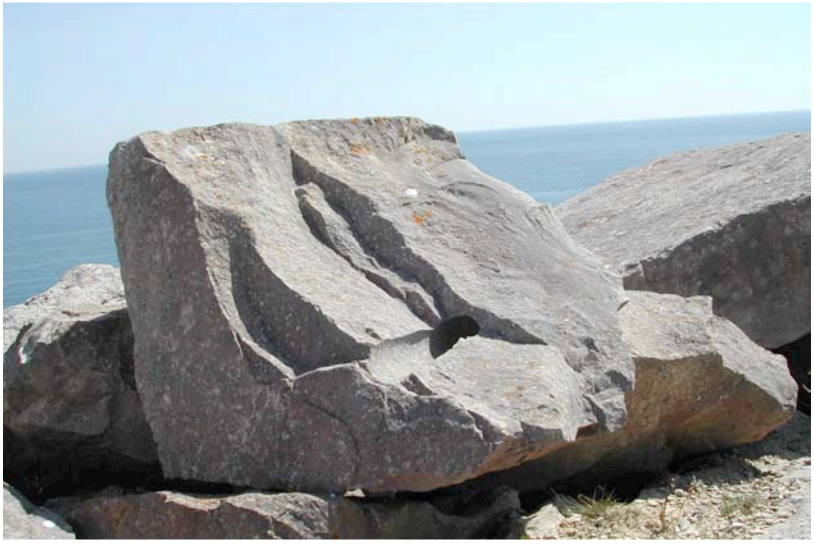
'Portland Stone - The ultimate building material.'

K.S 3: QCA Science - Unit 9G: Environmental Chemistry



The themes explored in Portland Stone – the ultimate building material, are designed to be used in conjunction with other resources to teach Unit 9G. The lessons provided deal with the chemical breakdown of rock, both in the landscape and when used for construction of buildings. Students will also carry out a range of experiments in class, which will require them to make predictions, plan, record results in an appropriate manner and use the information gained from the experiments to complete further tasks.

Portland Stone – the ultimate building material.

Teacher introduction and overview.

The themes explored in Portland Stone – the ultimate building material, are designed to be used in conjunction with other resources to teach Unit 9G. The lessons provided deal with the chemical breakdown of rock, both in the landscape and when used for construction of buildings.

- Students will examine the role of atmospheric gases in the creation of acid rain
- Students will evaluate the damage caused to Portland Stone by acid rain and consider ways in which the damage may be mitigated
- Using a range of secondary resources students will consider the role people's activities play in the production of gases such as sulphur dioxide and carbon dioxide.

Students will also carry out a range of experiments in class, which will require them to make predictions, plan, record results in an appropriate manner and use the information gained from the experiments to complete further tasks.

The basic structure is:

Lesson One

This lesson addresses the following questions:
Which pollutants are associated with the chemical weathering of rocks?
How do pollutants attack the surface of a rock or building stone?
Which factors promote chemical weathering?

An experiment to determine the effect of temperature and surface area on the rate of chemical weathering is included.

The homework task considers the national trends for atmospheric gases involved in the formation of acid rain and then asks the student to compare these trends with information on air quality in their local area. An alternative task is outlined which shows students how to collect primary data on the levels of pollution in their local area. The task could also be used as a whole class preparatory session if time allows.

Lesson Two

The lesson addresses the following question:
What happens to rocks and buildings over time?

The lesson reinforces the topics covered in lesson one, using the results form the student's experiments to discuss the factors influencing the rate of weathering. This knowledge is used to determine why some buildings, or parts of buildings experience more chemical weathering than others. A group activity asks students to consider a range of mediation methods that could be used to protect buildings made of Portland Stone, considering the feasibility of each in order to make a reasoned choice.

The homework task considers the role of the modern quarrying industry in promoting sustainable development. This task would also be suitable for use as a Citizenship activity.

Teacher Information
Following an introductory paragraph the way in which oolitic limestone is formed is described simply in a series of notes. Although this level of knowledge is not necessary for Key Stage 3 students teachers may find it useful to have the additional information in case they need to answer difficult questions!

Sections of QCA SOW covered

1. Learn that rocks, soils and building materials have a variety of chemical characteristics

- This quarry adapted unit only deals with the characteristics of limestone

2. Learn that chemical weathering alters rocks and building materials over time

3. Decide on the suitability of secondary sources for providing information on a particular question

- Only if first homework activity is used

Portland Stone – The Ultimate Building Material
Unit 9G Environmental chemistry

Science Year 9

About the unit

In this unit pupils:
- learn that rocks, soils and building materials have a variety of chemical characteristics
- learn that chemical weathering alters rocks and building materials over time
- consider how the atmosphere and water resources are affected by natural processes and the activity of humans
- consider how environmental conditions are monitored and controlled
- distinguish between different environmental issues

In scientific enquiry pupils:
- consider how scientists work to monitor the environment
- decide on the suitability of secondary sources for providing information on a particular question
- consider how evidence for climate and environmental change needs careful interpretation
- evaluate the evidence obtained
- investigate environmental change using evidence from secondary sources

This unit is expected to take approximately 7 hours.

Where the unit fits in

This unit builds on unit 7E 'Acids and alkalis', unit 7F 'Simple chemical reactions', unit 8G 'Rocks and weathering' and unit 8H 'The rock cycle', and on work on the reactions of acids in unit 9E 'Reactions of metals and metal compounds'. It relates to work on growing plants in unit 9D 'Plants for food' and work on using energy resources in unit 9I 'Energy and electricity'.

The unit builds on the use of sensors in unit 7 'Measuring physical data' in the ICT scheme of work. There are opportunities for citizenship education in this unit in the activities concerning the environment and sustainable development. It also relates to unit 14 'Can the earth cope? Ecosystems, population and resources' and unit 23 'Local action, global effects' in the geography scheme of work.

This unit provides opportunities to revisit and revise topics met in other units in years 7 and 8. With some pupils, teachers may wish to concentrate on some of the new topics, extending activities, and with others to spend more time on revision of previous work.

The unit provides the foundation for work in key stage 4 on changes to the atmosphere and Earth.

Expectations

At the end of this unit

in terms of scientific enquiry

most pupils will: make effective use of secondary sources of information about the relationship of soil type to plant growth and record their findings using ICT; identify and describe possible sources of information about the environment and select from these evidence about environmental change over time, identifying some strengths and weaknesses in the evidence

some pupils will not have made so much progress and will: select information from secondary sources relating plants to soil type and record findings using ICT; describe how some sources provide evidence about environmental change

some pupils will have progressed further and will: identify and explain the strengths and weaknesses of the evidence about environmental change obtained from secondary sources

in terms of materials and their properties

most pupils will: describe in terms of chemical reactions how acid rain arises and how it affects rocks, building materials and living things; describe how air and water pollution are monitored and how they might be controlled; distinguish between different environmental problems

some pupils will not have made so much progress and will: describe some of the consequences of acid rain and of other forms of pollution; identify why it is important to monitor and control pollution

some pupils will have progressed further and will: describe a variety of environmental issues and explain the implications of these

Prior learning

It is helpful if pupils:
- know that there are differences between soils which relate to the rocks they were formed from
- have experience of finding the pH of a variety of solutions and can relate the pH scale to the acidity of a solution

Health and safety

Risk assessments are required for any hazardous activity. In this unit pupils:

- investigate soils
- use a solution of sulphur dioxide
- use dilute solutions of acids

Model risk assessments used by most employers for normal science activities can be found in the publications listed in the *Teacher's guide*. Teachers need to follow these as indicated in the guidance notes for the activities, and consider what modifications are needed for individual classroom situations.

Language for learning

Through the activities in this unit pupils will be able to understand, use and spell correctly words and phrases:

- relating to environmental conditions and change
- with a more precise meaning in scientific contexts, *eg ozone depletion, global warming*
- relating to the environment, *eg vegetation cover, acid rain, catalytic converter, air and water quality, global warming*
- relating to scientific enquiry and sources of evidence, *eg reliable, biased, insufficient data*

Through the activities pupils could:

- appraise texts quickly and effectively for their usefulness
- recognise the standpoint of the author of a text and how it affects the meaning
- discuss and evaluate conflicting evidence to arrive at a considered viewpoint

Resources

Resources include:

- photographs and video clips of different rock formations, buildings, and rocks to illustrate weathering and sedimentation
- photographs of Cleopatra's Needle in London and similar obelisks in Egypt, illustrating weathering
- carbonate rocks, lime-cemented sandstone
- secondary sources for identifying local plants
- information about local environmental monitoring, *eg of air and water quality,* including ICT sources
- evidence indicative of air and/or water pollution at a particular time in the past, *eg pictures, descriptions, records of legislation, medical records, extracts from novels*
- simplified accounts, *eg video information about climate change,* of the greenhouse effect and the hole in the ozone layer

Out-of-school learning

Pupils could:

- read books, newspaper articles and periodicals about the environment, weather and climate changes. Activities relating to geological change will also support this unit
- watch feature films set in unfamiliar parts of the globe, *eg Arizona, deserts, volcanic regions*
- notice where lichens grow or do not grow in the locality
- look for information about air quality in local and national newspapers

LEARNING OBJECTIVES PUPILS SHOULD LEARN	POSSIBLE TEACHING ACTIVITIES	LEARNING OUTCOMES PUPILS	POINTS TO NOTE
How are soils different from each other?			
• that different soils have different characteristics, including pH ranges, and that this affects the plants that grow in them • to locate information about plants and preferred soil types in secondary sources • to use knowledge about acids, alkalis and neutralisation to suggest ways of reducing the acidity of soils	• Use secondary sources, *eg photographs, video clips,* to remind pupils about sedimentation and ask them what else they think plays a role in soil formation. Establish that vegetation and soil animals are also important. • Present pupils with information about different soils and show them soil-testing kits. Ask them to use secondary sources to find out why soils are acidic or alkaline, and to identify problems that this might cause and suggest possible cures. • Ask pupils to use the kits to test local and other soils. Use secondary sources to identify plants often found in particular soil types, *eg in the locality of the school,* the implications of soil type for agriculture and effects on some plants, *eg hydrangea colour.* Help pupils to summarise what they have found out in a database and use this to produce an information sheet.	• identify a range of differences between soils • use the results from work with soil-testing kits to rank soils in terms of acidity • identify and make a record of plants that are likely to grow well in a particular soil, *eg in the locality of the school*, and some that are not • suggest suitable methods of reducing acidity or alkalinity of soils	• In key stage 2 pupils are likely to have investigated some aspects of different soils, and animals and plants that are found in these. They are not likely to have considered the pH of soils. Soils could be tested with pH paper of an appropriate range rather than soil-testing kits. • See unit 3D 'Rocks and soils' and unit 6A 'Interdependence and adaptation' in the key stage 2 scheme of work. Unit 8G 'Rocks and weathering' covers the formation of sediment. The pH scale is introduced in unit 7E 'Acids and alkalis'. • It is important to make sure that pupils do not attribute all acidity in soils to acid rain. Contact with vegetation (roots) amplifies acidity. • Extension: pupils could survey wild flowers found in their immediate locality, relating this to preferred soil type, and exchange information with other schools via e-mail or the internet. **Safety** – if soils collected locally are used, check they are not contaminated with dog faeces. Wash hands after handling soils

What happens to rocks and building materials over time?

LEARNING OBJECTIVES PUPILS SHOULD LEARN	POSSIBLE TEACHING ACTIVITIES	LEARNING OUTCOMES PUPILS	POINTS TO NOTE
• that rocks and building materials change over time • about factors that affect the way in which materials change	• As a quick introductory activity, remind pupils of earlier work on local rocks and building materials and ask them to describe changes and compile a list of possible causes. Reinforce by showing video clips and/or photographs of a wide range of non-local weathered buildings and/or rocks and ask pupils to suggest a range of factors affecting weathering, *eg nature of rock, climate, local conditions of air, water, soil, position, vegetation cover*. • Ask pupils to identify factors that lead to extensive chemical weathering.	• describe how the appearance of landforms and/or buildings may change over time • identify factors, *eg low pH of air and rain together with high rainfall,* that favour chemical weathering	• Pupils could be shown photographs of Cleopatra's Needle in London and a corresponding obelisk in Egypt to compare the two. • The effect of vegetation could be illustrated by showing a photograph of a boulder of granite that has not weathered above the surface but beneath the soil and vegetation has been eaten away.

LEARNING OBJECTIVES PUPILS SHOULD LEARN	POSSIBLE TEACHING ACTIVITIES	LEARNING OUTCOMES PUPILS	POINTS TO NOTE
What causes acid rain?			
• that the atmosphere contains carbon dioxide from natural sources and the burning of fossil fuels, and this gas can dissolve in rainwater, causing it to be weakly acidic • that dissolved oxides of sulphur increase the acidity of rain • that oxides of sulphur in the air can arise from human activity and geological activity	• Ask pupils what they know about the importance of carbon dioxide in the air to plants and animals from their work on photosynthesis, and remind them that the atmosphere contains carbon dioxide from natural sources. Provide pupils with a range of solutions, *eg rainwater, water with dissolved carbon dioxide, water with dissolved sulphur dioxide*, and ask them to carry out tests to rank them according to pH. • Help pupils make a summary of the processes involved, *eg as a flow diagram.* Use video clips to illustrate how sulphur dioxide and oxides of nitrogen get into the air, *eg through volcanic eruptions, burning of fossil fuels*, and are transported away.	• identify which solutions are acidic • recognise that solutions with lower pH will be more corrosive • identify burning of fossil fuels, *eg in vehicles*, and volcanic activity as leading to acids in the environment • represent, *eg by drawing flow diagrams or equations*, a sequence of reactions in which acid rain is formed	• Pupils will have learnt in unit 7F 'Simple chemical reactions' that oxides are formed when materials burn. This may need to be reinforced in the context of burning carbon and sulphur. • Carbon dioxide as a raw material for photosynthesis is covered in unit 9C 'Plants and photosynthesis'. It is important that pupils realise that carbon dioxide in the air is essential for food production. • Some internet sites provide information about, and pictures of, recent volcanic eruptions. • Extension: pupils will already have represented some combustion reactions by word equations. It may be appropriate to introduce symbol equations to some pupils. **Safety** – sulphur dioxide is toxic and corrosive. Solutions should be left in stoppered bottles. Warn pupils with asthma not to inhale

What are the effects of acid rain and how can they be reduced?			
• about the effects of acid rain on rocks and building materials • why acid rain will dissolve some building stones • that acids in the environment can lead to corrosion of metal • to make careful observations over a period of time	• Provide pupils with named samples of a number of rocks, including some sandstones and some carbonates, *eg chalk, marble*, and metals, *eg zinc, iron, lead*, together with a very dilute solution of sulphuric acid (to represent acid rain), and ask pupils to investigate the effect of the acid on the materials. Ask them to suggest how to make and record careful observations of small changes over a period of time. Ask pupils to contribute results to a class record and bring together all the results.	• identify that acid rain affects some metals and carbonate-containing rocks • record observations accurately, indicating the time intervals between them	• Lime-cemented sandstone, *eg Cotswold type*, should be used. The sand grains fall apart as the cement dissolves. Before pupils use them, clay-cemented sandstones need to be investigated to see if water causes as much effect as 'acid rain'. • Pupils will have encountered the reactions of acids with carbonates and metals in unit 7F 'Simple chemical reactions' and unit 9E 'Reactions of metals and metal compounds'. • Extension: pupils could be asked to suggest what would happen if acid rain were to run into a stream passing through carbonate rocks, and to find out about the formation of limestone caves. **Safety** – a very dilute solution of sulphuric acid (0.005 mol dm^{-3}) is suitable for this activity
• that acid rain damages living organisms and materials • about ways in which emissions of oxides causing acid rain can be reduced • to use secondary sources to find information about key questions	• Ask pupils to use reference materials to identify the effect of acid rain on plants and animals in a particular location, and to identify the source(s) of the acid rain. • Ask them also to find out about ways, *eg catalytic converters, sulphur precipitators,* in which acidic emissions can be reduced. Summarise both sets of information in a class display or set of information cards.	• identify a source of acid rain and its effect on living organisms within a particular environment • describe how emissions from a particular source causing acid rain could be reduced	• Information about the effects and origins of acid rain can be found on the internet, *eg www.epa.gov/acidrain/student* • Extension: pupils could use very dilute acid to investigate the effect of acid rain on the germination of cress seeds.

LEARNING OBJECTIVES PUPILS SHOULD LEARN	POSSIBLE TEACHING ACTIVITIES	LEARNING OUTCOMES PUPILS	POINTS TO NOTE
Is pollution worse now?			
• how air or water pollution is monitored and controlled	• Invite an adult responsible for environmental matters, *eg an environmental health officer*, to talk about their work. Ask pupils to prepare questions to ask, *eg about the way in which air quality and water pollution are monitored, how the information is made public, what is done when air pollution rises.* Using the information from the talk and other sources, ask pupils to compile a summary sheet of what is done to protect their local environment, *eg the air and water quality.*	• describe ways in which pollution in their locality is monitored • identify steps taken to reduce pollution	• Indicator organisms, *eg lichens, tar spot of sycamore*, are susceptible to high acidity in air. The latter can be found in suburban areas.
• to decide what evidence should be collected • to collect evidence to answer a question • how to decide whether evidence is good enough to answer a question • to appraise texts quickly and effectively for their usefulness • to recognise the author's standpoint and how it affects the meaning	• Review with pupils ways in which quality of air and/or water is monitored or controlled and ask them whether they think there is more pollution, *eg of air or of water*, now than there was at a specific time in the past. Ask them to suggest the basis for their answers and then to think what evidence might be collected, *eg photographs, public records, paintings, individual medical records showing outbreaks of disease, descriptions of domestic and working environments, Clean Air Act and other legislation.* Consider a selection of available evidence and compare it with today's evidence. Ask pupils to decide whether the evidence is good enough to come to a firm conclusion, and to explain their decisions.	• identify and evaluate sources of information about the past, *eg photographs of city centres, contemporary descriptions of domestic/urban/rural life* • identify and evaluate sources of information about the present, *eg local and national monitoring records, media reports* • identify and describe differences between evidence from the past and present-day evidence • explain the strengths and weaknesses of present-day and past evidence	• Alternative questions relating to pollution in different localities could be investigated. • In this activity the emphasis should be on pupils' decisions about the strength of the evidence, rather than on the answer to the question about pollution.

LEARNING OBJECTIVES PUPILS SHOULD LEARN	POSSIBLE TEACHING ACTIVITIES	LEARNING OUTCOMES PUPILS	POINTS TO NOTE
Is global warming happening?			
• to use secondary sources to answer scientific questions • how to decide whether evidence is good enough to answer a question • to evaluate evidence put forward by others • to discuss and evaluate conflicting evidence to arrive at a considered viewpoint	• Present pupils with selected and simplified information, *eg on video*, about global changes in climate and ask groups to use it to prepare answers to questions, *eg* – *Have there been climate changes in the past?* – *What were the effects of these?* – *Is the Earth warming up? What evidence is there for this?* – *If the Earth is warming, what are the possible causes of this? What role does the burning of fossil fuels play? What evidence is there?* • Ask pupils to make brief presentations of their answers to the questions, making clear the evidence on which they are based. Ask other pupils to ask questions about the evidence. • Discuss pupils' presentations with them and examine the ways in which fuel is used and the impact of this on the environment and ways in which fuel consumption might be usefully limited.	• identify key trends in data and draw conclusions from these • explain how they used the evidence to draw conclusions • recognise where data is not sufficiently strong to support conclusions or can be interpreted in another way	• There are CD-ROMs offering information about global warming from a variety of perspectives. • This activity could be developed as role play, with pupils playing scientists who have different opinions. With some groups it may be helpful to prepare the information, suggest conclusions which can be drawn from it, and challenge pupils to identify whether the data supports the conclusions drawn. • Pupils may confuse the greenhouse effect and the hole in the ozone layer. It may be helpful to provide them with a simplified explanation of both effects.
Reviewing work			
• to identify the causes and effects of acid rain • to use scientific terminology accurately and with understanding	• Provide pupils with summary sheets about ways in which the environment is monitored and ask them to check their understanding using a series of prepared questions. • Consolidate key points with pupils.	• distinguish between different processes of environmental significance	• Aspects of sustainable development are also covered in unit 9D 'Plants for food', unit 9H 'Using chemistry' and unit 9I 'Energy and electricity'.

Lesson One

What are pollutants?

A pollutant is a toxic or harmful material released into the atmosphere.

What is chemical weathering?

All rocks at the Earth's surface weather as a result of physical, chemical or biological weathering. Chemical weathering occurs as certain chemicals, attack the minerals in a rock. The chemical reactions that take place can lead to dissolution of minerals or to the formation of new minerals. The most common chemicals involved with chemical weathering are atmospheric pollutants.

Which pollutants are associated with the chemical weathering of rocks?

- Sulphur oxides
- Nitrogen oxides
- Carbon dioxide

All occur naturally.

However the level of pollutants found in the atmosphere has steadily increased since the beginning of the industrial age, approximately 200 years ago. The levels of sulphur oxides, nitrogen oxides and carbon dioxide in urban areas can be mapped against human activity.

How do pollutants attack the surface of a rock?

- Wet deposition

The gases may combine with water droplets in the atmosphere to produce an acidic solution; when the water droplets are released, as rain, the rainwater is slightly acidic.

Carbon dioxide and water combine to form carbonic acid

$$H_2O + CO_2 \rightarrow H_2CO_3$$

This is acid rain.

- Dry deposition

The pollutant sulphur dioxide is often deposited on the rock surface in the form of a gas, which then either dissolves in the moisture already present in the stone or reacts with the calcium carbonate to produce a new mineral, gypsum.

$$CaCO_3 + SO_2 \rightarrow CaSO_3\ CO_2$$

This reaction also plays a role in the production of acid rain as the break down of the calcium carbonate releases carbon dioxide.

Where do the pollutants come from?

Sources of pollution for wet deposition may be many miles away from the building being attacked by the rain, the source of pollutants involved in dry deposition are local. The following activities are responsible for most of the pollution produced by human activity.

- Burning fossil fuels for energy production
- Emissions from car exhausts

Natural sources of the pollutants include

Volcanic eruptions

What effect does acid rain have on rock?

Acid rain reacts with the minerals in a rock; it reacts with rock composed of the mineral calcite, which is formed from calcium carbonate ($CaCO_3$). The rocks are described as carbonate rocks.

Rocks formed from calcite are:

Limestone
Chalk
Marble

When carbonic acid reacts with calcite the following chemical process takes place:

$$CaCo_3 + H_2CO_3 \rightarrow Ca + 2HCO_3$$

calcite | carbonic acid (acid rain) | calcium | bicarbonate ions

This is a chemical weathering process, the breakdown of rock *in situ* as a result of chemical changes to the minerals.

What happens to the rock as a result of this process?

The calcium and bicarbonate ions are carried away in solution. The outer layers of the rock are gradually lost as acid rain attacks the exposed surface. Rainwater will also attack the mineral crystals within the rock if the rock is sufficiently porous to allow water to seep into it.

Activity

- ❖ Question: What factors promote chemical weathering?

- The type of pollutants dissolved in rainwater.

- Rainwater containing dissolved carbon dioxide is slightly acidic. Acid rain however has a pH range of between1.5 to 5.6. Therefore the more sources of sulphur dioxide and nitrogen oxides there are in an area the more chemical weathering there will be.

- ❖ Question: What other factors promote chemical weathering?

Design and carry out an experiment to test the following questions.

1. Is the rate of chemical weathering affected by temperature?
2. Is the rate of chemical weathering affected by surface area?

This experiment could be conducted using an indigestion tablet such as Rennie with a calcium carbonate base, however they do not dissolve quickly and if the water is agitated to speed up the breakdown it becomes too cloudy to enable students to monitor the breakdown accurately. Using a tablet that fizzes in water, such as Alka Seltzer provides a more vivid example of the effects of changing the water temperature and surface area even though this does not have a carbonate base.

- Use a whole class activity to design the experiment. Ask students to predict what will happen if water temperature is increased or surface area increased. What will they need to do to ensure the experiment is controlled and results can be shared?

    - Decide on the amount of water to be used so each test is the same, say 100ml
    - Use a control. One group uses water at room temperature.
    - Ensure accurate measurement of water temperature
    - Ensure accurate division of tablets – if crushing do this with a pestle and mortar and ensure all grains are tipped into the water, if breaking the tablet in half measure and cut accurately.
    - Ensure accurate measurement of time. Students will use a stopwatch but will need to agree <u>how</u> to time – start when the tablet is submerged, stop when no bubbles are seen for example.
    - Use a common recording format

        - In order to complete the experiments in one lesson give each group a different water temperature to work with. Results will then be shared amongst the whole class.

Experiments

- Use whole tablets and different water temperatures (from iced water to water at 45 degrees C) to determine if temperature has an affect on chemical weathering rates

- 3 tests. Use a whole, a half and a crushed tablet dissolved in water to determine if surface area is important to the rate of chemical weathering. Each group carries out this experiment using water at the same temperature as for their first experiment.

- Either use an interactive whiteboard, a computer or a ready prepared OHT to collect the results. Have a table ready and ask one member from each group to fill in their group's results as they complete the experiment. Print the results so each group has access to the data.

- Do the results match the predictions?

Homework

Each student will need a copy of the free publication Sustainable Development Indicators In Your Pocket, 2005. These can be obtained in bulk from DEFRA Publications, telephone 08459 556000 and quote code PB 11008 for A6 size booklets or PB 11008A for A4 size.

The section of the book dealing with air quality highlights the effect road traffic is having on air quality. You know that certain air borne pollutants will lead to the formation of acid rain.

Task

Using the graphs in this section of the booklet identify trends for sulphur dioxide, nitrogen oxides and carbon dioxide and answer the following question:

Should we still be worrying about acid rain?

Next find out if the air quality in your area is good or bad.
Use the web site http://www.airquality.co.uk/archive/index.php
Use the map and click on your regional area
This will tell you what the air quality is like where you live

Follow the link - For More Information - to find more detailed information from the monitoring sites in your region – is there a monitoring site in your village or town?

Task
Based on the information you have found about your local area from the web site, **not** the information from the booklet, write another sentence or two to answer the same question:

Should we still be worrying about acid rain?

Which of the resources you have used do you think was most useful for helping you answer the question?

Alternative homework activity

What is air quality like in your area?

Each student will need a piece of laminated card with a hole punched near the top. Thread a piece of string through the hole. Cover the card with doubled sided sticky tape. The student chooses a place to hang the card, either in their garden or in the school grounds. Students will need a sealable bag in which to place their piece of card when it is collected. Cards should be collected on the morning of the next lesson and brought to class. What differences can be seen between the cards? Are the students surprised at the amount of airborne pollution in their area? Were those cards paced nearer the road dirtier than those placed in the school grounds?

What do the students think **they** could do to reduce levels of pollution?

Lesson Two

What happens to rocks and building materials over time?

Rocks and building stones are both subject to physical and chemical weathering processes, which break down the rock over time. Other building materials such as lime mortar are also subject to chemical weathering as acid rain attacks the carbonate component of the mortar.

How quickly do buildings decay as a result of chemical weathering?

This depends on:

- The building stone used
- The surface area open to attack
- Pollution levels
- Rainfall acidity
- The amount of rainfall
- The direction the building faces

  - ❖ Use the headings as support for an active question and answer session to ensure students have understood the interrelated factors involved in the formation of acid rain and the effect that has on certain types of building stone.

Type of building stone used:

Igneous rocks such as granite are hard, crystalline rocks resistant to weathering; they are often used as polished facing stones on buildings. Physical weathering is the dominant form of weathering associated with igneous rocks but once the crystal structure has been weakened chemical weathering will also take place.

Sedimentary rocks such as sandstone are used as blocks for building; their strength depends on the mineral cement holding the grains together. The stone is easily weathered and often turns an unsightly black colour if subjected to chemical weathering.

Carbonate rocks are used extensively for building purposes. The stone is attractive to look at and easy to work with. Following the Great Fire of

London in 1666 a particular type of carbonate rock, a limestone from the Island of Portland, Dorset, known as Portland Stone was used to build St Paul's Cathedral. Portland Stone is a very compact stone and relatively resistant to weathering when compared to the fossil rich limestones of Derbyshire and Yorkshire. It had been used as a building stone since Roman times but its use for such a prestigious building as St Paul's Cathedral meant it soon became a very popular building stone for important buildings in towns and cities across Britain. Today architects and town planners have to deal with the consequences of pollution and look at ways to repair, conserve and protect buildings made from Portland Stone.

The surface area open to attack

Students have experimental evidence to show that as surface area increases chemical weathering proceeds more rapidly. As minerals are weathered so their surface area is increased leading to an increase in the speed of the weathering process. If the building has been decorated by carving then those areas will be more susceptible to chemical weathering than the building bocks themselves as the surface area is greater. The rock will also have been subjected to stress when it was carved and this will also have weakened it.

Pollution levels

The amount of sulphur dioxide being produced through the burning of fossil fuels has fallen since the 1950's. Pollution levels in London have fallen dramatically since the Clean Air Act. The rate of chemical weathering on St Paul's Cathedral was monitored between 1980 and 2000, a dramatic decrease being seen after 1983 the year the coal fired Battersea Power Station closed down. The number of cars on the roads continues to increase however so levels of nitrogen oxides and carbon dioxide is increasing.

Rainfall acidity and amount of rainfall

In rainwater acidity is increased by the pollutants it contains. In Britain rainfall occurs throughout the year and so the potential for the chemical weathering of rock and building stone is greatly enhanced.

The direction the building faces

On exposed surfaces the reaction products will be washed away by rainfall. As this happens so the surface of the building stone recedes. In sheltered spots the reaction products accumulate and form a black crust on the building stone. North facing buildings are likely to stay wetter longer giving the acidic rainwater a longer time to act.

Activity
How can we protect our buildings from chemical weathering?

This activity could be run as a class discussion, teacher led using the options outlined or as a group work activity where groups are asked to consider the various options provided and agree on a course of action.

For the group activity each group will need a copy of the task entitled "How can we protect our buildings?" They will also need a copy of each of the options and associated problems. In their groups students should work together to identify ways of mitigating the problems; they should agree on the best choice or combination of options and prepare a brief explanation of why they have opted for that choice. The group should elect a spokesperson to present the group's decision, and the reasons for that choice, to the rest of the class.

Suggestions for overcoming the problems are provided; these should be reproduced and given to the groups once they have begun their own discussions. The options available for the company to consider vary in complexity; differentiation could be achieved by selecting specific tasks for particular groups or by distributing options and suggestions cards at the same time.

How can we protect our buildings from chemical weathering?

A hypothetical case study.

New Town was once the centre of the cotton industry in Britain, the industry brought wealth to the area and in 1759 the owners of the local mills paid for a new town hall to be built using Portland Stone. The front of the building, which faces north, was intricately carved and busts of the local mill owners were housed in niches around the magnificent front door. After years of neglect the present council has decided it must do something about the damage caused to the building by the effects of chemical weathering.

Your company has been asked to consider a range of options and decide which would be the best option or combination of options for the council to employ to protect and conserve the building. A spokesperson for your company will be asked to give a verbal report to the council on your decision.

Option One: Patch up with mortar or new blocks of building stone

Card One

Patching up with mortar is not a long - term solution.

Mortar is a mix of sand grains and lime or cement and water. The lime or cement is the binder that gives the mortar its strength.

Problems

- Although lime mortar is easy to work it has high permeability to water and water vapour.

Removing weathered material and replacing with new stone

Problems

- New building stone may not match the original material used
- Removing the old stone may cause damage to remaining sound stone, which would allow chemical weathering processes to operate more quickly on the exposed surface.

Option One: Patch up with mortar or new blocks of building stone

Card Two

How could we solve the problems?

- Local building material would not match the original stone, remember Portland Stone is a very specific type of limestone found in the south of England. Unless new building stone can be quarried from the same area as the original stone the likelihood of the finished work being acceptable is slim.
- If the damage to the building is extensive it may be worth considering using a new facing material on the front of the building, this could be of a local material, of Portland stone or of a different limestone.
- As the front of the building faces north any carbonate rock will be weathered rapidly so perhaps consideration should be given to the use of a different rock type.

Option Two: Air quality is improving so leave the building alone!

Card One

During the 1700 and 1800's the air was heavily polluted as a result of industrialisation. When coal was used as the main means of producing energy, either through the creation of steam or in coal fired power stations the air was heavily polluted, sulphur dioxide being released from the burning coal.
Since the 1950's the level of air pollutants, in particular sulphur dioxide, in the atmosphere has been gradually decreasing. This is due to legislation. The Great Smog in London in 1956, brought about by a combination of unusual weather conditions and an increase in the amount of coal being burnt not just in power stations but in homes as well, led to the Clean Air Act. The Clean Air Act stated that only smokeless fuel could be burnt in London and gradually in the rest of the country. As the country became free from smoke so rates of chemical weathering began to decrease.

Problems

There may be less smoke and soot in the air but the levels of carbon dioxide and nitrogen oxides are increasing rapidly. The emissions from cars and lorries are called transboundary pollutants as the wind carries them long distances from where they were actually produced. So even if New Town were to make the centre of the town traffic free these pollutants would still lead to the formation of acid rain which would attack the building

Option Three: Cleaning the building

Card One
Cleaning removes salts and dirt, which build up on the surface of the building stone.

Problems

- Over enthusiastic cleaning removes the surface of the stone thereby providing a fresh surface for attack by pollutants
- Environmental damage – cleaning a building requires a huge amount of water and very strong chemicals, run off may pollute local rivers and the chemicals may destroy local plant life.
- Buildings crumble – if the building stone has been subjected to chemical weathering over a sustained period it may be that the salts are actually playing a part in holding the building stone together

Option Three: Cleaning the building

Card Two

How could we solve the problems?

- Use a slow and gentle water flow rather than blasting the building with high power water jets
- Use eco friendly cleaning agents, collect the run off and pump directly into the drains or collect the run off and transport directly to the water treatment plant – not very likely as would prove too expensive.
- Carry out a thorough survey of the building checking how weak the structure of the stone was, this could result in only partial cleaning of areas which were strong enough to withstand this approach

Option Four: Shield the building

Card One

It may be possible to protect certain parts of the building, say a statue or carving, by encasing them in glass or plastic, as this would reduce the amount of rain reaching the carving.

Problems

- Unsightly
- Could trap moisture in the stone
- May encourage the growth of lichens which generate carbonic acid which leads to chemical weathering

Option Four: Shield the building

Card Two

How could we solve the problems?

- Decide if it would be better to remove the carving or statue and display it within the building
- Only use shielding if there is no other choice
- Monitor the moisture levels of the carving or statue electronically to ensure no further damage is taking place
- Physically inspect the encased statue or carving regularly to look for evidence of decay or the growth of lichens

Option Five: Add a Surface Coating

Card One

Surface coatings can be sprayed onto the building. They need to be water repellent because water is involved in the chemical weathering processes.

Problems

- The coating may be permeable to gas in which case sulphur dioxide could still penetrate the stone and attack it.
- The coating will trap any moisture already in the stone and may actually increase the rate of chemical weathering taking place.
- May not last long – no research beyond 25 years to show how the coatings behave when subjected to constant attack by acid rain.

Option Five: Add a Surface Coating

Card Two

How could we solve the problems?

- Use directional membranes, these allow moisture to escape but not to enter.
- Carry out research into polymers which protect the building stone from further chemical attack yet allow the building to breathe so moisture can escape.

Homework

Sustainable development means using the resources we have available today to good effect without impacting on the lives of people in the future. Sustainable development doesn't mean we have to stop using things like building stone but it does mean we have to think about the way we use it and the impact we have on the environment when using it. Quarrying stone and aggregates such as sand and gravel is important for the lives we lead today; we use them for construction of houses, roads, airports, and reservoirs and in the manufacture of goods such as glassware.

La Farge, a large quarrying company, extracts 50,000 tonnes of sand and gravel from Besthorpe Quarry in North Lincolnshire every year and sends it to Whitworth Wharf in Wakefield, Yorkshire. From 2005 they will be transporting the sands and gravel by canal. This will save 80 lorry journeys each week (20,000 over 5 years).

Task

Using the knowledge you have about chemical weathering and any secondary sources you think useful explain what impact the decision La Farge has made will have on air quality and the sustainability of buildings in the East Midlands.

Then answer the following questions

1. The UK Government has agreed that companies can use even larger lorries on the roads than they do now; the reason given for the decision was that larger lorries mean fewer journeys. Do you think this is what is meant by sustainable development?
2. Should the government encourage more industries to use canals or the railways instead of roads?

What difficulties might this cause for industry?

Teachers Information on the Formation of Portland Stone

Usually when students think of limestones they think of rocks containing the visible remains of ancient organisms, fossils. Oolitic limestones are different; they are formed from thousands and thousands of concentric structures, which form on the sea floor. This regularity is what makes Portland Stone so valuable as a building stone, it is easy to carve, relatively resistant to weathering and, as a bonus, is a beautiful creamy white colour. During the Industrial Revolution Portland Stone was seen as the ultimate building stone, chemical weathering led to the loss of the outer layer of the stone revealing the clean stone beneath. In contrast sandstones used as building stone turned black as the chemical reactions, caused by acid rain, took place on its surface.

- ❖ The limestone found on the Isle of Portland in Dorset was formed during the Jurassic period, approximately 208 to145 million years before the present. At that time the landmass we call Southern England was at approximately latitude 30 to 35 degrees north, where Florida and Israel can be found today. Much of the landmass was below sea level until the late Jurassic. A series of changes in sea level led to parts of Southern England being exposed for periods of time until a rise in sea level led to them being inundated once again. A series of sea level changes such as this is described as transgression and regression. As sea levels rose and fell a series of basins developed. The Isle of Portland lay in the west basin, the west and east basin being separated by a swell, strong currents running northeast to southwest. The waters would have been warm and shallow, with high tidal activity but perhaps most importantly, at this time the waters would also have been supersaturated with calcium carbonate. This very specific set of features enabled a particular type of limestone to form.

- Oolites form in shallow, high-energy marine waters, usually in near shore environments. They form today on the Bahamas Banks and in the Persian Gulf.
- Oolites form when there is a high level of dissolved calcium carbonate in the water.

- The Sun heats the water and dissolved carbon dioxide escapes as a gas into the atmosphere.
- The calcium and bicarbonate ions left in the water combine to form calcium carbonate ($CaCO_3$).

- The amount of dissolved calcium carbonate in the water continues to increase until the water is supersaturated. At this point crystals of calcium carbonate (in the form of the mineral calcite) begin to grow and form lime muds on the sea floor.

  - ❖ Should you wish to show your students how this happens here is an easy experiment, which shows how crystals grow out of solution. Add common household salt to warm water until the water has turned white and can hold no more salt. Pour some of the salt solution into a saucer; add a short piece of string, submerged in the water but long enough to leave a "tail" overhanging the saucer edge. Place the saucer on a sunny windowsill and, as the water evaporates, salt crystals will begin to grow on the string, the supersaturated water cannot "fit" all the salt into a smaller volume of water and so it precipitates onto an available surface.

- In the shallow seas of the Jurassic the strong currents of the swell rolled tiny pieces of broken shell and sand grains backwards and forwards.
- As that happened the calcium carbonate on the sea floor formed concentric layers around the nucleus these tiny grains provided.

- Occasionally the newly forming oolite was buried in the muds and so stopped rolling. This gave the calcium carbonate time to harden.
- When the little ball was re-exposed the rolling and accumulation of calcium carbonate continued.
- The process of exposure and burial continued over time, most oolites were small with diameters of <0.5mm but a very few reached sizes of up 2 mm.

  - ❖ A good analogue to use with students is the idea of a snowball, a small amount of snow needs to be formed into a small hard ball to begin the process (the grain forming the nuclei) then the ball can be rolled backwards and forwards in the snow gradually becoming larger and larger.

- ❖ For a visual impression of oolites, if no actual rock samples are available, look at a tray of crushed polystyrene. As the polystyrene is crushed it forms small balls not dissimilar to oolites.

- Eventually the many thousands of thousands of oolites were compressed together and lithified. Lithification is the process that turns loose sediments into rock by cementing the sediments together, in this case with more calcium carbonate. This is Portland Stone.