate ions, provided it is not too high. You can also use simple colour matching, although the results will be less precise and only qualitative.

Scenario

As explained in worksheet 1[w3], the students should place themselves in the role of a quality analyst from a small independent quality control firm that checks results to ensure that they meet the requirements of the UK Environment Agency.

The effluent of an industrial plant such as the Tata Steel site in Scunthorpe is known to contain around 250 mg/dm^3 (250 ppm) of thiocyanate ions. However, the safe level given by the UK Environment Agency is 10 mg/dm^3, so the effluent is treated and the thiocyanate concentration is reduced to 1 mg/dm^3, well below safe limits. The thiocyanate ions are removed from the effluent before it is fed into the River Trent.

There has been a recent period of severe cold weather, which can affect the activity of micro-organisms. The company is concerned that this has affected its water treatment plant and has reduced its effectiveness at removing thiocyanate ions from waste water.

The water is normally analysed for thiocyanate at the plant three times a day using a simple test: an acidic solution of iron(III) chloride is added to the water sample and the concentration of thiocyanate is measured photometrically by measuring the absorbance due to the iron(III) thiocyanate complex. A total of 16 separate tests are carried out every week.Samples of incoming effluent and the water ready for discharge into the river are also taken back for accurate analysis.

The company's analysts have checked, but the company is seeking an independent analyst: you!

Chemistry

Industrial landscape near Vancouver, Canada

Image from Flickr, courtesy of Evan Leeson

Image from Flickr, courtesy of k bottema

ACTIVITY

Become a water-quality analyst – general outline

Safety note

You should wear suitable eye and hand protection to handle acids and thiocyanates. You can check the safety guidelines on the *Science in School* website (www.scienceinschool.org/safety) and at the end of this print issue.

The following activity is aimed at students aged 16–18 and takes about 2 hours.

Preparation work

1. Make the following solutions in advance of the practical activity:
   a Solution of potassium thiocyanate (KSCN) at 250 mg/dm^3 (250 ppm) Dissolve 4.5 g potassium thiocyanate in 500 cm^3 of distilled water. Then dilute 50 cm^3 of this solution to 1 dm^3: it is now at a concentration of 250 mg/dm^3 of thiocyanate ions.
   b Solution of acidic iron(III) chloride ($FeCl_3(H_2O)_6$) at 0.41 mol/dm^3 Dissolve 50 g of $FeCl_3(H_2O)_6$ in about 250 cm^3 of a solution of hydrochloric acid (HCl) at 1 mol/dm^3
   c Twelve labelled samples of different concentrations of thiocyanate ions
      - Samples 1 to 4 represent water from the inlet pipe that goes into the waste water treatment plant. Dilute 10 times the solution of potassium thiocyanate at 250 mg/dm^3 to obtain a concentration of 25 mg/dm^3. It should then be slightly diluted to provide variation in concentration across the four samples.
      - Samples 5 to 8 represent water taken from the pipe releasing effluent from the waste water treatment plant to the river. They should be made at a concentration of 5 mg/dm^3: pipette 10 cm^3 of the solution of potassium thiocyanate at 250 mg/dm^3 into a 500 cm^3 volumetric flask and add distilled water up to the mark.
      - Samples 9 to 12 represent the water from the settling-in tanks. They should be made by mixing the solution of potassium thiocyanate at 25 mg/dm^3 with an equal volume or twice the volume of distilled water. The exact proportions of thiocyanate solution to water are not critical.
2. Provide the students with a plan of the plant (figure 1), worksheet 1[w3] outlining the scenario, and worksheet 2[w4] describing all the details about the analysis process.
3. The students should write a letter to the company that operates the waste water treatment plant requesting samples for analysis. They should specify at what point in the flow of effluent through the plant they would like samples to be taken, how many samples they require and when they should be taken. They should also specify the quantity of each sample needed, how they should be taken and what kind of container they should be collected with.
4. The students should work in pairs to analyse their samples according to the method described in worksheet 2[w4].

Materials

- Burette
- 7 volumetric flasks of 100 cm^3
- colorimeter and suitable filter (blue) – a solution of the complex displays maximum absorption at 480 nm
- 30 cm^3 of a solution of potassium thiocyanate at 250 mg/dm^3 for the thiocyanate ions (250 ppm)
- 70 cm^3 of a solution of iron(III) chloride solution at 0.41 mol/dm^3
- 10 cm^3 of a solution of unknown thiocyanate concentration (which you will need to test in your role as a quality analyst)

Procedure

Care: Wear eye protection: the solution of iron(III) chloride is an irritant.

1. Create a calibration graph

a. Fill three burettes, one with 250 mg/dm^3 potassium thiocyanate solution for the thiocyanate ions, one with distilled water, and one with the iron(III) chloride solution.

b. To six 100 cm^3 volumetric flasks, add 0.0, 2.0, 4.0, 6.0, 8.0 and 10.0 cm^3 of the solution of 250 mg/dm^3 potassium thiocyanate and label them A to F.

c. Add distilled water to each flask to bring the volume up to about 80 cm^3.

d. To each flask, add 10 cm^3 of the iron(III) chloride solution and then add distilled water to bring the volume up to 100 cm^3. Mix the solutions thoroughly.

Image courtesy of the Royal Society of Chemistry

Inside the analytical laboratory at the Tata Steel plant

Flask	A	B	C	D	E	F
Volume of potassium thiocyanate solution (cm^3)	0.0	2.0	4.0	6.0	8.0	10.0
Thiocyanate	0	5	10	15	20	25 (ppm)

e. Measure the absorbance of each solution using a colorimeter.

f. Plot a graph of absorbance (*y* axis) against the concentration of thiocyanate ions in ppm (*x* axis) for the six solutions.

Image courtesy of the Royal Society of Chemistry

Inside the analytical laboratory at the Tata Steel plant

Image from Flickr, courtesy of Global Water Partnership

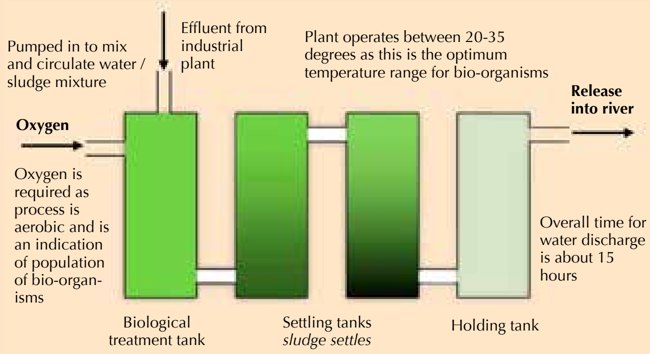

Figure 1. Annotated plan of the waste water treatment plant showing where samples can be taken

2. Analyse the sample

a. Add 10 cm^3 of the solution of unknown thiocyanate concentration to a 100 cm^3 volumetric flask and add distilled water to bring the volume in the flask up to about 80 cm^3.

b. Add 10 cm^3 iron(III) chloride solution to the flask and then add distilled water to bring the volume up to 100 cm^3. Mix the solution thoroughly.

c. Measure the absorbance of the solution using a colorimeter.

d. Use the graph to find the concentration of thiocyanate ions in the unknown solution.

3. Write a report to the waste water treatment company summarising your findings, including a recommendation about whether the effluent should be fed into the river or not. Students should describe the evidence on which their recommendation is based and comment on their confidence in the results, taking into account any percent error that may be involved in their analytic procedures.

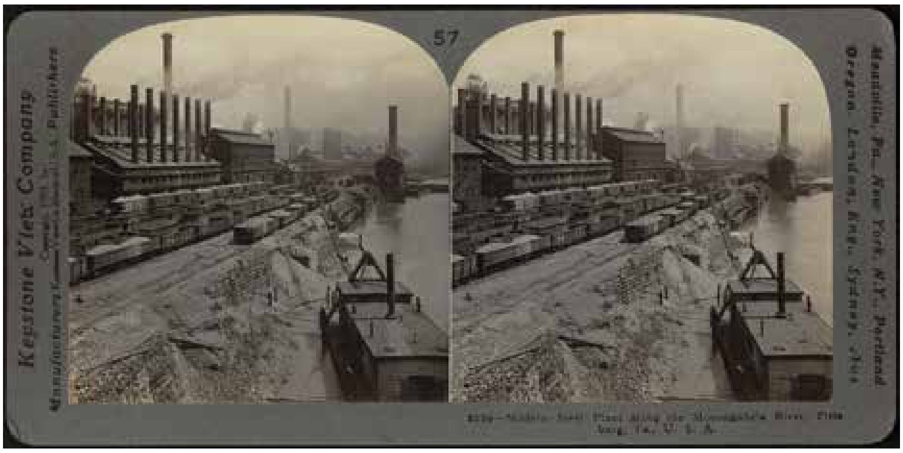

Image in the Public Domain. Source: Boston Public Library

Steel plant in Pittsburgh, PA, USA, in 1905.

Web references

w1 – To read more about a case study on bioremediation see: http://tiny-url.com/knfrqw3

w2 – To learn more about phytoremediation, visit: http://tinyurl.com/lrcc5ar

w3 – Download worksheet 1, outlining the scenario behind the activity, from the *Science in School* website. See: www.scienceinschool.org/2014/issue29/thiocyanate#w3

w4 – Download worksheet 2, describing the analysis process, from the *Science in School* website. See: www.scienceinschool.org/2014/issue29/thiocyanate#w4

Resources

To learn more about contaminated soils, see: http://tinyurl.com/lm-loqgg

This activity was originally designed by the Royal Society of Chemistry. See: http://rsc.li/1kj9YCV

If you found this article interesting, you may like to explore the other articles on chemistry published in *Science in School*. See: www.scienceinschool.org/chemistry

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Image courtesy of Global Water Partnership/Flickr

Water treatment plant in the Netherlands

The Riverside Walk by the River Anton at Goodworth Clatford in Hampshire, UK

To learn how to use this code, see page 57.