AIR POLLUTION

Air Pollution is one of a series of enquiries and additional resources which together form **Beyond fair testing: Teaching different types of scientific enquiry,**

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SEP
Science Enhancement Programme

King's College London
University of London

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Teachers Guide

Student Materials

AIR POLLUTION: OVERVIEW

There are three enquiries in the 'Air Pollution materials: enquiries A, B and C.

Enquiry type:

- Enquiry A: Exploring enquiry
- Enquiry B: Pattern-seeking enquiry
- Enquiry C: Pattern seeking enquiry

The enquiry activities were designed for use with Y8 or Y9, but you may find that the enquiry activities are also of use with Y10 classes studying air pollution.

Air Pollution Enquiry A: overview
(Exploring enquiry)

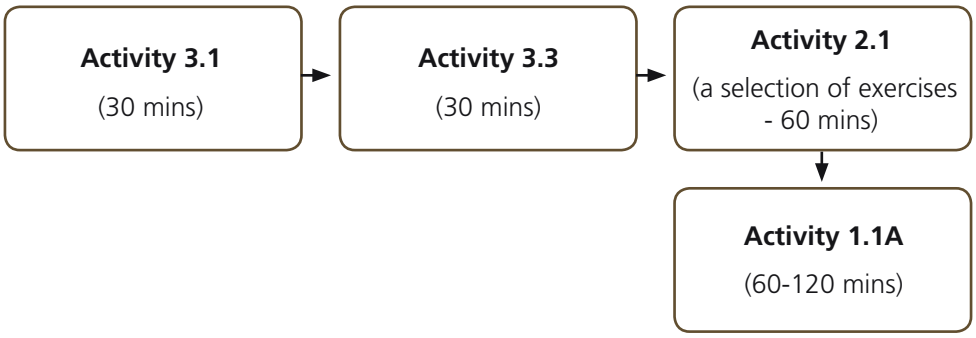
Section	Activity	Links to KS3 PoS/ Scheme of work	Links to KS4 PoS	Learning objectives Students will be able to:	Assumed prior knowledge and understanding
1. Core enquiry	Enquiry A Activity 1.1A	**Sc1: investigative skills:** Obtaining and presenting evidence, Considering evidence Evaluating.	**How science works:** Practical and enquiry skills. Communication skills.	• look for patterns in graphical data and assess the strength of any patterns observed • look for relations between two variables using a scattergraph • use patterns in data to make predictions and judge the likelihood of these predictions being correct.	None
2. Background knowledge	2.1	**Sc3: Changing materials; Patterns of Behaviour** **QCA SoW** 9G: Environmental Chemistry; aspects of 7E: Acids and Alkalis 7F: Simple Chemical Reactions	**Chemical and material behaviour:** (6a and 6c) **Environment, Earth and universe:** Effects of human activity on the environment (8a and 8b)	• name sources of air pollution and those which cause acid rain. • identify areas which suffer higher pollution levels and account for differences in pollution levels. • describe how acidic air pollution is deposited. • relate information on pollution to their own part of the UK. • describe the chemical reactions involved in the formation of acid rain	Some simple chemical formulae and equations.
3. Procedural understanding	3.1	**Sc1: investigative skills:** Considering evidence Evaluating	**How science works:** Practical and enquiry skills. Communication skills.	• decide whether or not there is a correlation between two variables in a scattergraph • decide whether or not the sample size is big enough to be confident about an apparent correlation. • create scattergraphs on a spreadsheet.	Familiarity with excel spreadsheets
	3.3	**Sc1 Investigative skills:** Considering evidence Evaluating	**How science works:** Practical and enquiry skills. Communication skills.	• identify daily patterns in concentrations of air pollutants • make judgements about the strengths of any patterns identified.	Ability to read graphs

ENQUIRY A: ROUTES

Route 1 (assumes students have already learnt the skills and knowledge to begin activity 1.1A)
The overall time depends on the extent to which students are given access to additional data in part 3 of the enquiry in order to explore their research question more thoroughly. The overall time will be between 1 and 2 hours.

Activity 1.1A
(60-120 mins)

Route 2 (uses activities from sections 2 and 3 to provide relevant knowledge and procedural understanding to begin core enquiry in section 1)
Activity 2.1 is about the causes of acid rain. Choose a selection of exercises from activity 2.1 to match the needs of your students. We recommend a maximum of 1 hour on activity 2.1.
Overall time is roughly 3-4 hours.

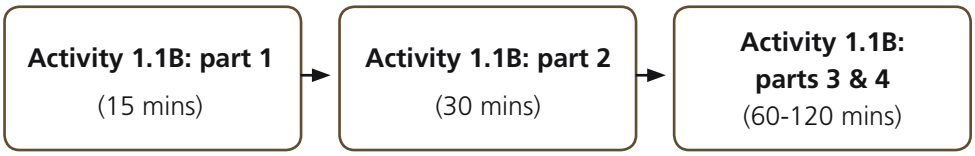


Air Pollution Enquiry B: overview
(Pattern-seeking enquiry)

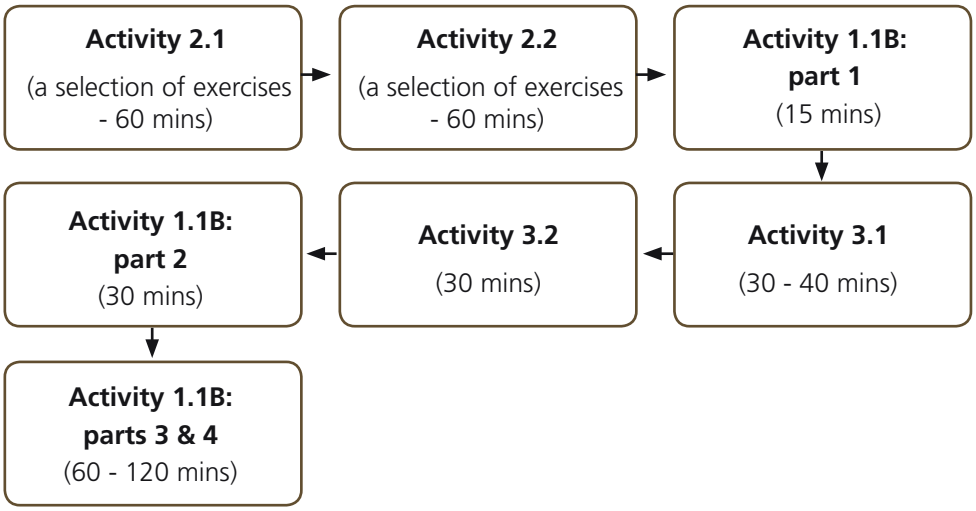
Section	Activity	Links to KS3 PoS/ Scheme of work	Links to KS4 PoS	Learning objectives Students will be able to:	Assumed prior knowledge and understanding
1. Core enquiry	Enquiry B 1.1B	**Sc1: investigative skills:** Obtaining and presenting evidence, Considering evidence Evaluating.	**How science works:** Practical and enquiry skills. Communication skills.	• sort out the causes and effects within the data table and use scientific models in creating and answering questions • judge the qualities of a good problem statement in the context of a pattern-seeking enquiry • plan how they will analyse data to address a problem • manipulate data (work with tables and scattergraphs) to look for patterns of relations between two variables • draw a conclusion based on evidence • explain their conclusion in terms of scientific ideas • evaluate the extent to which the conclusions drawn are supported by the evidence.	Knowledge of possible causes of acid rain and how it is transported.
2. Background knowledge	2.1	**Sc3: Changing materials;** Patterns of Behaviour **QCA SoW** 9G: Environmental Chemistry and aspects of 7E: Acids and Alkalis & 7F: Simple Chemical Reactions	**Chemical and material behaviour:** (6a and 6c) **Environment, Earth and universe:** Effects of human activity on the environment (8a and 8b)	• name sources of air pollution and those which cause acid rain. • identify areas which suffer higher pollution levels and account for differences in pollution levels. • describe how acidic air pollution is deposited. • relate information on pollution to their own part of the UK. • describe the chemical reactions involved in the formation of acid rain	Some simple chemical formulae and equations.
	2.2	**Sc3: Changing materials; Patterns of Behaviour** **QCA SoW** 9G: Environmental Chemistry	**Environment, Earth and universe:** Effects of human activity on the environment (8a and 8b)	• describe how rivers and their drainage systems become acidic and how this affects aquatic life. • describe some ways in which acid rain affects buildings, trees and people. • describe how acid rain and air pollution are word-wide problems, not just something affecting the UK or Europe. • consider the evidence linking effects and their possible causes.	pH scale as a measure of acidity of a solution.
3. Procedural understanding	3.1	**Sc1 Investigative skills:** Considering evidence Evaluating	**How science works:** Practical and enquiry skills. Communication skills.	• decide whether or not there is a correlation between two variables in a scattergraph • decide whether or not the sample size is big enough to be confident about an apparent correlation. • create scattergraphs on a spreadsheet.	Familiarity with excel spreadsheets
	3.2	**Sc1 Investigative skills:** Considering evidence Evaluating	**How science works:** Practical and enquiry skills. Communication skills.	• rearrange data in a table and work out mean values for air pollution by wind direction • describe factors which affect whether or not there is a pattern relating levels of two variables. These include the size of differences between means of values, the variability of the data, the number of readings for each value and factors other than the ones studied which might have an impact on air pollution.	Familiarity with excel spreadsheets

ENQUIRY B: ROUTES

Route 1 (assumes students have already learnt the skills and knowledge to begin activity 1.1B)
The overall time depends on students' facility with Excel. The overall time will be about 2 hours.



Route 2 (uses activities from sections 2 and 3 to provide relevant knowledge and procedural understanding to begin core enquiry in section 1)
Activity 2.1 is about the causes of acid rain. Whether all four exercises in this activity are used will depend what students already know.
Overall time is roughly 5 hours.



Air Pollution Enquiry C: overview
(Pattern-seeking enquiry)

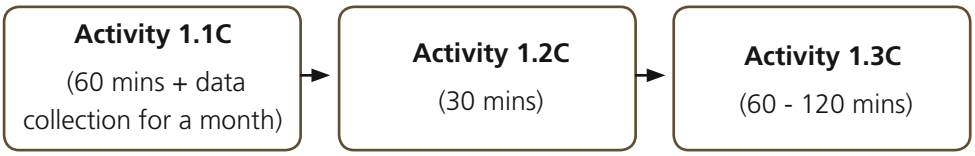
Section	Activity	Links to KS3 PoS/ Scheme of work	Links to KS4 PoS	Learning objectives Students will be able to:	Assumed prior knowledge and understanding
1. Core enquiry	Enquiry C Activity 1.1C	**Sc1: investigative skills:** Obtaining and presenting evidence.	**How science works:** Practical and enquiry skills. Communication skills.	• retrieve data from the internet • make first hand measurements of the volume and pH of rain water • record data in a table or an electronic spreadsheet.	None
	Enquiry C Activity 1.2C	**Sc1: investigative skills:** Planning Considering evidence Evaluating.	**How science works:** Practical and enquiry skills. Communication skills.	• tabulate data, work out mean concentrations of pollutants and compare the levels of pollution for different wind directions and wind speeds • draw scattergraphs to look for patterns in data.	Knowledge of possible causes of acid rain and how it is transported.
	Enquiry C Activity 1.3C	**Sc1: investigative skills:** Planning Considering evidence Evaluating.	**How science works:** Practical and enquiry skills. Communication skills.	• sort out the causes and effects within the data table and use scientific models in creating and answering questions based upon their data collection • judge the qualities of a good problem statement in the context of a pattern-seeking enquiry. • plan how they will analyse data to address a problem • manipulate data (work with tables and scattergraphs) to look for patterns of relations between two variables • draw a conclusion based on evidence • explain their conclusion in terms of scientific ideas. • evaluate the extent to which the conclusions drawn are supported by the evidence.	Knowledge of possible causes of acid rain and how it is transported.
2. Background knowledge	2.1	**Sc3: Changing materials; Patterns of Behaviour** **QCA SoW** 9G: Environmental Chemistry and aspects of 7E: Acids and Alkalis & F: Simple Chemical Reactions	**Chemical and material behaviour:** (6a and 6c)	• name sources of air pollution and those which cause acid rain. • identify areas which suffer higher pollution levels and account for differences in pollution levels. • describe how acidic air pollution is deposited. • relate information on pollution to their own part of the UK. • describe the chemical reactions involved in the formation of acid rain	Some simple chemical formulae and equations.
	2.2	**Sc3: Changing materials Patterns of Behaviour** **QCA SoW** 9G: Environmental Chemistry	**Environment, Earth and universe:** Effects of human activity on the environment (8a and 8b)	• describe how rivers and their drainage systems become acidic and how this affects aquatic life. • describe some ways in which acid rain affects buildings, trees and people. • understand that acid rain and air pollution are world-wide problems, not just something affecting the UK or Europe. • consider the evidence linking effects and their possible causes.	pH scale as a measure of acidity of a solution.

Air Pollution Enquiry C: (continued)

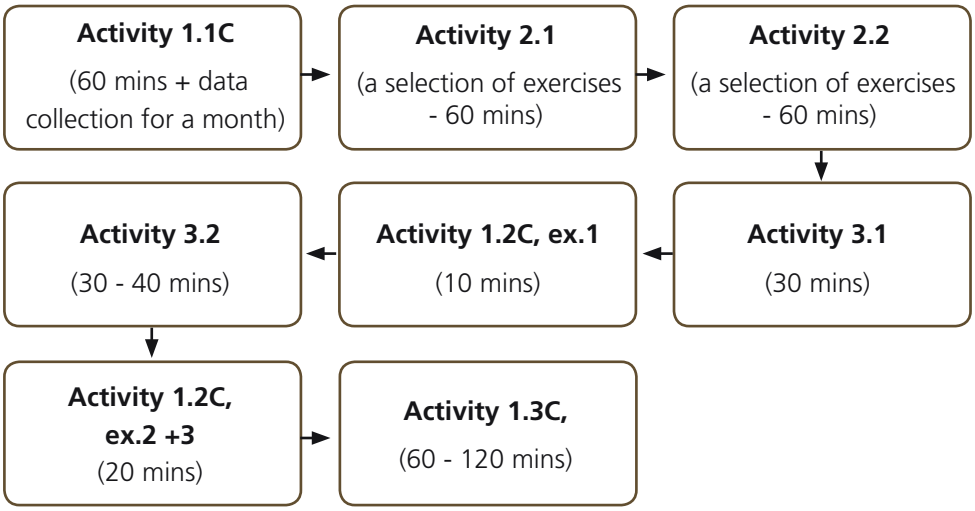
Section	Activity	Links to KS3 PoS/ Scheme of work	Links to KS4 PoS	Learning objectives Students will be able to:	Assumed prior knowledge and understanding
3. Procedural understanding	3.1	**Sc1 Investigative skills:** Considering evidence Evaluating	**How science works:** Practical and enquiry skills. Communication skills.	• decide whether or not there is a correlation between two variables in a scattergraph • decide whether or not the sample size is big enough to be confident about an apparent correlation. • create scattergraphs on a spreadsheet.	Familiarity with excel spreadsheets
	3.2	**Sc1 Investigative skills:** Considering evidence Evaluating	**How science works:** Practical and enquiry skills. Communication skills.	• rearrange data in a table and work out mean values for air pollution by wind direction • describe factors which affect whether or not there is a pattern relating levels of two variables. These include the size of differences between means of values, the variability of the data, the number of readings for each value and factors other than the ones studied which might have an impact on air pollution.	Familiarity with excel spreadsheets

ENQUIRY C: ROUTES

Route 1 (assumes students have already learnt the skills and knowledge to begin activity 1.1)
Activity 1.1 starts with a lesson in which students learn how to collect different data. The data collection activities then carry on for a period of about a month. This data collection could be mainly homework.
Overall time is about 3 hours.



Route 2 (uses all activities from sections 2 and 3 to provide relevant knowledge and procedural understanding to begin core enquiry in section 1)
Overall time is about 6 hours.



HEALTH AND SAFETY

For practical activities, the Science Enhancement Programme has tried to ensure that the experiments are healthy and safe to use in schools and colleges, and that any recognised hazards have been indicated together with appropriate control measures (safety precautions). It is assumed that these experiments will be undertaken in suitable laboratories or work areas and that good laboratory practices will be observed. Teachers should consult their employers' risk assessments for each practical before use, and consider whether any modification is necessary for the particular circumstances of their own class/ school. If necessary, CLEAPSS members can obtain further advice by contacting the Helpline on 01895 251496 or e-mail science@cleapss.org.uk.

ENQUIRY A (EXPLORING ENQUIRY)

ACTIVITY 1.1A:
ARE THERE DAILY PATTERNS IN AIR POLLUTION?
(CORE ENQUIRY ACTIVITY)

WHAT STUDENTS DO

Students examine graphical data collected at a monitoring site. They carry out an 'exploring' enquiry, looking for patterns in sulfur dioxide and nitrogen dioxide concentrations in the air over time, using the data supplied and further data that they either download from the internet or from a data set provided on the CD, in **Air Pollution**, ***Additional Resources***

Learning objectives

Students will be able to:

- look for patterns in graphical data and assess the strength of any patterns observed
- look for relations between two variables using a scattergraph
- use patterns in data to make predictions and judge the likelihood of these predictions being correct.

Resources needed

- **Student Activity 1.1A:** ***Are there daily patterns in air pollution?***
- Photocopies of data showing hourly records of air pollution over a week (See 'Notes for retrieving air pollution data' below).
- Access to IT facilities
- Excel file labelled '**Enquiry A**', in **Air Pollution**, ***Additional Resources***.

NOTES FOR RETRIEVING AIR POLLUTION DATA

You can obtain hourly air pollution data in two ways:

1. Excel file labelled '**Enquiry A**', in **Air Pollution**, ***Additional Resources***.

   The spreadsheet contains three tables, one for each of the following locations in the UK:

   - Cardiff Centre
   - Edinburgh St Leonards
   - London Hillingdon

You might wish to select the data in the location which is closest to your school or which has pollution conditions similar to those in your area.
Each table lists recordings of the NO_2 and SO_2 concentration levels for every hour of the day, for every day in May and June 2004. The first reading of each day is highlighted.

Using the data on this spreadsheet, you can produce graphs showing hourly concentration levels of a pollutant. Two graphs have been created for you, starting at Cell R14 and R37 on the spreadsheet. These show hourly concentration of nitrogen dioxide and sulfur dioxide for the week beginning on May 1st, in London.

If you want to create similar graphs:

- Select the columns with readings of the hour and of the concentration of the pollutant you wish to create a graph for. Click 'Chart Wizard'.
- Step 1: Select 'Column', first sub-type. Click Next.
- Step 2: Select 'Series in': Columns. Click Next.
- Step 3: Select 'Titles': Fill-in the title of the chart, 'category x-axis': Date, and 'category y-axis': Concentration. Click 'Finish'.

This will give you a graph, like the example shown at Cell AD14. This needs a few modifications:

- Enlarge the graph. This can be done by clicking and dragging at the corners of the graph.
- Click on the 'Series' box. Press 'Delete'.
- Click on the hour values. This leads you to a screen, where you select 'Scale'. Type in the following values: 'Number of categories between tick-mark labels': 24, 'Number of categories between tick marks':24.
- These steps will take you to the final graph shown at Cell R14.
- From the 'Drawing toolbar', select 'Text box'. Create text boxes with the relevant dates and paste them below the times shown on the graph.

2. From the internet, at the UK Air Quality website, at ***www.airquality.co.uk/archive/index.php***

   This site provides hourly pollution data, which cover the previous week, for different parts of the UK.

You may wish to retrieve up-to-date data from a site near to your school. To do this:

- Go to the UK air quality website: ***www.airquality.co.uk/archive/index.php***
- On the map of UK, click on the area where your school is
- Click on '**For More Information** >**CLICK HERE**<'.

A new map will appear with the monitoring sites in the area you have selected.

- Decide which monitoring site is the nearest to your school. Click on to that site. You will also have to click on 'weekly graph' before you click on '**SUBMIT**'.
- This gives graphs of pollution levels at hourly intervals over the last week. Find the graphs showing the concentrations of NO^2 and SO^2 and print them out.

Note: *Concentration levels for both pollutants may not be available for the site you selected. In this case, you might wish to select another monitoring site nearby.*

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

The enquiry is in four parts:

- Part 1: Generating a research question
- Part 2: Planning
- Part 3: Considering evidence
- Part 4: Evaluating

Part 1: Generating a research question

Plenary:
Show the students the graphs of hourly nitrogen dioxide and sulfur dioxide measurements. Ask them about possible sources for these pollutants and where in the locality or in the surrounding regions the pollutants might be coming from. This should alert them to possible patterns in the data.
Explore with the class whether there are any obvious patterns in the data.
Ask students for possible reasons for the changes in the levels of pollutants over time.

Group work:
Arrange the students in groups and ask each group to formulate at least one research question and to write it down. Whilst they are working, look at the questions that they are writing and make a selection of a few of them to put on the board.

Plenary:
Sort out those questions that can be answered with the kinds of data available and those that cannot.

Part 2: Planning

Students plan their data analysis and consider the need for further data collection.

Students may look for the following patterns:

(i) Comparing the patterns from day to day. Students could compare peaks and troughs on different days. They could assess the strength of the relationship by judging the extent to which the patterns are the same each day.

(ii) Comparing sulfur dioxide and nitrogen dioxide levels: This is best done using a scattergraph plotting sulfur dioxide and nitrogen dioxide levels against one another.

(iii) Comparing weekdays and weekends: It is impossible to verify any pattern unless several weekends are included in the data.

Part 3: Considering evidence

Students should both search for patterns in the data and identify data that do not fit in the pattern: they should consider to what extent these data affect the reliability of the pattern observed. This can then lead back to planning more data collection and move into a second round of enquiry, if time allows.

If students think they need more data, you could either provide them with more data or you could ask them to collect further data themselves.
Data can be obtained from two sources:

- The dataset provided on the Beyond Fair Testing CD, in the Excel file labelled **'Enquiry A', in Air Pollution, *Additional Resources***. or
- The internet, at *www.airquality.co.uk/archive/index.php*

Part 4: Evaluating

Evaluating is difficult and students often need support to learn how to evaluate. The student activity sheet gives some questions to ask when evaluating the extent to which the conclusions drawn are supported by the evidence. You could use these questions as a focus for either whole class discussion or group work.

For example, you could either:

- get groups to present their conclusions to the class and give the class opportunities to ask questions about the enquiry

or

- get different groups to swap their completed planning sheets. Each group could then prepare three questions to ask the other group about the enquiry, focusing on the quality of the evidence.

Moving on from an exploring enquiry

Having explored if there is a pattern in air pollution or not, students may naturally move on to considering causes which could explain the patterns observed. Enquiries B and C investigate how patterns in air pollution are related to different causal factors.

You might wish to use a plenary to discuss with students possible reasons which could account for the patterns observed.

ENQUIRY B (PATTERN-SEEKING ENQUIRY)

ACTIVITY 1.1B:
WHAT FACTORS AFFECT AIR QUALITY?
(CORE ENQUIRY ACTIVITY)

WHAT STUDENTS DO

Students examine air pollution and weather data provided to them on a spreadsheet. They carry out a 'pattern seeking' enquiry, looking for patterns in the data that can link air pollution levels to some of their causes. The data is supplied on the Beyond Fair Testing CD, in **Air Pollution**, ***Additional Resources***

Learning objectives

Students will be able to:

- sort out the causes and effects within the data table and use scientific models in creating and answering questions
- judge the qualities of a good problem statement in the context of a pattern-seeking enquiry
- plan how they will analyse data to address a problem
- manipulate data (work with tables and scattergraphs) to look for patterns of relations between two variables
- draw a conclusion based on evidence
- explain their conclusion in terms of scientific ideas
- evaluate the extent to which the conclusions drawn are supported by the evidence.

Resources needed

- **Student Activity 1.1B:** ***What factors affect air quality?***
- Access to IT facilities.
- Excel file labelled **'Enquiry B'**, in **Air Pollution**, ***Additional Resources***.
- Optional: ***'Checklist for a good research question'***, in **Air Pollution**, ***Additional Resources***

NOTES ON THE CONTENTS AND USE OF THE DATA SET PROVIDED

Excel file **'Enquiry B'** contains air pollution and weather data for three locations in the UK. These are:

- Cardiff Centre
- Edinburgh St Leonards
- London Hillingdon

The file contains five spreadsheets. Their contents are summarised below:

'Cardiff', 'Edinburgh' and 'London' spreadsheets [1]
These contain the data sets to be used in the enquiry.
Each spreadsheet contains the following information for each day in two months (May and June 2004).

Note: There is a key providing more information at Cell P10.

- **Column A** shows the day of the month. May dates are placed first, followed by dates in June (marked in yellow).
- **Columns B-K** show weather data which might cause changes in the concentration of pollutants in the air. These are:
  - Temperature readings (columns B, C and D)
  - Amount of rain (column E)
  - Hours of sunshine (column F)
  - Wind speed and wind direction (columns G, H,I and J)
  - Weather type (column K)

Note: To change the time of day for which pollution data is shown: Go to cell L11 (first reading for the time on May 1st) and type in the time of the day you wish to use. Press enter. This will automatically update the contents of columns M and N:

- **Column L** shows the time of the day, linked with pollution data in columns M and N. The time is the same for all dates, as meaningful comparisons of pollution levels across dates can only be made if the data refer to the same time of the day (concentration of pollutants fluctuates a lot during the day).
- **Columns M and N** show the hourly concentrations of pollutants NO_2 and SO_2, respectively. The data is from spreadsheet 'Aux 1-Air Quality Data Hourly'.

Column L will show the time you have selected for all dates, while columns M and N will show the concentration of the pollutants for this time of the day.

You might wish to select the data from the location which is nearest to your school or which has similar pollution conditions to your area. Alternatively, you might wish to assign different groups to work with a different data set (say, one group with London data, one with Edinburgh data and one with Cardiff data) and then have them compare their results in the end.

'Aux 1-Air Quality Data Hourly' spreadsheet [2]**:**
This is an auxiliary spreadsheet, to allow you to modify the concentrations of pollutants in the data sets.

There are three tables in the spreadsheet, one for each of three different locations in the UK (Cardiff Centre, Edinburgh St Leonards and London Hillingdon).

Each table lists recordings of the NO_2 and SO_2 concentration levels for every hour of the day, for every day in May and June 2004. The first reading of each day is highlighted.

'Aux2- Wind' spreadsheet
This is also an auxiliary spreadsheet. It provides the conversion of wind direction readings in degrees from the North into compass readings. For example, 0-20 degrees all correspond to a 'North' wind direction.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

The enquiry is in four parts:

- Part 1: Generating a research question
- Part 2: Planning
- Part 3: Considering evidence
- Part 4: Evaluating

Part 1: Generating a research question

Plenary:
In order to be able to ask good questions about the relationship between levels of air pollution and other factors, students need to have relevant scientific knowledge. As a preliminary activity, ask students questions to review their knowledge of the following:

- The pollutants that can be found in the air,
- The sources of pollution – local, national and international,
- The chemical changes that take place in the air to convert these pollutants into acid rain,
- How the pollution is transported from one place to another and
- How it is deposited.

Show the students the data set from one location, say London. Sort out which of the data columns are causes and which are effects.

Next, get the students to look at the data set and ask them to brainstorm to try to generate questions that link the levels of pollution to factors that might influence the levels of pollution. Probe the students' understanding by going through each of the data columns, asking the students questions such as:

- How did the wind direction on this day affect the acidity of the rain?
- Does the amount of rain affect the concentration of pollutants in the air?

Use these questions and answers to help students to make links to scientific models. Discuss the students' questions one by one, asking if they have the data to address that question and why they think there might be a link between the levels of pollution and that factor.

Group work:
Arrange students in groups to discuss the question they want to investigate. Whilst they are working, look at the questions that they are writing and make a selection of a few of them to put on the board.

Plenary:
Discuss students' questions one by one. Ask the students

- which research questions are better and
- why they are better.

The purpose of this discussion is to help elicit the criteria which characterise a good research question.

A good research question:

1….identifies the dependent variable, along with any pattern observed over time in the dependent variable.

2….. identifies a possible causal factor that might influence the dependent variable and includes a rationale for choosing this variable as a possible causal factor.

3…..describes the expected pattern of relation between the two variables.

4…..mentions expected variations from the pattern due to uncontrolled variables.

An example of a good research question and prediction is given below:

Research question: What is the effect of wind direction on levels of air pollution where I live?

Prediction: When air pollution is blown in from other parts of the country where there is industry or there are large cities, the air pollution levels will be high. This is because the level of pollution depends on how much pollution is carried from the sources to the monitoring site, and this depends on the wind direction.

There will be cases when the wind direction is from a direction of low pollution yet the pollution is high. This is because using wind direction assumes that the air travels in straight lines, whereas in reality it follows weather patterns and winds curve around the cyclones (lows pressure areas) and anticyclones (high pressure areas).

Note:* 'Checklist for a good research question'** *contains these criteria and the exemplar research question, ready for presentation using a data projector. It can be found in* **Air Pollution, *'Additional Resources' *on the CD.*

Group work:
Give each group time to improve their research question before going on to the planning phase. Students should write down their agreed research question.

Part 2: Planning

Students should select the data they are going to examine and search for patterns in the data indicating how the concentration of NO_2 and/or SO_2 relate to the causal factors they are investigating.

Part 3: Considering evidence

Modelling the process of analysis

Students may need guidance in handling the data in the data set. It would be useful to model the process for them. You could do this by working through an example, ***'What is the effect of the quantity of rain on the concentration of nitrogen dioxide?'*** using the Excel spreadsheet labelled **'Exercise 2'**, in Excel file **'Activity 3.1, Ex1_2'**, in **Air Pollution**, ***'Additional Resources'*** and the instructions from
Student Activity 3.1: Exercise 2: *Creating scattergraphs on a spreadsheet*.

When students have finished their analysis they should be able to:

- say whether there is a correlation between the dependent variable and the factor that they are investigating
- make a judgment about the strength of the correlation
- explain why they think that the factor affects the dependent variable and
- comment on the effects of any uncontrolled factors.

Part 4: Evaluating

Evaluating is difficult and students often need support to learn how to evaluate. The student sheet gives some questions to ask when evaluating the extent to which the conclusions drawn are supported by the evidence. You could use these questions as a focus for either whole class discussion or group work. For example, you could either:

- get groups to present their conclusions to the class and give the class opportunities to ask questions about the enquiry

or

- get different groups to swap their completed planning sheets. Each group could then prepare three questions to ask the other group about the enquiry, focusing on the quality of the evidence.

Footnotes

[1] Data provided by the Met Office Education website, at *www.met-office.gov.uk/education/data/catalogue.html*

[2] This sheet contains data supplied by Netcen. (This is equivalent to what you could obtain by daily visits to *www.airquality.co.uk/* , the website of the UK National Air Quality Information Archive maintained by Defra and the Devolved Administrations).

ENQUIRY C (PATTERN-SEEKING ENQUIRY)

This enquiry has three phases. In the first phase, students collect data to monitor air pollution (Activity 1.1C), while in the other two phases students analyse their data. Once students are about half-way through their data collection, they start doing some preliminary analysis in Activity 1.2C. Finally, when they have collected all their data, in Activity 1.3C they design an enquiry to look for patterns in the data so as to decide what factors affect air pollution in their locality. You might choose to omit Activity 1.2 and have students do all their analysis when they have collected all their data.

ACTIVITY 1.1C:
MONITORING AIR POLLUTION
(CORE ENQUIRY ACTIVITY)

WHAT STUDENTS DO

Students collect data over a period of about a month (longer if possible) to monitor the quality of the air in the locality. The data collected fall into the following categories: pollution data, factors that affect the chemistry of how the pollutants react in the air (e.g. temperature, hours of sun), and weather data which are related to the transport of the pollutants and their eventual deposition.

Learning objectives
Students will be able to:

- retrieve data from the internet
- make first hand measurements of the volume and pH of rain water
- record data in a table or a spreadsheet.

Resources needed
- **Student Activity 1.1C:** ***Monitoring Air Pollution.***
- **Class Data Sheet**. This is available as an Excel spreadsheet and as a pdf document labelled **'Enquiry C', in Air Pollution**, ***Additional Resources***.
- Access to the internet for daily weather information which is not available through first hand measurements.

NOTES AND SUGGESTIONS FOR ORGANISING THE DATA COLLECTION

The recommended period for data collection is four weeks.

As there is a variety of data to acquire, we recommend that each student is given the opportunity to obtain and measure each of the items that are on the data sheet at some point. One way of doing this is to divide the students into teams (perhaps three teams as there are three main data collection exercises). Have each team work on one exercise for a few days, to become familiar with the procedure, and then rotate. To make this activity more student-centred, have the team that has become familiar with one exercise teach the next team how to go about doing that exercise when switching. You also might want to give responsibility to the most persistent and responsible students as the time for collecting data needs continued motivation and effort. In addition, it is a good idea to gather some data of your own as a back up.

Plenary:
Go over the Class Data Sheet as a class.
Start this activity by showing the students the Class Data Sheet and discuss how the various different factors on the sheet might be related. Discuss the key at the bottom of the data sheet.
The data collected in Activity 1.1C can be recorded on paper or on a computer spreadsheet. Students can write down the data they are retrieving in a notebook before writing directly on the Class Data Sheet to avoid making too many mistakes.

EXERCISE 1: MEASURING THE QUANTITY OF RAIN, ITS PH AND CONTAMINANTS

- Measuring the volume of precipitation that has fallen
- Measuring the pH in the acid rain collection jar
- Contaminants (if any) in the pH monitoring container

The quantity of rain and the pH are measured in separate gauges. Care must be taken to avoid any contamination in the pH gauge and if any bits fall into the collector they need to be recorded as possible contaminants.

EXERCISE 2: FINDING THE NO_2 AND SO_2 LEVELS

These are retrieved from the internet, at *www.airquality.co.uk/archive/index.php* Detailed instructions on how to retrieve the data are provided in **Student Activity 1.1C: *Monitoring Air Pollution.***

It is important that the daily readings are taken at the same time. This probably means that you will be using the 'weekly graphs' to obtain these data. Students may have difficulty in reading values of the two pollutants from graphs, so a useful exercise would be to print out a graph and get the students to practise reading values for different times and different days.

EXERCISE 3: WEATHER DATA

These can be retrieved from the internet, at *http://www.met-office.gov.uk/education/archive/uk/*

- Wind speed
- Wind direction
- Temperature
- Hours of sun
- Rain type and type of weather

Students can collect data about the wind speed and direction and about the temperature either from first-hand measurements or from the internet. Detailed instructions on how to retrieve the data from the internet are provided in **Student Activity 1.1C: *Monitoring Air Pollution.***

Students will need to make first hand observations of the weather the previous day to record the hours of sun, rain type and type of weather.

EXERCISE 4: WHERE IS MY SCHOOL LOCATED?

- Direction and distance from the coast
- Direction and distance from the town centre
- Direction and distance from the nearest power station
- Location of the school on a plateau, a hill top, a flat plain, a mountain, a valley bottom or a valley side.

All this information should be looked up in local maps and books, with the exception of the location of the nearest power station which can be looked up on the internet, at *www.naei.org.uk/mapping/mapping_2001.php*

Detailed instructions on how to retrieve the data are provided in **Student Activity 1.1C: *Monitoring Air Pollution.***

The data collected in this exercise only need to be collected once. You could:

- give the students this information
- or collect the information in a whole class activity
- or set it as a task for a group of students to find out.

ACTIVITY 1.2C:
LOOKING FOR PATTERNS
(CORE ENQUIRY ACTIVITY)

WHAT STUDENTS DO

***Note:** If you want to present the results to the class, then the most effective way would be to use the spreadsheet on a computer linked to a data projector; if there are no ICT facilities in the laboratory or the class have entered results on paper only, then you will need to create a transparency for use with an overhead projector.*

Students begin to explore patterns in the data that they are collecting.

Learning objectives
Students will be able to:
- tabulate data, work out mean concentrations of pollutants and compare the levels of pollution for different wind directions and wind speeds
- draw scattergraphs to look for patterns in data

Resources needed
- **Student Activity 1.2C: *Looking for patterns***
- Class Data Sheet with some data on.
- Optional: Access to IT facilities.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

Note:** Some students are likely to need help in using the spreadsheet to produce a scattergraph.* **Activity 3.1, Exercise 2: *Creating scattergraphs on a spreadsheet *is designed to support this.*

EXERCISE 1: LOOKING FOR LINKS BETWEEN DIFFERENT POLLUTANTS

Plenary:
Discuss with the students whether you should expect a relationship and why. Whether or not there is a relationship will depend on whether the two pollutants originate from the same source and the processes that occur after emission to form these two gases. It will also depend on whether the gases are removed from the air at the same rate.

Group or individual work:
Students use their data to construct a scattergraph.
As any pattern in the graph may be unclear after only two weeks, you could get the students to add to this scattergraph as they collect more data.

EXERCISE 2: ARE POLLUTION LEVELS RELATED TO WIND DIRECTION?

EXERCISE 3: ARE POLLUTION LEVELS RELATED TO WIND SPEED?

In exercises 2 and 3, students analyse tabulated data. This can be easier to do if students have recorded the data in a spreadsheet, as they can select 'Data' and then 'Sort' by wind speed or by wind direction. (Make sure they have selected all the data – i.e. across all the columns, not just wind speed or direction – so that all the data for one record stay in the same row.)

ACTIVITY 1.3C:
WHAT FACTORS AFFECT AIR QUALITY WHERE I LIVE?
(CORE ENQUIRY ACTIVITY)

WHAT STUDENTS DO

Students examine pollution and weather data they have collected over a period of time. They carry out a 'pattern seeking' enquiry, looking for patterns in the data that can link air pollution levels in the locality to some of their causes.

Learning objectives

In this activity students have the opportunity to use this learning in a whole enquiry. Students will be able to:

- sort out the causes and effects within the data table and use scientific models in creating and answering questions based upon their data collection
- judge the qualities of a good research question in the context of a pattern-seeking enquiry.
- plan how they will analyse data to address a problem
- manipulate data (work with tables and scattergraphs) to look for patterns of relations between two variables
- draw a conclusion based on evidence
- explain their conclusion in terms of scientific ideas
- evaluate the extent to which the conclusions drawn are supported by the evidence.

Resources needed

- **Student Activity 1.3C:** ***What factors affect air quality where I live?***
- A completed Class Data Sheet.
- Access to IT facilities.
- Optional: ***'Checklist for a good research question',*** in **Air Pollution**, ***Additional Resources***

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

The enquiry is in four parts:

- Part 1: Generating a research question
- Part 2: Planning
- Part 3: Considering evidence
- Part 4: Evaluating

Part 1: Generating a research question

Plenary:
In order to be able to ask good questions about the relationship between levels of air pollution and other factors, students need to have relevant scientific knowledge. As a preliminary activity, ask students questions to review their knowledge of the following:

- The pollutants that can be found in the air,
- The sources of pollution – local, national and international,
- The chemical changes that take place in the air to convert these pollutants into acid rain,
- How the pollution is transported from one place to another and
- How it is deposited.

Look at the table and sort out which of the data columns are causes and which are effects. Next, get the students to look at the Class Data Sheet and ask them to brainstorm to try to generate questions that link the levels of pollution to factors that might influence the levels of pollution. Go through each of the data columns, asking the students questions to probe their understanding, such as:

- How did the wind direction on this day affect the acidity of the rain?
- Does the amount of rain affect the concentration of pollutants in the air?

Use these questions and answers to help the students to make links to scientific models.

Collect the students' questions on the board. Discuss the students' questions one by one, asking if they have the data to address that question and why they think there might be a link between the levels of pollution and that factor.

Group work:
Arrange students in groups to discuss the question they want to investigate. Whilst they are working, look at the questions that they are writing and make a selection of a few of them to put on the board.

Plenary:
Discuss students' questions one by one. Ask the students

- which research questions are better and
- why they are better.

The purpose of this discussion is to help elicit the criteria which characterise a good research question.

A good research question:

1…identifies the dependent variable, along with any pattern observed over time in the dependent variable.

2…. identifies a possible causal factor that might influence the dependent variable and includes a rationale for choosing this variable as a possible causal factor.

3….describes the expected pattern of relation between the two variables.

4….mentions expected variations from the pattern due to uncontrolled variables.

An example of a good research question and prediction is given below:

Research question: What is the effect of wind direction on levels of air pollution where I live?

Prediction: When air pollution is blown in from other parts of the country where there is industry or there are large cities, the air pollution levels will be high. This is because the level of pollution depends on how much pollution is carried from the sources to the monitoring site, and this depends on the wind direction.

There will be cases when the wind direction is from a direction of low pollution yet the pollution is high. This is because using wind direction assumes that the air travels in straight lines, whereas in reality it follows weather patterns and winds curve around the cyclones (lows pressure areas) and anticyclones (high pressure areas).

Note:* 'Checklist for a good research question'** *contains these criteria and the exemplar research question, ready for presentation using a data projector. It can be found in* **Air Pollution, *Additional Resources *on the CD.*

Ask the class to improve on a research question that does not match the criteria for a good question.

Highlight the criteria for judging the quality of research questions and predictions in pattern-seeking enquiries.

Group work:
Give each group time to improve their research question before going on to the planning phase. Students should write down their agreed research question.

Part 2: Planning

Students should select the data they are going to examine and search for patterns in the data indicating how the concentration of NO_2 and/or SO_2 relate to the causal factors they are investigating.

Part 3: Considering evidence

Modelling the process of analysis
Students may need guidance in handling the data in the data set. You could model the process for them by working through an example, 'What is the effect of the quantity of rain on the concentration of nitrogen dioxide?' using the Excel spreadsheet labelled **'Exercise 2'**, in Excel file '**Activity 3.1, Ex1_2**', **in Air Pollution**, ***Additional Resources*** and the instructions from **Student Activity 3.1: Exercise 2: *Creating scattergraphs on a spreadsheet***

When students have finished their analysis they should be able to:

- say whether there is a correlation between the dependent variable and the factor that they are investigating
- make a judgment about the strength of the correlation
- explain why they think that the factor affects the dependent variable and
- comment on the effects of any uncontrolled factors.

Part 4: Evaluating

Evaluating is difficult and students often need support to learn how to evaluate. The student sheet gives some questions to ask when evaluating the extent to which the conclusions drawn are supported by the evidence. You could use these questions as a focus for either whole class discussion or group work. For example, you could either:

- get groups to present their conclusions to the class and give the class opportunities to ask questions about the enquiry

or

- get different groups to swap their completed planning sheets. Each group could then prepare three questions to ask the other group about the enquiry, focusing on the quality of the evidence.

ACTIVITY 2.1:
WHAT IS ACID RAIN AND WHERE DOES IT COME FROM?

EXERCISE 1: WHAT IS ACID RAIN?

WHAT STUDENTS DO

Students carry out an interactive (DART) reading comprehension activity on the causes and formation of acid rain.

Learning objectives
Students will be able to:

- name sources of air pollution
- describe how nitrogen oxides and sulfur dioxide can be converted into acid rain
- describe how acidic air pollution is deposited.

Resources needed
- **Student Activity 2.1, Exercise 1: *What is acid rain?***
- Black and red pens or pencils.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

This exercise provides a general introduction to the entire acid rain enquiry. It links with all other exercises in Activity 2.1.
Students could complete this activity on their own or in groups.

The completed exercise should look like this

Rain water is naturally acidic because of carbon dioxide that has dissolved in the rain. Natural rain has a pH of 5.6. Despite rain water being slightly acidic, it is not called acid rain unless the pH value is lower than 5.6.

There are many factors that cause acid rain. Some are natural and some are the result of human activities. Pollution due to human activities is the most common cause of acid rain. Though there are many pollutants in the air, the main pollutants causing acid rain are sulfur dioxide (SO_2) and nitrogen oxides (NOx). These air pollutants come mainly from burning fossil fuels for energy e.g. burning coal, industrial factories and road transport. Coal burning is the single largest source of sulfur dioxide accounting for about 50% of annual global emissions, with oil burning accounting for a further 25 to 30%. Natural sources of sulfur dioxide include releases from volcanoes, ocean sea spray and forest fires.

Nitrogen oxides are gases that are by-products of burning at extremely high temperatures e.g. cars and some factories, and of some chemical industries (fertiliser production).
Natural sources of nitrogen oxides are biological decomposition in soils, forest fires, volcanic activity and lightning.

Once in the atmosphere, sulfur dioxide and nitrogen oxides are carried by the wind, and can (in time, after several complex steps of chemical reactions), be converted into sulfuric and nitric acids. These conversions occur in the atmosphere when sulfur dioxide and nitrogen oxides react with water and oxygen and become acid rain. The brightness of sunlight is another factor that affects how quickly nitrogen oxides and sulfur dioxide are converted to nitric and sulfuric acids.

When acid falls to the ground it is called acid deposition. There are two different forms – dry and wet deposition. Acids are carried through the atmosphere by winds. Dry acid deposition falls to the Earth in the form of gas and dust. Wet acid deposition (acid rain) falls to the Earth as precipitation in the forms of rain, snow or fog. Dry acid deposition tends to fall to the Earth earlier than wet acid deposition. This is because the distance that dry acid deposition travels before falling to the Earth just depends on wind speed and wind direction and does not have to wait for it to rain. For example, in a dry desert region, if there is acid deposition, it will almost always be dry acid deposition since there is so little rain falling. In the UK, there is both dry and wet acid deposition. Wet acid deposition is more common here in the UK than in the south of Spain, as there is a higher amount of rainfall in the UK.

ACTIVITY 2.1:
WHAT IS ACID RAIN AND WHERE DOES IT COME FROM?
EXERCISE 2: THE FORMATION OF ACID RAIN

WHAT STUDENTS DO

Students use the printed or digital resources provided to create a simplified diagram showing the formation and deposition of acid rain.

Learning objectives

Students will be able to:
- identify sources of air pollution which cause acid rain
- describe how nitrogen oxides and sulfur dioxide can be converted into acid rain
- describe how acidic air pollution is deposited.

Resources needed
- **Student Activity 2.1, Exercise 2: *The formation of acid rain.***
- Scissors, glue, extra paper and pens if you are doing this with printed sheets

Or
- Access to IT facilities and a printer if students are going to use the Word version at a computer.
- It may also be useful for students to have **Student Activity 2.1, Exercise 1** available to refer to.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

This should be a consolidation exercise: the thinking process is more important than producing a beautiful, neat diagram.

- For some groups, it may be more helpful to provide them with boxes, arrows and pictures printed on card and cut out ready to use as the basis for a discussion, moving the pieces around on the desk or (with the help of a bit of temporary adhesive) on the board. This may be followed by students creating their own diagrams, but does not have to be.
- The printed sheet is meant to give support and to avoid the need for students to spend time drawing, but is not meant to constrain the activity. If students have a preferred or more elegant idea for a diagram, then let them sketch it out quickly before they produce their 'neat' copy.
- If students use the Word document, then they can easily remove the instructions and 'customise' the final diagram using additional arrows and text boxes.

ACTIVITY 2.1:
WHAT IS ACID RAIN AND WHERE DOES IT COME FROM?

EXERCISE 3: AN INTERNET-BASED ACTIVITY ABOUT THE SOURCES OF ACID RAIN POLLUTANTS IN THE UK

WHAT STUDENTS DO

Students use the internet to find out about sources of air pollution which contribute to acid rain.

Learning objectives
Students will be able to:
- identify significant sources of acid rain pollution in the UK
- identify areas which suffer higher pollution levels and account for differences in pollution levels
- relate information on pollution to their own part of the UK.

Resources needed
- **Student Activity 2.1, Exercise 3:** ***An internet-based activity about the sources of acid rain pollutants in the UK.***
- Access to IT facilities if students are going to work on the Word version of this document at a computer.
- Access to the internet.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

For students to gain a better understanding of where acid rain is coming from in the UK they need to know about the location and variation of emission sources of sulfur dioxide and nitrogen oxides. The internet provides access to a huge amount of information on air pollution and acid rain, so it is especially important to give some structure and help direct students' attention to important issues and information.

Ideally, each student would find out the answers to all of these questions, but if time is limited you might direct different groups of students to one or other website and use a plenary session to combine all the information.
You can help students to focus on the search for information by getting the websites added to an appropriate folder in 'Favourites' before students carry out this activity.

Alternatively, you could give them this activity as an electronic worksheet (but check first that your school network security does not block internet links from Word).

The National Atmospheric Emissions Inventory website at *www.naei.org.uk/mapping/mapping_2001.php* gives the students the opportunity to look up levels of pollutants across the UK through the 'Emissions maps 2001' option. This website provides information on point sources of pollution by using the 'Emissions data by postcode' option: students can vary the radius of search if the default radius of 5km does not give suitable results.
The British Energy factfile on acid rain at *www.britishenergy.com/education/factfiles/items/item50.html* provides a short summary of sources and effects of acid rain.
The Encyclopedia of the Atmospheric Environment website at *www.ace.mmu.ac.uk/eae/english.html* provides a lot of information links: students should follow the 'acid rain' link, then 'acid deposition' then 'transboundary problem' (from the text).

Answers to questions

1. England between Birmingham and York, around London, Newcastle and Edinburgh
2. Around cities – particularly London
3. Aberdeen or Plymouth – depends upon wind direction and wind speed- but not Manchester.
4. Local answer
5. Local answer
6. 25%
7. Reduction of about 70%
8. High rainfall areas of the North and West are most affected (rain brings wet deposition!)
9. Wet
10. Between 5% and 10% of acid rain pollution in Norway and Sweden comes from the UK.
11. Prevailing wind is from the west or southwest in Northern Europe.

ACTIVITY 2.1:
WHAT IS ACID RAIN AND WHERE DOES IT COME FROM?

EXERCISE 4: CHEMISTRY OF ACID RAIN

WHAT STUDENTS DO

Students carry out a cloze activity to complete descriptions of reactions and give the formulae of reaction products.

Learning objectives

Students will be able to:

- describe the chemical reactions involved in the formation of acid rain.

Some students will be able to:

- produce balanced chemical equations for these reactions.

Resources needed

- **Student Activity 2.1, Exercise 4: *Chemistry of acid rain.***
- Access to IT facilities if students are going to work on the Word version of this document at a computer.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

Students can finish this activity on their own, in pairs, groups or as an entire class. If this activity is completed together as a class, using an OHP or a computer with digital projector is recommended.

Answers to questions

1. Nitrogen monoxide is formed in car engines and in some industrial processes when nitrogen and oxygen react together at high temperatures:

$$N_2\,(g) + O_2\,(g) \longrightarrow 2NO\,(g)$$

2. The highly reactive nitrogen monoxide reacts with oxygen to produce nitrogen dioxide:

$$2NO\,(g) + O_2\,(g) \longrightarrow 2NO_2\,(g)$$

3. In the presence of sunlight, nitrogen dioxide combines with water and more oxygen in the atmosphere to form nitric acid:

$$4NO_2\,(g) + 2H_2O\,(g) + O_2\,(g) \longrightarrow 4HNO_3\,(g)$$

4. Sulfur in fossil fuels burns with oxygen to form sulfur dioxide:

$$S\,(s) + O_2\,(g) \longrightarrow SO_2\,(g)$$

5. Sulfur dioxide reacts with oxygen in the atmosphere to form sulfur trioxide:

$$2SO_2\,(g) + O_2\,(g) \longrightarrow 2SO_3\,(g)$$

6. Sulfur trioxide reacts with water to form sulfuric acid:

$$SO_3\,(g) + H_2O(l) \longrightarrow H_2SO_4\,(aq)$$

ACTIVITY 2.2:

THE DAMAGING EFFECTS OF ACID RAIN AND AIR POLLUTION

EXERCISE 1: THE DAMAGING EFFECTS ON AQUATIC LIFE

WHAT STUDENTS DO

Students read the passage and carry out a DART activity, then draw a diagram based on the information in the passage.

Learning objectives
Students will be able to:

- describe how rivers and their drainage systems become acidic, and how this affects aquatic life.

Resources needed

- **Student Activity 2.2, Exercise 1:** ***The damaging effects on aquatic life.***
- Black red and blue pens and pencils (or three suitable highlighting pens).

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

This activity will help introduce students to the damaging effects of acid rain on aquatic ecosystems. It is recommended that a discussion on freshwater aquatic ecosystems (i.e. lakes, ponds, rivers, streams and marshes – areas where water collects) precedes this activity.

The completed activity should look like this
The effects of acid rain are often seen in lakes, rivers, streams and marshes. Watersheds are defined as a drainage or catchment area. Acid rain falls directly on watersheds or flows to watersheds after falling on forests, fields, buildings and roads. Most lakes and streams have a pH between 6 and 8, although some lakes are naturally acidic even without the effects of acid rain. It is a complicated process for watersheds to become acidic due to acid rain. Usually it occurs when there isn't enough limestone or other minerals in the soil to neutralise acid rain and prevent a build-up of acidity.

The plants and animals living within an ecosystem are highly interdependent. When a watershed does become acidic due to acid rain, the effects can become magnified through the food web. The acidity can affect animal and plant species directly or indirectly. For example, a direct effect would be if the acidity of the water killed fish immediately, or if their immune system was so weakened that they were unable to reproduce. An indirect effect works as follows: some types of plants and animals are able to survive in acidic waters but if their source of food cannot survive then eventually they are affected as well. For example, frogs may tolerate relatively low pH levels, but if they rely on eating insects like mayflies, they may be affected because part of their food supply may disappear.

Generally, the young of most species are more sensitive to environmental conditions than adults. At pH 5, most fish eggs cannot hatch but adult fish would be likely to survive until a lower pH level is reached.

ACTIVITY 2.2:

THE DAMAGING EFFECTS OF ACID RAIN AND AIR POLLUTION

EXERCISE 2: DIFFERENT EFFECTS ON DIFFERENT SPECIES

WHAT STUDENTS DO

Students read the passage and answer a set of questions based on a table showing the effects of acidity on different aquatic animals.

Learning objectives
Students will be able to:

- describe the effects of acidification in an ecosystem and
- describe and explain what aquatic species would be observed and what the vegetation would look like.

Resources needed

- **Student Activity 2.2, Exercise 2:** ***Different effects on different species.***

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

Before this activity, students should have reviewed their understanding of the interdependency of species within given ecosystems. One of the key effects of acid rain is the reduction of species diversity: beyond a certain point, the water may be too acidic to support much life at all, but as pH drops, the populations of some species will increase while those of other, less tolerant, species decline.

Plenary:
Ask the students why it is very quiet and there are no signs of life.
Explain what the table shows. The shaded boxes show pH values at which particular animals survive (e.g. Snails survive at pH 6.0 and 6.5 but not at 5.5 or below whereas frogs survive at pH values between 4.0 and 6.5).
It may be worth reminding students that rainwater is naturally slightly acidic, anyway, and that the soil that rainwater drains through can also affect the final acidity level, so some lakes would be naturally more acidic even before the effects of acid rain (e.g. those where the drainage is through peat).

Group or individual work:
Students answer the questions in groups or individually.

Answers to questions

1. The water is acidic as it is pH 5.0.
2. Snails, mayfly, frogs, crayfish, perch
3. Snails, crayfish, mayflies.
4. Perch and frogs.
5. a) 5.5 b) An important source of food for the frogs cannot survive in water at this pH, so the frogs probably do not have enough to eat: the numbers of frogs are likely to fall unless they can find enough other things to eat.
6. Lower pH levels are increasingly acidic. Water available to the trees through the soil will also be acidic. Acidity affects the health of the trees by weakening their abilities to fight off disease and causing leaf/needle loss.
7. Below 5.0. To reduce the pH of the lake water to pH 5.0 needs water of pH less than 5.0.
8. The sources of acid rain pollutants are usually miles away but air pollutants can be carried long distances (hundreds of miles) by winds.

ACTIVITY 2.2:

THE DAMAGING EFFECTS OF ACID RAIN AND AIR POLLUTION

EXERCISE 3: THE EFFECTS OF ACID RAIN ON THE ENVIRONMENT

WHAT STUDENTS DO

Students use the internet to find answers to questions on the effects of acid rain.

Learning objectives
Students will be able to:

- describe some ways in which acid rain affects buildings, trees and people.

Resources needed

- **Student Activity 2.2, Exercise 3:** ***The effects of acid rain on the environment.***
- Access to the internet.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

Question 4 invites consideration of a range of effects: you may wish to explore what these might include before students carry out their research.

It is helpful to follow up this exercise with a class discussion of the answers. Students may be aware that it is not only acid rain which can cause death and symptoms of stress in trees. Other causes such as local outbreaks of tree disease might produce similar symptoms. Students may also be able to offer local examples of buildings or statues which show the effects of acid rain, as well as the examples suggested on the websites.

Answers to questions

1. You would see trees that are stressed: ends of branches may be bare and leaves yellowing. You would see more dead trees than normal.
2. Limestone and marble are most affected; granite is least affected.
3. Statues that have been affected by acid rain lose some of their detail.
4. For example on drinking water; deterioration of environment in terms of appearance of buildings, richness of wildlife.

ACTIVITY 2.2:

THE DAMAGING EFFECTS OF ACID RAIN AND AIR POLLUTION

EXERCISE 4: THE EFFECTS OF AIR POLLUTION AND ACID RAIN IN ASIA

WHAT STUDENTS DO

Students read a newspaper article and extract information about the damaging effects of air pollution in Asia.

Learning objectives

Students will be able to:

- understand that acid rain and air pollution are world-wide problems, not just something affecting the UK or Europe
- describe some of the effects of air pollution
- consider the evidence linking effects and their possible causes.

Resources needed

- **Student Activity 2.2, Exercise 4**: ***The effects of air pollution and acid rain in Asia.***
- Black, red and blue pens or pencils.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

This uses a newspaper article from the Daily Telegraph dated 13 August, 2002.

Plenary:

Introduce the topic of the article and locate the area on a map. Emphasise the scale of the problem. Discuss the difficulties of linking cause and effect, for example:

- A black cloud of smoke can be seen to be linked to a forest fire. The forest fire causes the effect.
- Children develop asthma all over the world. How could we gather evidence that asthma in particular children was caused by air pollution?
- Natural disasters occur all the time in different parts of the world. What evidence would be needed to establish a link to air pollution?

There are two components to the answer:

- First, there must be sufficient data to see a pattern linking two variables.
- Second, there should be a plausible mechanism linking the cause and effect. For example, it is difficult to see how 'filth in the sea off the beaches near Bangkok' could be linked to air pollution even if the level of air pollution correlated with the level of sea pollution.

Group or individual work:
Get the students to do the DART activity on the first three paragraphs of the article.

Plenary:
When the students have finished, take the following pieces of text and discuss if they should be underlined in black:
Paragraph 2: 'could distort climate patterns in Europe'
Paragraph 3: 'a plane crash-landed in Borneo'
Is any evidence given that these were caused by air pollution? What kind of evidence would be needed to establish the link to air pollution?

Group or individual work:
Students complete the rest of the activity.

The completed activity is shown on the following page.

Alex Spillius reports from Bangkok on the world's new atmospheric pollution problem, a two-mile high deadly brown cloud of pollution stretching from Afghanistan to China.

Toxic umbrella that is choking Asia (Filed: 13/08/2002)

Welcome to beautiful, charming Asia. Land of exotic settings, sumptuous sunsets and, we now learn, more acid rain than Europe and North America combined. Those of us who live under the "Asian Brown Cloud" knew that the air around us and above us was bad; we just did not know how bad until the release of a United Nations report identifying the world's new atmospheric pollution phenomenon. The study makes for uncomfortable reading. A toxic umbrella stretches from Afghanistan to China, critically disrupting weather patterns, causing droughts and floods. Foul air is sending thousands upon thousands of people to premature deaths from respiratory illness. Harvests are ruined. Half the world's population is affected.

The two-mile-high cloud could be carried by prevailing air currents across the world in a week and could distort climate patterns in Europe. The viscous haze has a depressingly wide range of causes: aerosols, forest fires, fossil fuels burnt in industry, power stations and an ever-growing number of vehicles; emissions from millions of inefficient cookers burning wood, cow dung and other "bio-fuels". In Bangkok, the weather doesn't provide much to talk about: it is either hot or very hot, quite humid or very humid. But pollution is almost as commonly discussed in Asia - at least by expatriates - as the weather is at home.

A dinner party almost invariably produces a round of pollution stories: the friends whose children developed chronic asthma in Delhi; the horrors of heavy industrial waste in Beijing; the filth in the sea off the beaches near Bangkok. But anybody who endured the 1997 haze in Kuala Lumpur or Singapore generally wins the raconteur's first prize. The smog caused by forest and plantation fires in Indonesia was so intense that visibility was reduced to yards, schools were closed and children had to stay indoors. The populations of whole cities wore protection masks. A plane crash-landed in Borneo killing all on board. And still the fires blight South-East Asia every year.

Reporting from the region has involved regular disasters of landslides, flood and famine. Vietnam is now expecting its third year of heavy floods. Millions in Bangladesh and north-eastern India are already cut off by heavy rain but, after the mass deaths two years ago, have barely made the news. Large areas of Afghanistan and Pakistan where there were once abundant orchards of grapes, pomegranates, apples, apricots and plums have turned to desert. A spectacularly harsh winter in Afghanistan in 2000-01 claimed hundreds of lives and sent thousands into refugee camps. The UN Environment Programme study, compiled by 200 scientists, has drawn this climatic calamity together and given the trend a name - the Asian Brown Cloud - which it probably needs if proper local action is to be taken. It would be encouraging to think that the combination of factors that have put this noxious blanket over our heads would merit discussion at the World Summit on Sustainable Development in Johannesburg beginning later this month. But it is apparently too late to be squeezed on to even the biggest agenda in the history of conferences. Those of us who live in Asia will have to seek consolation in the striking landscapes and dramatic dusks, even if they are getting hazier by the day.

ACTIVITY 3.1:

WORKING WITH SCATTERGRAPHS

EXERCISE 1: READING SCATTERGRAPHS

WHAT STUDENTS DO

Students study three scattergraphs and make judgments about whether there is a correlation between two variables. Then they look at four other scattergraphs and take part in a class discussion so as to consider the effects of removing specific points on the graph on whether or not there appears to be a pattern.

Learning objectives

The students will be able to:

- decide whether two variables in a scattergraph are correlated
- decide whether the sample size is big enough to be confident in an apparent correlation.

Resources needed

- **Student Activity 3.1, Exercise 1**: ***Reading scattergraphs – is there a pattern?***
- The graphs for this exercise are also available in an Excel spreadsheet labelled '**Exercise 1 (Parts A and B)**' in Excel file '**Activity 3.1, Ex1_2**', in '***Additional Resources***' on the CD and as a pdf file labelled '**Activity 3.1, Ex1**' for use with a computer and data projector (or for you to make transparencies to use with an overhead projector).

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

This exercise has two parts.

Part A is a set of questions for students to answer, and there is a corresponding student activity sheet.

Part B is a teacher-led activity. There is no corresponding student activity sheet for Part B.

Part A: Is there a pattern?

Plenary:

Make sure that the students understand the context, i.e. that cars are passing a monitoring station. At different times of the day, different numbers of cars pass and as they do so the levels of nitrogen dioxide are being measured. (Unlike the other graphs and data used in **'Air Pollution'**, graphs 1, 2, and 3 are deliberately constructed to ensure that students experience the different strengths of relationship - or lack of it - between variables. The graphs are what you would expect for each of those situations, however).

Discuss graph 1 with the whole class. Ask where they think a line of best fit would go. Ideally, this should be done using an interactive whiteboard or data projector, or using overhead transparencies of the graphs.

Group or pair work:
Students discuss and answer the questions in their books.

Plenary:
Discuss the students' answers using the projected images of graphs 1, 2 and 3.

Part B: Is the sample size big enough?

Plenary:
Lead a whole class discussion about the following graphs:

Graph 4
This graph is based on data collected in Aberdeen in the first week of November 2002. The information was obtained from the UK Air Quality website ***www.airquality.co.uk/archive/index.php*** and the UK Met Office ***www.met-office.gov.uk/education/data/ukdata.html***. The graph shows nitrogen dioxide concentration plotted against wind speed.
Show graph 4 and discuss whether wind speed and nitrogen dioxide levels are correlated. Cover up the two points [(1,80) and (16,4)] and ask what the students think if these two points are removed. Any apparent pattern disappears, indicating that there is not sufficient data to be sure.

Graph 5
Now show graph 5 and discuss whether there is a relationship. This is also a graph of nitrogen dioxide concentration versus wind speed for Aberdeen, but with a longer data collection period (November 2002 –January 2003). Although the relationship is weak, removing any two points from the graph does not make the pattern disappear, so it appears that there is a pattern.
Ask students to describe the shape of the pattern. This is difficult as the points are so scattered, but it appears that at very low wind speeds nitrogen dioxide levels are often high (presumably because of pollution from vehicles within the city). You could discuss what other factors apart from wind speed might cause the points to be so scattered.

Graph 6
This graph shows sulfur dioxide concentration versus wind speed in Manchester, in the first week of November 2002. Ask whether there is a relationship. This time, removing any two points from the graph does not make the pattern disappear entirely. We are left wondering whether there is really a relationship, although there is not really enough data to be sure.

Graph 7
This graph shows sulfur dioxide concentration versus wind speed in Manchester, but during an extended data collection period (November 2002- January 2003). Ask whether there is a relationship now. This time, the extra points suggest that there is no pattern after all.

Answers to questions

1. A good answer will include a description of the direction of the relationship (i.e. as the rate of cars passing increases the levels of nitrogen dioxide concentrations also increase) and the shape of the relationship (there is a steady increase of nitrogen dioxide concentrations with an increase in numbers of cars passing per hour, or nitrogen dioxide concentrations are directly proportional to the numbers of cars passing per hour).
2. a - I am confident there is a relationship.
3. It is easy to draw a line of best fit (regression line) close to all the points.
4. There is no relationship.
5. c - I am confident there is no relationship.
6. It is impossible to draw a line of best fit (regression line) close to all the points.
7. A good answer will include a description of the direction of the relationship (i.e. as the distance from the power station increases the concentrations of sulfur dioxide decrease) but will also note that there is a lot of variation around that pattern.
8. b - I am uncertain whether there is a relationship. This is open to discussion. There is probably enough data to justify the choice of (a) as well.
9. Although there appears to be a relationship there is so much scatter that we cannot be certain without more data.

ACTIVITY 3.1:

WORKING WITH SCATTERGRAPHS

EXERCISE 2: CREATING SCATTERGRAPHS ON A SPREADSHEET

WHAT STUDENTS DO

Students follow the instructions provided and create scattergraphs on a spreadsheet with given data.

Learning Objectives

The students will be able to:

- create scattergraphs using a spreadsheet.

Resources needed

- **Student Activity 3.1, Exercise 2:** ***Creating scattergraphs on a spreadsheet***.
- Access to IT facilities.
- Spreadsheet labelled **'Exercise 2'**, in Excel file **'Activity 3.1, Ex1_2'**, in ***'Additional Resources'***.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

This activity could be done in class or could be set as homework.
Some students might need guidance in order to realise that the column which will be marked first is the one which will appear on the x-axis.

ACTIVITY 3.2:
USING TABLES TO SORT OUT DATA

WHAT STUDENTS DO

Note: *Two maps are provided: one shows levels of sulfur dioxide in 2001, the other shows cities and point sources of pollution in 1996. The1996 version is included because some students may find it easier to find Aberdeen in relation to other parts of the UK.*
Although the map relates to 2001 and the data to 2002, pollution patterns and sources of pollution would not

Students study two maps of sulfur dioxide emissions in the UK and use them to predict wind directions which would bring sulfur dioxide pollution to Aberdeen. Students then rearrange tabulated data to calculate average pollution levels when the wind is in different directions. Students use these average values to test their predictions and to decide how confident they are in their conclusions.

Learning Objectives
Students will be able to:
- rearrange data in a table and work out mean values for air pollution by wind direction
- describe factors which affect whether a pattern can be seen relating levels of two variables. These include the size of differences between means of values, the variability of the data, the number of readings for each value and factors other than the ones studied which might have an impact on air pollution.

Resources needed
- **Student Activity 3.2:** Using tables to sort out data.
- Optional: pdf file labelled **'Activity 3.2'**, in the **Air Pollution *'Additional Resources'*** on the CD, for use with a data projector (or for you to make a transparency for use with an overhead projector).
- Optional: Excel spreadsheet **'Activity 3.2'**, in **Air Pollution *'Additional Resources'*** and
- Access to IT facilities.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

Group work:
Students discuss and answer the questions in their groups.
Students will need to rearrange data and calculate average pollution concentration levels.
This can be done either on paper or using the Excel spreadsheet provided.
Student Activity 3.2 contains two versions of Questions 2 and 3, according to whether students are working on paper or on the computer. Direct students to the version which is suitable for their way of working.
If students are working with the spreadsheet, before they select 'Data' and then 'Sort', make sure they have selected all the data – i.e. across all the columns, not just wind direction - so that all the data for one record stay in the same row.

Plenary:
Use students' answers to questions 4 – 6 to discuss factors which affect the decision about whether a pattern can be seen relating air pollution levels to wind direction. This decision depends on:

- The size of the differences between the means. If there are large differences between mean values for different wind directions then we can be fairly confident that there is a real difference.
- The variability of the data. If the values for a particular wind direction vary a lot, then less confidence can be placed on the mean values.
- The number of readings for each value (the wind direction). If the wind does not blow from a particular direction, we cannot draw conclusions relating to that wind direction. If the number of readings from a particular direction is small, this gives us less confidence in the mean value.
- Factors other than the wind direction that might have had an impact on the pollution levels. For example, low wind speeds may mean that local pollution becomes more important than pollution travelling from a distance.

Answers to questions

1. The emission maps indicate that pollution levels of sulfur dioxide should be high when the wind is blowing from the south or southwest.
2. Students complete the table.
3. The mean values for sulfur dioxide levels in ppb for the different wind directions are shown below. The highest mean is for the southerly direction at 7.9ppb, closely followed by north (7.0ppb) and southeast (6.3ppb).

N	NE	E	SE	S	SW	W	NW
7.0	-	1.3	6.3	7.9	3.7	1.7	1.5

4. There are no readings for the north east direction and so the data do not allow any conclusions to be drawn about that wind direction. Whether there are sufficient values for each direction depends on the variability of the values. One way of checking variability is to work out the mean after taking out first the highest and then the lowest value. If the two means are very different then it indicates that not enough readings have been taken. This is the case for all the wind directions.
5. The answer to be selected is therefore ‘not sure’.
6. The high values of the sulfur dioxide concentrations when the wind was in the north are interesting. Both these values occurred when there was a very low wind speed and so the pollution is in fact locally produced pollution rather than pollution carried from elsewhere. The important point to make here is that the pollution levels are affected by a range of factors and that this activity deals with only two.

ACTIVITY 3.3:
LOOKING FOR PATTERNS OVER TIME

WHAT STUDENTS DO

Students study graphs showing concentrations of nitrogen dioxide every hour for a week, for two different locations. They look for peaks and troughs in the graphs to try identify daily patterns in the variation of the concentration of nitrogen dioxide.

Learning objectives
Students will be able to:

- identify daily patterns in concentrations of air pollutants
- make judgements about the strengths of any patterns identified.

Resources needed
- **Student Activity 3.3:** Looking for patterns over time.
- **Graphs A and B** from the pdf file labelled **'Activity 3.3'**, in ***'Additional Resources'*** on the CD, for use with a computer and data projector. (Alternatively, create overhead transparencies of graphs A and B to be used with an overhead projector).

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

Students will need help in reading the graphs. Make sure you go through the preliminary activity outlined below before students start working through the questions, to ensure that they understand how to use the graphs correctly.

Preliminary (plenary) activity:
Go through the following information with students:
The beginning of each day is marked and labelled with the date. Each hour a vertical line is drawn to show the concentration of nitrogen dioxide (in ppb). The first vertical line on the graph is at midnight as 12/05/04 ends and 13/05/04 starts. The reading was 15ppb.
Get the students to look at midnight between 13/05/04 and 14/05/04 and read the concentration at that time. Repeat this at midnight between other days.
Next, ask the students to identify the first peak on 13/05/04 and to read off the concentration (31ppb) and the time when this occurred (6am). To do this they will need to count along from the start of 13/05/04. Repeat this with different peaks and troughs.

Group work:
Students answer the questions. Encourage them to write down their agreed answers.

Questions 5-8 and 9-12 ask the same questions about each of the two graphs, to provide plenty of practice: you may prefer to use only one set of these for students to work on, particularly if time is short. Alternatively, you might give questions 5-8 to some groups and questions 9-12 to others.

Answers to questions

For graph A:

1. Students should have drawn horizontal lines on graph A every 5ppb.
2. Completed tables for 13/05/04 (Allow +/-1 for ppb: the pattern of peaks and troughs is more important than the exact value in this case)

13/05/04, Time (am)	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nitrogen dioxide level (ppb)	15	10	8	8	12	18	31	28	24	20	32	27

13/05/04, Time (pm)	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nitrogen dioxide level (ppb)	25	22	20	16	14	19	21	26	33	27	27	20

3. Highest values and times on 13/05: 33ppb – 8pm, 32ppb – 10am, 31ppb – 6am.
4. Lowest values and times on 13/05: 8ppb – 2am and 3am, 12ppb – 4am, 14ppb – 4pm
5. The strongest, most regular peaks tend to occur at 6-8am, but there are also peaks at round 11pm-1am.
6. The troughs tend to occur around 3-6pm and 2-4am.
7. There is a weak pattern: although there are noticeable peaks and troughs at regular times, there are also exceptions to the pattern and there is a lot of variability.

8.a) About 12-20ppb.

b) The value at 12pm is 15ppb. On two of the other dates in the sample, the 1pm value was lower than the 12pm value (by up to 3ppb) and on four other dates it was higher (by up to 5ppb).

For graph B:

9. The peaks are spaced fairly evenly, and peaks usually occur around 4-6am, and again around 8 to 9pm.
10. The deepest troughs are spaced fairly evenly and tend to occur between midnight and about 2am; there is not a regular, noticeable 'daytime' trough.
11. There is a lot of variability in the pattern. The peaks and troughs seem to occur at similar times but their intensity and exact times vary.

12.a) About 3-5ppb.

b) The value at 8am is 3ppb. The concentration values around this time in the morning tend to stay roughly the same: on the dates in the sample, the 9am value was within 2ppb of the 8am value.

Activity 1.1A: Are there daily patterns in air pollution?

If you want to go outside and breathe fresh clean air, when is the best time to go out?

Find out by looking for patterns in the graphs provided.

In this enquiry you will be given graphs showing the concentrations of nitrogen dioxide and sulfur dioxide. Use these to explore how the levels of air pollution change hour by hour.

This enquiry has four parts:

- Part 1: Generating a research question
- Part 2: Planning
- Part 3: Considering the evidence
- Part 4: Evaluating

Part 1: Generating a research question

Look at the graphs provided: these are the kinds of data that you will use for this enquiry. You will be able to collect more data as your enquiry proceeds. Your first job is to come up with a good question to answer.

- You could look at patterns in concentrations of particular pollutants from day to day. This would involve you in identifying daily patterns and the strength of these patterns.
- You could look at whether concentrations of particular pollutants are related to one another. This could involve either comparing the patterns seen in graphs or it could involve making a table of the hourly data for two pollutants and then drawing a scattergraph.
- You could look at whether patterns are different at the weekend and during weekdays. This would involve describing the patterns on weekdays and at the weekends and collecting enough data to be able to compare the patterns.

Write down your research question.

Activity 1.1A: Are there daily patterns in air pollution?

Part 2: Planning

a) Getting started

Look at the data that you have been given. Do you have enough data to answer your research question with confidence?

Try working on the data you have been given and see how far you can get.

b) Planning data collection and analysis

Look at your research question.
Do you think you need more data to be able to explore whether there is a pattern and how strong it is? How much data do you need?

Describe your plan for using the data to explore the pattern: What will you do with the data? How will this show you whether there is a pattern?

Part 3: Considering the evidence

If you have decided that you need to collect more data, you can use two sources:

1. The data set provided in the Excel file labelled '**Enquiry A**'. Your teacher will show you how to select the data you need.

or

2. The Internet, at the UK Air Quality website.

To retrieve data, follow these instructions:

- Go to the UK Air Quality website, at ***www.airquality.co.uk/archive/index.php***
- On the map of UK, click on the area where your school is.
- Click on 'For More Information >**CLICK HER**E<.
- A new map will appear, with the monitoring sites in the area you have selected. Decide which measuring site is the nearest to your school. Click on to that site. You will also have to click on 'weekly graphs' before you click on '**SUBMIT**'.
- This gives you graphs of pollution levels at hourly intervals over the last week. Find the graphs showing the concentrations of NO_2 and SO_2 and print them out. (If both concentration levels are not available for the site you selected, choose another one nearby).

Describe how you analysed the data.
Does your analysis show whether there is a pattern? If there is a pattern, describe the pattern, including how strong the pattern is and any exceptions to it.

Activity 1.1A: Are there daily patterns in air pollution?

Part 4: Evaluating

Evaluating is about looking at conclusions and the strength of the evidence used to come to the conclusions. Look at the enquiry and think about these questions:

- Is the sample size big enough?
- Is the range of values big enough?
- Have you described any patterns carefully?
- Have you commented on the strength of the patterns?
- What predictions could you make based on these patterns?

Write down your evaluation of the quality of the evidence and its relation to the conclusion.

Consider the strength of the evidence supporting your conclusions. How could you improve the quality of the evidence collected?

Activity 1.1B: What factors affect air quality?

What factors affect air quality?

If you look outside on a bright summer's day, the air might look clear and fresh, but things are not always as they seem! Most air pollution is invisible.

Find out which factors affect the quality of the air by looking for patterns in the data provided to you.

In this enquiry you will be given a table with data showing the concentration of nitrogen dioxide and sulfur dioxide, along with weather data which might be related to air pollution. Use these to look for factors which affect air pollution.

This enquiry has four parts:

- Part 1: Generating a research question
- Part 2: Planning
- Part 3: Considering the evidence
- Part 4: Evaluating

Part 1: Generating a research question

When you write down your research question, remember to include:

- which pollutant or pollutants you are investigating
- which factor you will be investigating to see if it affects the pollution levels
- why you think this factor might affect the pollution levels
- what pattern you expect to find
- what other factors might be influencing the pollution levels, apart from the factor that you are investigating.

Write down your research question.

Activity 1.1B: What factors affect air quality?

Part 2: Planning

Some questions to think about:

- What data will you use?
- You may have a lot of data, but does it match what you need for your enquiry?
- How much data do you need?
- What sample size should you use?
- What about the range of data?

Select the data that you need from the spreadsheet.
Decide how you are going to look for patterns in the data and write down your plan.

Part 3: Considering evidence

Carry out your analysis looking for patterns.

What have you found out? You need to consider these questions:

- Is the level of pollution affected by the factor that you investigated?
- Is it a strong relationship?
- How sure are you that there is a link between this factor and the level of pollution?
- Can you explain the relation between the level of pollution and the factor that you investigated?
- Are there any other factors that might have been influencing the level of pollution?

Write down your conclusion.

Part 4: Evaluating

Evaluating is about looking at conclusions and at the strength of the evidence used to come to the conclusions.
Look at the enquiry and think about these questions:

- Is the sample size big enough?
- Do the levels of pollution and the factors that might affect the pollution levels change enough from day to day to be able to see a pattern?
- How much variation is there around any pattern observed?
- Are there other factors that might have caused the effects?

Write down your evaluation of quality of the evidence and its relation to the conclusion.

Activity 1.1C: Monitoring air pollution

Do you know what factors affect the quality of the air where you live?

To answer this question, in Activity 1.1C you are going to collect data about the quality of air over a long period. In Activity 1.2C you will begin to look for patterns in the data and in Activity 1.3C you will design an enquiry to explore patterns in the data.

In this activity you collect and record a lot of first-hand data about the quality of air and the weather outside. You also use the Internet to collect information which is not available from first-hand measurements. In the following activity you will be using the data to look for factors which affect air quality.

Exercise 1: Measuring the quantity of rain, its pH and contaminants

Measure the daily quantity of rainfall in a rain collector gauge; measure its pH in a separate acidity gauge.

Date

- Record the date when you are making the measurements in your Class Data Sheet.

Quantity of rainfall

- Use the rain gauge.
- Measure the depth of the water at the same time of day each day.
- Record the depth of rain that fell since the previous day in your Class Data Sheet.

To make a rain gauge, take a clean and empty 2-litre plastic drinks bottle. Cut off the upper third of the bottle **(Check with your teacher before you do this)**. Use the top portion to act as your funnel. Turn it upside down and fit it inside the bottom part of the bottle. Tape a clear plastic ruler against the bottle to provide a scale. Pour enough water in the bottle so that you can see the water surface clearly, well above the curvy bottom part of the bottle and above the lowest mark on the ruler. (The mark the water surface is level with is your 'zero reading'; the reading should go up by the same number of scale markings every time you add the same amount of water, but the odd shape of some plastic drinks bottles could distort this if you start too low down.)
Place the rain gauge in an open area away from buildings or trees and fix it to a post so that the height from the ground to the top of the collector is more than 150cm.

Activity 1.1C: Monitoring air pollution

pH of rainfall

- Use the acidity gauge.
- Measure the pH of any rain collected by using indicator paper or a pH meter.
- Record the pH in your Class Data Sheet.
- Look at the water collected: record any contaminants in your Class Data Sheet. Remember to replace the plastic bag before you put the gauge back.

For the acidity gauge, use a clean jam jar or a plastic beaker.
Line the inside of the container with a new plastic bag each day. **Do not touch the inside of the plastic bag. Use a different plastic bag as a glove to push the plastic bag into the container. Hold the plastic bag in place with a rubber-band around the edge of the container.**
Place the pH gauge in an open area away from buildings or trees and fix it to a post so that the height from the ground to the top of the collector is more than 150cm.

Exercise 2: Finding the NO_2 and SO_2 levels

It is important to record the levels of nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) at the same time each day as the level of these pollutants changes hour by hour throughout the day.

Date

- Record the date when you are making the measurements in your Class Data Sheet.

Concentrations of NO_2 and SO_2

Go to the UK Air Quality website, at: ***www.airquality.co.uk/archive/index.php***

- On the map of UK, click on the area where your school is
- Click on 'For More Information >CLICK HERE< '
- A new map appears with the monitoring sites in the area you have selected. Decide which measuring site is the nearest to your school. Click on to that site. You will also have to click on either 'last hour's data' or 'weekly graphs' before you click on 'SUBMIT'
- If you use **'Last hour's data'**, record the concentrations of NO_2 and SO_2 in your Class Data Sheet.

Alternatively,

- If you use **'Weekly graphs'**, you will have to be more of an investigator. On the weekly graphs, you will see a week of dates, with 24 lines between each date on each graph. The axis mark for each date is written at midnight of that day: for example, if you need to find the pollution level for 10am on March 10, you will have to count ten lines from the line where the 10/3 is written, and then look at the number written on the y-axis on the left side.
- You need to do this for both pollutants. Record the concentrations of NO_2 and SO_2 in your Class Data Sheet, along with the dates when these levels occurred.

If both concentration levels are not available for the site you selected, choose another one nearby.

Activity 1.1C: Monitoring air pollution

Exercise 3: Weather data

The weather affects the transport of pollutants in the air and chemical processes that turn certain kinds of air pollution into acid rain.

Wind direction, Wind speed, Temperature

You can collect the data in two ways:

1. You can get first-hand measurements:
   Measure and record the wind direction, wind speed and temperature in your Class Data Sheet.

   Remember! It is important that **the time of day is the same** every time you gather data.

Alternatively,

2. You can get this information from the Internet.
   Go to the UK Met Office website: ***www.met-office.gov.uk/education/archive/uk/***
   - Go to the date you need information for and click on the time that your class has chosen for recording the weather data each day.
   - A new page will come up with a long list of cities and towns across the UK, grouped by regions. Find the nearest location to where you are.
   - Record the wind speed, wind direction and the temperature in your Class Data Sheet.

Weather type, Rain Type, Hours of sun

Use your observations of the weather over the last 24 hours and record the type of weather, the rain type and the hours of sun in your Class Data Sheet.

Activity 1.1C: Monitoring air pollution

Exercise 4: Where is my school located?

The levels of pollution in the air depend on where the air has come from.

Find out and record the following information:

Direction and distance of your school from the coast
Direction and distance of your school from the centre of the town

Look up this information in local maps and books.
Record the information in your Class Data Sheet.

Direction and distance of your school from the nearest power station

Go to ***http://www.naei.org.uk/mapping/mapping_2001.php***

- Type in your post code (the whole code, not just the first part) and click 'go'
- This will identify nearby 'point sources' of pollution and how much they produce. A 'point source' is a single source of pollution, such as a factory or power station. If there are no appropriate 'point sources' within 5km of your school, you can choose a bigger radius and try again
- Convert the distance of the nearest power station from your school into miles and record it in your Class Data Sheet
- Record the name of the nearest power station in your Class Data Sheet
- Look up in books and local maps the direction from the power station you identified to your school.

Record this information in your Class Data Sheet

Whether pollution gets trapped in a particular site depends on the geography of that site.

Use your Class Data Sheet to record whether your school is on a plateau, a hill top, a flat plain, a mountain, a valley bottom or a valley side.

Activity 1.2C: Looking for patterns

Are there patterns linking air pollution to certain factors in the data I am collecting? How will I find out?

As you collect data about air pollution and factors that may be related to pollution levels you can begin to look for patterns in the data.

Exercise 1: Looking for links between different pollutants

After you have collected data for about two weeks you should be able to see whether the levels of NO_2 and SO_2 go up and down together.

1. Draw a scattergraph of concentrations of NO_2 on one axis and concentrations of SO_2 on the other.

2. After two weeks do you think that you can see a pattern?

   yes ☐ not sure ☐ no ☐

3. Do you think that the levels of NO_2 and SO_2 go up and down together?

   yes ☐ no ☐

4. Explain your answer to 3.

As you collect more data, add them to the scattergraph.

5. What does the scattergraph show after another week or two?

Activity 1.2C: Looking for patterns

Exercise 2: Are pollution levels related to wind direction?

After you have collected data for about two weeks you should be able to begin to see if the levels of NO_2 and SO_2 are related to the wind direction.

1. Make up a table for pollution levels when the wind is in eight different wind directions (North - N; North East - NE; East - E; South East - SE; South - S; South West - SW; West - W; North West – W). Work out the average pollution levels for the different wind directions and put these in your table.

2. Which wind directions have the highest levels of pollution?

3. Which wind directions have the lowest levels of pollution?

4. What do you think that the data about wind direction and pollution tell you about the effect of wind direction on pollution levels? Is there a pattern or do you need more data to find out? Comment on whether you can see a pattern emerging, what the pattern is, how strong the pattern appears to be and what more data you would need to make sure.

Exercise 3: Are pollution levels related to wind speed?

After you have collected data for about two weeks you should begin to see whether or not the levels of NO_2 and SO_2 are related to the wind speed.

1. Make up a table for pollution levels when the wind is low (5 knots or less) and high (15 knots or higher). Work out the average pollution levels for the different wind speeds and put these in your table.

2. What do you think that the data about wind strength and pollution tell you about the effect of wind strength on pollution levels? Is there a pattern or do you need more data to find out? Comment on whether you can see a pattern emerging, what the pattern is, how strong the pattern appears to be and what more data you would need to make sure.

Activity 1.3C: What factors affect air quality where you live?

What factors affect air quality where you live?
If you look outside on a bright summer's day, the air might look clear and fresh, but things are not always as they seem! Most air pollution is invisible.

By now, you will have been monitoring the quality of the air over the last few weeks. In this activity you are going to try to find out which factors affect the quality of the air outside by looking for patterns in the data you have collected.

This enquiry has four parts:

- Part 1: Generating a research question
- Part 2: Planning
- Part 3: Considering the evidence
- Part 4: Evaluating

Part 1: Generating a research question

When you write down your research question, remember to include:

- which pollutant or pollutants you are investigating
- which factor you will be investigating to see if it affects the pollution levels
- why you think this factor might affect the pollution levels
- what pattern you expect to find
- what other factors might be influencing the pollution levels, apart from the factor that you are investigating.

Write down your research question.

Part 2: Planning

Some questions to think about:

- What data will you use?
- By now you may have a lot of data, but does it match what you need for your enquiry?
- How much data do you need?
- What sample size should you use?
- What about the range of data?

Select the data that you need from the Class Data Sheet. Decide whether you will need to collect any additional data, and if so, what this will include.

Decide how you are going to look for patterns in the data and write down your plan.

Activity 1.3C: What factors affect air quality where you live?

Part 3: Considering evidence

Carry out your analysis, looking for patterns.

What have you found out? Consider these questions:

- Is the level of pollution affected by the factor that you investigated?
- Is it a strong relationship?
- How sure are you that there is a link between this factor and the level of pollution?
- Can you explain the relation between the level of pollution and the factor that you investigated?
- Are there any other factors that might have been influencing the level of pollution?

Write down your conclusion.

Part 4: Evaluating

Evaluating is about looking at conclusions and at the strength of the evidence used to come to the conclusions. Look at the enquiry and think about these questions:

- Is the sample size big enough?
- Do the levels of pollution and the factors that might affect the pollution levels change enough from day to day to be able to see a pattern?
- How much variation is there around any pattern observed?
- Are there other factors that might have caused the effects?

Write down your evaluation of quality of the evidence and its relation to the conclusion.

Activity 2.1: What is acid rain and where does it come from?

Exercise 1: What is acid rain?

How do you fancy taking an acid shower?
This is what you are doing sometimes when you step out into acid rain.

In this exercise, you can find out what acid rain is and what causes it.

Read the passage. Use coloured pens/pencils to circle or highlight and to underline words or phrases as indicated below.

- Find the **natural sources** contributing to acid rain. Circle these in RED (or highlight in colour 1).
- Some **pollutants** which contribute to acid rain are **caused by human activities**. Circle these in BLACK (or highlight in colour 2).
- Find the **processes by which acid rain is formed in the atmosphere**. Underline these in RED.
- Find the **ways in which acidic pollution falls to the Earth**. Underline these in BLACK.

Activity 2.1: What is acid rain and where does it come from?

What is acid rain?

Rain water is naturally acidic because of carbon dioxide that has dissolved in the rain. Natural rain has a pH of 5.6. Despite rain water being slightly acidic, it is not called acid rain unless the pH value is lower than 5.6.

There are many factors that cause acid rain. Some are natural and some are the result of human activities. Pollution due to human activities is the most common cause of acid rain. Though there are many pollutants in the air, the main pollutants causing acid rain are sulfur dioxide (SO_2) and nitrogen oxides (NOx). These air pollutants come mainly from burning fossil fuels for energy e.g. burning coal, industrial factories and road transport. Coal burning is the single largest source of sulfur dioxide accounting for about 50% of annual global emissions, with oil burning accounting for a further 25 to 30%. Natural sources of sulfur dioxide include releases from volcanoes, ocean sea spray and forest fires.

Nitrogen oxides are gases that are by-products of burning at extremely high temperatures e.g. cars and some factories, and of some chemical industries (fertiliser production). Natural sources of nitrogen oxides are biological decomposition in soils, forest fires, volcanic action and lightning.

Once in the atmosphere, sulfur dioxide and nitrogen oxides are carried by the wind, and can (in time, after several complex steps of chemical reactions), be converted into sulfuric and nitric acids. These conversions occur in the atmosphere when sulfur dioxide and nitrogen oxides react with water and oxygen and become acid rain. The brightness of sunlight is another factor that affects how quickly nitrogen oxides and sulfur dioxide are converted to nitric and sulfuric acids.

When acid falls to the ground it is called acid deposition. There are two different forms – dry and wet deposition. Acids are carried through the atmosphere by winds. Dry acid deposition falls to the Earth in the form of gas and dust. Wet acid deposition (acid rain) falls to the Earth as precipitation in the forms of rain, snow or fog. Dry acid deposition tends to fall to the Earth earlier than wet acid deposition. This is because the distance that dry acid deposition travels before falling to the Earth just depends on wind speed and wind direction and does not have to wait for it to rain. For example, in a dry desert region, if there is acid deposition, it will almost always be dry acid deposition since there is so little rain falling. In the UK, there is both dry and wet acid deposition. Wet acid deposition is more common here in the UK than in the south of Spain, as there is a higher amount of rainfall in the UK.

Activity 2.1: What is acid rain and where does it come from?

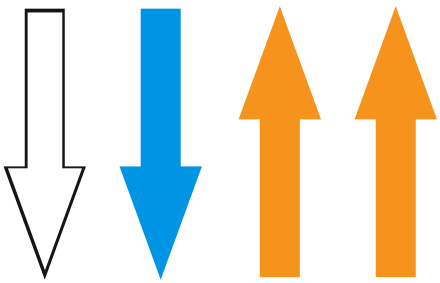
Exercise 2: The formation of acid rain

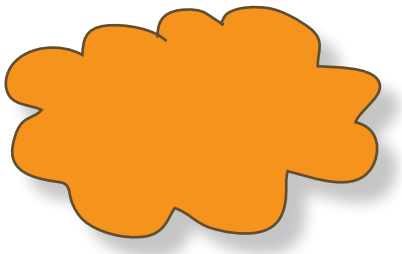
How does acid rain form and travel out there in the real world?

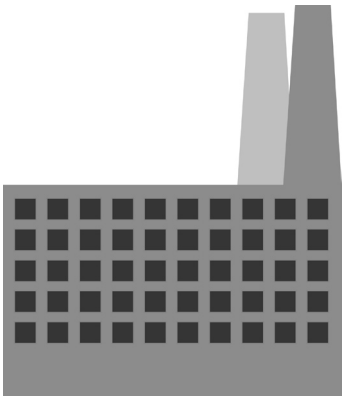
Use what you have learned in Exercise 1 to create a diagram that is easy to read and shows how acid rain is formed and comes down to the Earth.

Use the pictures, arrows and words below for your diagram: you can use extra blank boxes and arrows if you need to.

sulfur dioxide	nitrogen oxides	nitric acid
sulfuric acid	gas and dust	wind speed
wet deposition	dry deposition	rain or snow







Activity 2.1: What is acid rain and where does it come from?

Exercise 3: An Internet-based activity about the sources of acid rain pollutants in the UK

How close are you to a major source of sulfur dioxide?

Find out about sources of acid rain pollutants in the UK on the Internet.

Use the sites given below to answer the questions.

The National Atmospheric Emissions Inventory
www.naei.org.uk/mapping/mapping_2001.php

This website page allows you to explore maps of levels of pollutants in the UK, based on data for 2001. First, choose a pollutant from the 'Emissions maps 2001' menu then click 'Go' to see the whole of the UK.

1. What areas of the UK were most affected by sulfur dioxide levels in 2001?

2. Which areas were most polluted by nitrogen oxides in 2001? Why?

3. Do you think the air is cleanest in Manchester, Aberdeen or Plymouth based on these maps?
   Explain your answer

4. Enter your school's postcode in the 'Emissions data by postcode' box and click on 'Go'. Find the nearest to your school power plant that produces sulfur dioxide. What wind direction would be likely to carry pollution from the power plant over your town?

   What other sources of sulfur dioxide are listed?

   If you have not got any sources listed, try changing the search radius ('alternative distance') at the bottom of the page.

5. How big a problem is nitrogen dioxide in your area? How can you tell?

Activity 2.1: What is acid rain and where does it come from?

British Energy factfile
www.british-energy.com/education/factfiles/items/item50.html and

The Encyclopedia of the Atmospheric Environment
www.ace.mmu.ac.uk/eae/english.html ('acid rain' link, followed by 'acid deposition' link then 'transboundary problem')

6. How much do fossil-fuel plants currently contribute to pollution levels that cause acid rain in the UK?

7. How has this changed over time?

8. What areas of the UK are most affected by acid rain? Why?

9. Is wet or dry acid deposition causing the most damage in the UK?

10. How much UK pollution is affecting forests in Norway and Sweden?

11. Why are Norway and Sweden the countries most likely to be affected by acid rain due to UK sources?

Activity 2.1: What is acid rain and where does it come from?

Exercise 4: Chemistry of acid rain

What are the reactions that lead to the formation of acid rain?

In this exercise, you will complete chemical reactions which lead to the formation of acid rain.

Fill in the missing words describing the reaction and give the formula for the final product of each reaction.

1. Nitrogen monoxide is formed in car engines and some industrial processes when nitrogen and _____ react together at _____ temperatures.

$N_2(g) + O_2(g) \longrightarrow$

2. The highly reactive nitrogen monoxide reacts with _____ to produce nitrogen dioxide.

$2NO(g) + O_2(g) \longrightarrow$

3. In the presence of sunlight, _____ combines_____with _____and more in the atmosphere to form nitric acid:

$4NO_2(g) + 2H_2O(g) + O_2(g) \longrightarrow$

4. _____ in fossil fuel burns with _____ to form sulfur dioxide:

$S(s) + O_2(g)$

5. Sulfur dioxide reacts with _____ in the atmosphere to form sulfur trioxide:

$2SO_2(g) + O_2(g) \longrightarrow$

6. Sulfur trioxide reacts with _____ to form sulfuric acid:

$SO_3(g) + H_2O(l) \longrightarrow$

Some formulae you may find useful

H_2O NO SO_2 O_2

H_2SO_4 NO_2 SO_3 HNO_3

Activity 2.2: The damaging effects of acid rain and air pollution

Exercise 1: The damaging effects on aquatic life

What effects does acid rain have on rivers and lakes?

In this activity, you will find out how watersheds become acidic and what effect this has on life in streams, rivers, lakes and marshes.

Acid rain and air pollution damage natural ecosystems such as watersheds and forests, as well as affecting buildings and human beings.

1. Read the passage titled **'Becoming acidic'**. Use coloured pens/pencils to circle or highlight and to underline words or phrases as indicated below.

- Find **types of watersheds** (where rain water collects): circle these in BLUE (or highlight in colour 1).
- Find the **normal pH level** for lakes and streams and circle this in RED (or highlight in colour 2).
- Find the **species that are affected by acidity in watersheds** and circle these in BLACK (or highlight in colour 3).
- Find the phrases or sentences that describe **how lakes, streams, rivers or marshes become acidic** and underline these in BLUE.
- Find the phrases or sentences that describe **general effects of acidic water in lakes, streams, rivers and marshes**. Underline these in RED.
- Find phrases or sentences that describe **specific effects of acidity on animal species in aquatic environments**. Underline these in BLACK.

2. Use this information to help you draw a diagram that represents how watersheds become acidic and affect aquatic life.

Activity 2.2: The damaging effects of acid rain and air pollution

Becoming acidic

The effects of acid rain are often seen in lakes, rivers, streams and marshes. Acid rain falls directly on to these areas or flows to them after falling on forests, fields, buildings and roads. Most lakes and streams have a pH between 6 and 8, although some lakes are naturally acidic even without the effects of acid rain. It is a complicated process for watersheds to become acidic due to acid rain. Usually it occurs when there isn't enough limestone or other minerals in the soil to neutralise acid rain and prevent a build-up of acidity.

The plants and animals living within an ecosystem are highly interdependent. When a watershed does become acidic due to acid rain, the effects can become magnified through the food web. The acidity can affect animal and plant species directly or indirectly. For example, a direct effect would be if the acidity of the water killed fish immediately, or if their immune system was so weakened that they were unable to reproduce. An indirect effect works as follows: some types of plants and animals are able to survive in acidic waters but if their source of food cannot survive then eventually they are affected as well. For example, frogs may tolerate relatively low pH levels, but if they rely on eating insects like the mayfly, they may be affected because part of their food supply may disappear.

Generally, the young of most species are more sensitive to environmental conditions than adults. At pH 5, most fish eggs cannot hatch but adult fish would be likely to survive until a lower pH level is reached.

Activity 2.2: The damaging effects of acid rain and air pollution

Exercise 2: Different effects on different species

Fancy going fishing in a lake that has become acidic?
Sometimes the open countryside is not as unpolluted as it seems.

In this exercise, you will find out some of the effects that acids have on animals in water.

Read the passage below, then use the information in the table to help you answer the questions.

Signs of Life

While walking along one day in the Lake District, you decide to take a rest by a small lake somewhere in the western area of the National Park. You've been looking for this lake as a guidebook told you that if you look carefully you might see signs of snails, mayflies, frogs, crayfish and perch.

After sitting there a few minutes and looking carefully around, you notice that some of the trees surrounding the lake look a bit unhealthy. There aren't as many needles on the pine trees as there should be. It is also very quiet and you don't see many signs of life. You decide to test the pH of the water with your new science kit that you remembered to put into your rucksack: the lake water is about pH 5.0.

The table provides information on the acidity tolerance of different aquatic animals. This table can help predict the effects of change in pH if you know something about the food web of a given ecosystem. For example: Frogs can tolerate water that is more acidic than trout can, but may lose their food supply if they rely on mayflies.

Animal species	pH 6.5	pH 6.0	pH 5.5	pH 5.0	pH 4.5	pH 4.0
Snails						
Crayfish						
Mayflies						
Trout						
Perch						
Frogs						

Key: Animals survive in this pH

Activity 2.2: The damaging effects of acid rain and air pollution

Questions

1. Is the water in this lake acidic? How do you know?

2. According to the guidebook, which aquatic animals should be alive here?

3. Which of these animals might not be living here right now due to the pH of the water?

4. Which of the species might be unhealthy?

5. You remember that mayflies are the main food of frogs.

   (a) What is the lowest pH level that mayflies are able to survive?

   (b) How might this affect the frogs?

6. What might be the link between the pH level of the lake and the health of the trees?

7. What do you think the pH level of the rain in that area might be?

   Explain why you chose this pH level.

8. It is curious that that acid rain might be a problem in such a beautiful, clean and peaceful area. Why do you think this is the case?

Activity 2.2: The damaging effects of acid rain and air pollution

Exercise 3: The effects of acid rain on the environment

Have any buildings on the high street been affected by acid rain?

Find out what buildings, forests and rivers look like if they have been affected by acid rain.

Use the websites below to answer the following questions.

Pagewise: Acid rain information
http://nm.essortment.com/acidrainwhati_rhja.htm
This website describes the sources of acid rain and how it affects wildlife and human beings.

The Encyclopedia of the Atmospheric Environment
*http://*www.ace.mmu.ac.uk/eae/english.html (follow 'acid rain' link). This website provides descriptions of the effects of acid rain on buildings, wildlife and people.

1. If you entered a forest this summer how would you know if the forest had been affected by acid rain? Describe what you would see.

2. Which building materials are most affected by acid rain, and which least?

3. How would a statue made of limestone or marble change over the years in a city polluted by acid rain?

4. Describe some of the effects of acid rain on people.

Activity 2.2: The damaging effects of acid rain and air pollution

Exercise 4: The effects of air pollution and acid rain in Asia

What is it like living in the middle of a toxic cloud?

In this exercise, you will find out some of the effects of air pollution and acid rain in Asia.

Read the following article from the DailyTelegraph on 13 August, 2002. The article describes the devastating effects that air pollution and acid rain have on human health and the environment in Asia.

While you read this article, use coloured pens or pencils and follow the directions below.

- Find **effects** that you think are (or might be) caused by air pollution: underline these in BLACK.
- Find what you think might be the **causes** of air pollution, and underline these in RED.
- Use BLUE to underline the description of **how** air pollution is being carried to different regions of Asia.

Activity 2.2: The damaging effects of acid rain and air pollution

Toxic umbrella that is choking Asia
(Filed: 13/08/2002)

Alex Spillius reports from Bangkok on the world's new atmospheric pollution problem, a two-mile high deadly brown cloud of pollution stretching from Afghanistan to China.

Welcome to beautiful, charming Asia. Land of exotic settings, sumptuous sunsets and, we now learn, more acid rain than Europe and North America combined. Those of us who live under the "Asian Brown Cloud" knew that the air around us and above us was bad; we just did not know how bad until the release of a United Nations report identifying the world's new atmospheric pollution phenomenon. The study makes for uncomfortable reading. A toxic umbrella stretches from Afghanistan to China, critically disrupting weather patterns, causing droughts and floods. Foul air is sending thousands upon thousands of people to premature deaths from respiratory illness. Harvests are ruined. Half the world's population is affected.

The two-mile-high cloud could be carried by prevailing air currents across the world in a week and could distort climate patterns in Europe. The viscous haze has a depressingly wide range of causes: aerosols, forest fires, fossil fuels burnt in industry, power stations and an ever-growing number of vehicles; emissions from millions of inefficient cookers burning wood, cow dung and other "bio-fuels". In Bangkok, the weather doesn't provide much to talk about: it is either hot or very hot, quite humid or very humid. But pollution is almost as commonly discussed in Asia - at least by expatriates - as the weather is at home.

A dinner party almost invariably produces a round of pollution stories: the friends whose children developed chronic asthma in Delhi; the horrors of heavy industrial waste in Beijing; the filth in the sea off the beaches near Bangkok. But anybody who endured the 1997 haze in Kuala Lumpur or Singapore generally wins the raconteur's first prize. The smog caused by forest and plantation fires in Indonesia was so intense that visibility was reduced to yards, schools were closed and children had to stay indoors. The populations of whole cities wore protection masks. A plane crash-landed in Borneo killing all on board. And still the fires blight South-East Asia every year.

Reporting from the region has involved regular disasters of landslides, flood and famine. Vietnam is now expecting its third year of heavy floods. Millions in Bangladesh and north-eastern India are already cut off by heavy rain but, after the mass deaths two years ago, have barely made the news. Large areas of Afghanistan and Pakistan where there were once abundant orchards of grapes, pomegranates, apples, apricots and plums have turned to desert. A spectacularly harsh winter in Afghanistan in 2000-01 claimed hundreds of lives and sent thousands into refugee camps. The UN Environment Programme study, compiled by 200 scientists, has drawn this climatic calamity together and given the trend a name - the Asian Brown Cloud - which it probably needs if proper local action is to be taken. It would be encouraging to think that the combination of factors that have put this noxious blanket over our heads would merit discussion at the World Summit on Sustainable Development in Johannesburg beginning later this month. But it is apparently too late to be squeezed on to even the biggest agenda in the history of conferences. Those of us who live in Asia will have to seek consolation in the striking landscapes and dramatic dusks, even if they are getting hazier by the day.

Activity 3.1: Working with scattergraphs

Exercise 1: Reading scattergraphs – Is there a pattern?

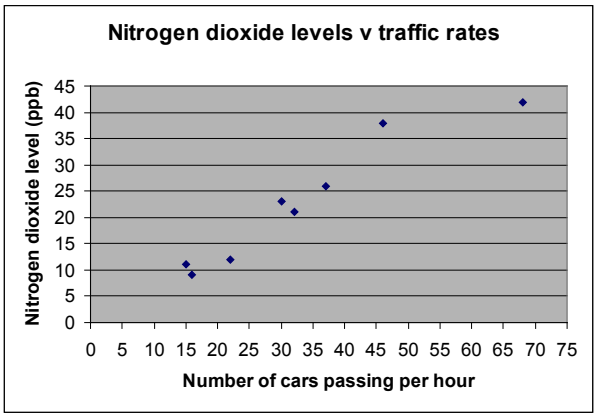
How confident are you at finding patterns in a scattergraph? Scattergraphs are useful in determining whether or not a relationship exists between different variables.

In this exercise you will use scattergraphs to determine whether relationships exist between air pollution levels and different factors.

Use the scattergraphs below to answer the questions.

The next three scattergraphs show measurements comparing nitrogen dioxide levels with traffic patterns with cars and bicycles.
Graph 1 shows the nitrogen dioxide concentrations next to a busy road in a National Park on one day in August.

Graph 1



1. Describe the relationship between the nitrogen dioxide levels and the number of cars passing per hour.

2. How confident are you that this graph shows a relationship between traffic patterns and the levels of nitrogen dioxide? Choose a, b or c.

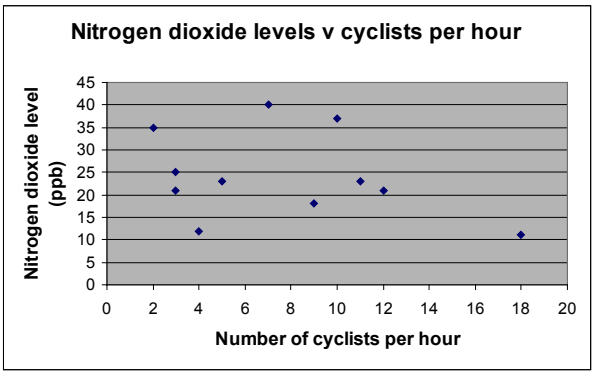
   (a) I am confident there is a relationship
   (b) I am uncertain whether there is a relationship
   (c) I am sure there is no relationship

3. Explain your answer for question 2.

Activity 3.1: Working with scattergraphs

Graph 2 shows the nitrogen dioxide concentrations next to a busy cycle path in a National Park on the same day in August.

Graph 2



4. Describe the relationship between the number of cyclists and the levels of nitrogen dioxide in Graph 2.

5. How confident are you that this graph shows a relationship between the number of cyclists and the levels of nitrogen dioxide? Choose a, b or c.

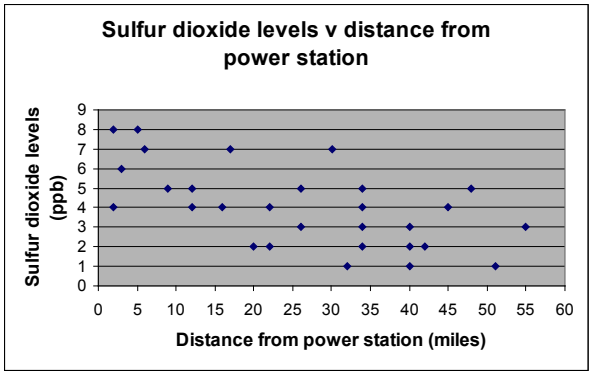
(a) I am confident there is a relationship
(b) I am uncertain whether there is a relationship
(c) I am sure there is no relationship

6. Explain your choice for Question 5.

Activity 3.1: Working with scattergraphs

Graph 3 shows the concentrations of sulfur dioxide taken at different distances from a power station. The readings were taken in sites located all around the power station at different distances from the power station.

Graph 3



7. Describe the relationship between the distance from the power station and the levels of sulfur dioxide in Graph 3

8. How confident are you that this graph shows a relationship between the distance from the power station and the levels of sulfur dioxide? Choose a, b or c

a) I am confident there is a relationship
b) I am uncertain whether there is a relationship
c) I am sure there is no relationship

9. Explain your choice for Question 8.

Activity 3.1: Working with scattergraphs

Exercise 2: Creating scattergraphs on a spreadsheet

How can you create a scattergraph on a spreadsheet?

In this exercise, you will use data provided on a spreadsheet to create scattergraphs.

Look at the spreadsheet labelled 'Exercise 2' in Excel file 'Activity 3.1, Ex1_2'. This contains air quality and weather data for London, in May and June 2004.

Study the instructions below and create scattergraphs which show:

1. how the levels of nitrogen dioxide are related to the amount of rain
2. how the levels of sulfur dioxide relate to the minimum temperature.

Instructions for creating a scattergraph

Suppose you want to create a scattergraph which shows how sulfur dioxide concentration levels relate to nitrogen dioxide levels for May 2004.

This is what to do:

- Mark the readings for the x-variable (in this example, this is the nitrogen dioxide levels) for the period you wish to create the scattergraph (in this example, this is May 2004, Cells I11-I41)
- Keeping the 'Control' button on your keyboard pressed, mark the readings for the y-variable (in this example, this is the sulfur dioxide levels) for the same period (Cells J11-J41).
- Click 'Chart Wizard'. This takes you to:

  Step 1: Select 'XY-Scatter', first sub-type. Click Next.
  Step 2: Select 'Series in': Columns. Click Next.
  Step 3: Select 'Titles':
  Type-in the title of the chart (In this example, this is 'Sulfur dioxide vs nitrogen dioxide concentration levels in London, May 2004')
  Type-in 'category x-axis' (In this example, this is 'Nitrogen dioxide concentration (ppb)')
  Type-in 'category y-axis' (In this example, this is 'Sulfur dioxide concentration (ppb)').

- Click 'Finish'. This gives you your graph.
- Click on the 'Series' box. Press Delete.

You should then have the graph shown in the spreadsheet, starting at cell L10.

You may wish to enlarge your graph. To do so, click and drag at the corners of the graph.

Activity 3.2: Using tables to sort out data

Does the wind direction affect levels of air pollution?

In this activity you study data from the Internet to find out whether the way the wind blows affects pollution in Aberdeen.

One way of finding out whether wind direction affects air pollution levels is to collect data about air pollution and wind direction over quite a long period of time and see if there are patterns in the data.

Use the table and map to answer the questions.

Aberdeen is a city in north east Scotland. One of the pollutants found in the air in Aberdeen is sulfur dioxide. This pollutant reacts with the air to make sulfuric acid, which is found in acid rain.

You are provided with two sources of data:

- A map which shows emissions of sulfur dioxide. This map tells you the average levels of sulfur dioxide in different parts of the United Kingdom in 2001. There is also a map showing cities and point sources of sulfur dioxide in 1996, which you may find helpful.
- A table of pollution levels of sulfur dioxide recorded at the same time each day. This table also contains information about wind direction and wind speed.

Questions

1. Study the maps and predict the directions of the wind when sulfur dioxide concentrations would be high in Aberdeen and when they would be low.

Remember! The wind direction tells you which direction the wind is blowing from. For example, when the wind is in the north direction, air is being carried from the North Sea to Aberdeen.

Activity 3.2: Using tables to sort out data

There are two ways of dealing with questions 2 and 3.

If you are working on paper:

2. Take the readings from the table and rearrange them under headings for the SO_2 concentration for each wind direction. The first three are given for you.

Direction	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
SO_2 concentration	SO_2 (ppb)	SO_2 (ppb)	SO_2 (ppb)	SO_2 (ppb)	SO_2 (ppb)	SO_2 (ppb)	SO_2 (ppb)	SO_2 (ppb)
						5	2	3
Average SO_2 concentration								

3. Work out the average SO_2 concentration for each wind direction and complete the row for the average SO_2 concentration in your table.

If you are working on the Excel spreadsheet labelled 'Activity 3.2':

2. Sort out the data on your table by wind direction.
   To do so:
   - Select 'Data', then 'Sort' by wind direction.

3. Work out the average SO_2 concentration for each wind direction and record it in your table.
   To do so:
   - Insert a blank row at the bottom of each wind direction and calculate the average concentration of SO_2 for each direction by using 'Paste function'. In 'Paste function', select 'Statistical', then 'Average'.

Activity 3.2: Using tables to sort out data

4. Discuss these questions in your group:
   - Do you have evidence about whether pollution levels of sulfur dioxide are high or low when coming from the north-east?

   - How many readings do you need before you can be sure that you are confident in your average? Are three readings enough? Are seven readings enough? Do you need more?

5. Was your prediction in question 1 right? Choose one of these answers:

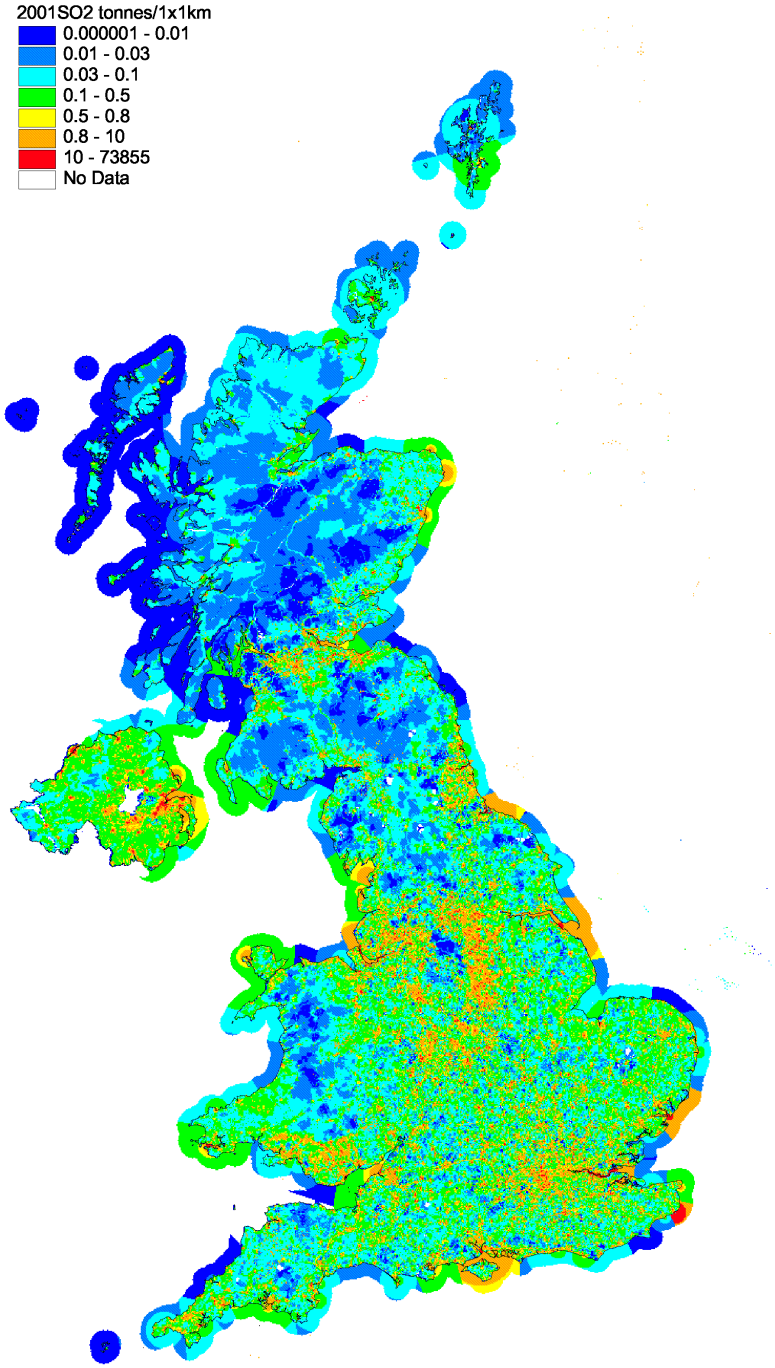
   a) My prediction was right
   b) My prediction was partly right
   c) My prediction was not right
   d) I'm not sure if my prediction was right or not

6. Write an explanation of why you think that sulfur dioxide levels were high when the wind direction was north. In writing this explanation, consider the following questions:

   - Are there other possible explanations for high levels of sulfur dioxide in Aberdeen?
   - Look carefully at the pollution levels when the wind was coming from the north. The pollution levels are quite high. If you look at a map you will see that there is no major source of pollution north of Aberdeen, so where could the pollution have come from? Look at the wind speeds to provide your answer. Wind speed information is given in the table. Does this give you a clue?

Activity 3.2: Using tables to sort out data

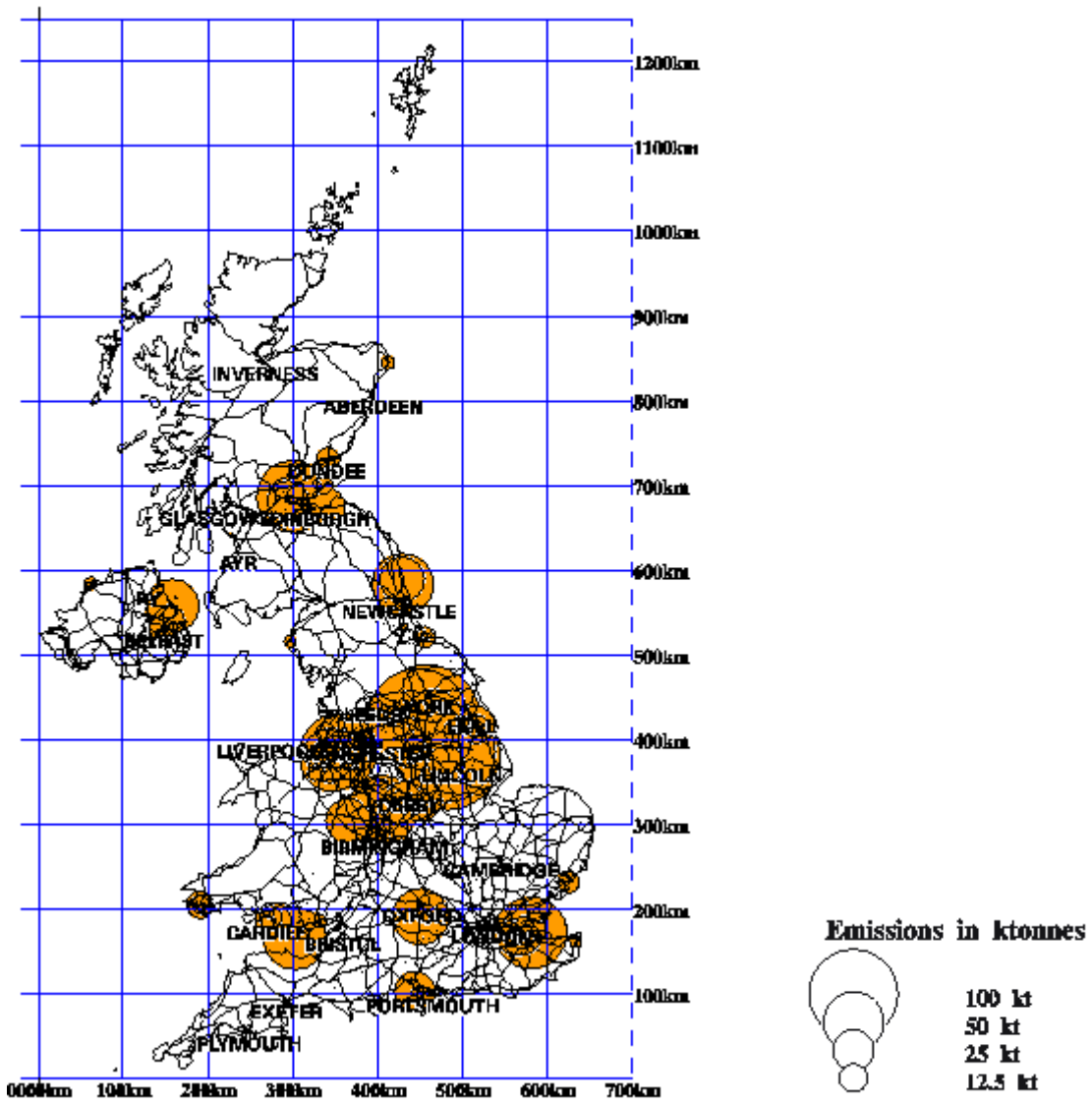
Sulfur dioxide emissions map, 2001



Map from the NAEI web site *http://www.naei.org.uk/mapping/mapping_2001.php*

Activity 3.1: Using tables to sort out data

Point sources of sulfur dioxide, 1996



Map from: National Atmospheric Emissions Inventory
http://www.aeat.com/cgi-bin/emlev1.pl

Activity 3.2: Using tables to sort out data

Table of pollution levels of sulfur dioxide

Date	Wind direction	Concentration of sulfur dioxide (ppb)	Wind speed (kmph)
5/11/02	SW	5	1
6/11/02	W	2	10
7/11/02	NW	3	5
8/11/02	SW	2	7
9/11/02	W	3	9
10/11/02	SW	4	10
11/11/02	S	3	8
12/11/02	S	3	8
13/11/02	N	5	2
14/11/02	E	3	16
15/11/02	W	0	12
16/11/02	NW	1	13
17/11/02	NW	1	5
18/11/02	N	9	0
19/11/02	SE	8	14
20/11/02	SE	12	14
21/11/02	SE	6	21
26/11/02	S	16	13
27/11/02	SE	5	19
28/11/02	SE	6	10
29/11/02	S	14	4
30/11/02	S	10	7
1/12/02	SE	7	15
2/12/02	S	6	5
4/12/02	S	3	7
5/12/02	NW	1	10
6/12/02	SE	15	7
7/12/02	SE	0	6
8/12/02	E	1	11
9/12/02	SE	0	13
10/12/02	E	0	5

Data obtained from Met-office archive
http://www.met-office.gov.uk/education/archive/uk/
This table is also available as a spreadsheet in the Excel file labelled 'Activity 3.2'.

Activity 3.3: Looking for patterns over time

If you want to go outside and breathe fresh, clean air, when is the best time to go out?

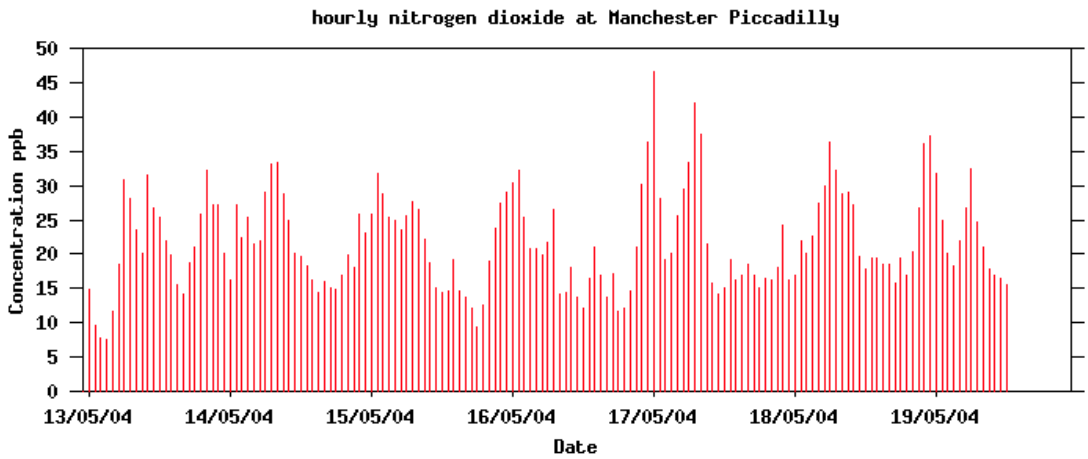
In this activity you will be using graphs to decide at what time in the day the air might be cleanest.

Many places in the UK have air quality detectors that measure the quality of the air every hour, twenty-four hours a day.

You will use graphs A and B to find out whether there are patterns in the levels of air pollution over time: this should help you to identify the times of day when the air might be cleanest.
If you find any patterns, you will be assessing how strong these patterns are. You will also have to decide how sure you are that there is a pattern and whether you will need more data to be sure of a pattern.

For both graphs A and B, there are hourly readings for each day. The mark on the x-axis is immediately below the 12.00am (midnight) reading. This is the first reading for the date shown below the mark.

Graph A shows the variation in nitrogen dioxide levels at Manchester Piccadilly during the week beginning on Thursday, 13/05/04.



(Data obtained from The Air Quality Archive website at *http://www.airquality.co.uk/archive/index.php)*

For graph A:

1. Draw horizontal lines (in pencil) across the graph from each concentration interval of 5. (These are to help you read off values more easily).

Activity 3.3: Looking for patterns over time

2. Fill in the tables below to show the readings during each hour of the day (the first 3 have been filled in for you):

13/05/04, Time (am)	12	1	2	3	4	5	6	7	8	9	10	11
Nitrogen dioxide level (ppb)	15	10	8									

13/05/04, Time (pm)	12	1	2	3	4	5	6	7	8	9	10	11
Nitrogen dioxide level (ppb)												

3. What were the 3 highest levels of nitrogen dioxide, and at which times were these obtained?

4. What were the 3 lowest levels of nitrogen dioxide, and at which times were these obtained?

5. Are the peaks spaced out fairly evenly? If the answer is yes, look at the graph carefully and work out roughly at what time or times of the day there are peaks in nitrogen dioxide pollution. Write down the time or times.

6. Are the troughs spaced out fairly evenly? If the answer is yes, look at the graph carefully and work out roughly at what time or times of the day there are troughs in nitrogen dioxide pollution. Write down the time or times.

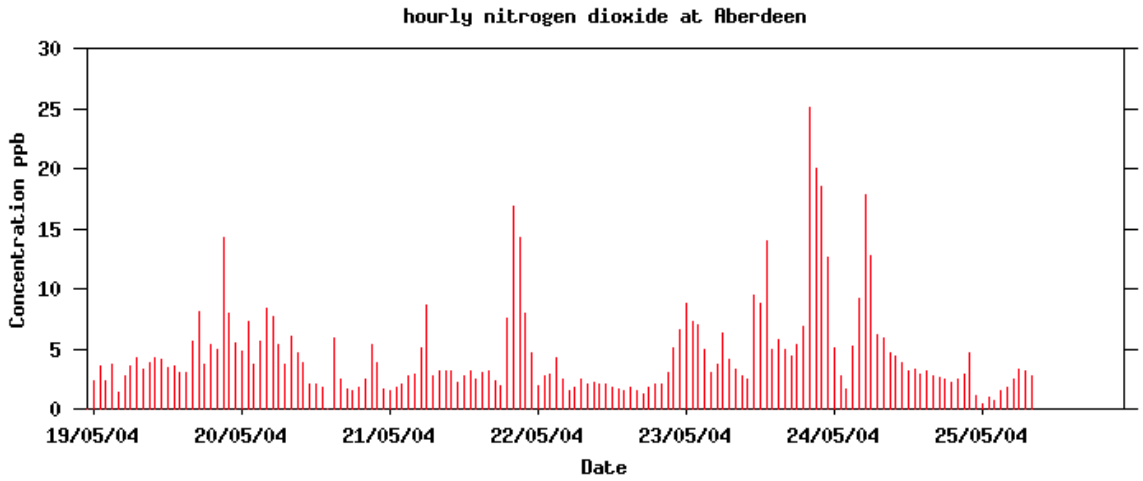
7. Now decide how strong the pattern of nitrogen dioxide air pollution is each day. To do this look at the pattern of peaks and decide if it is regular from day to day or whether there is a lot of variation from day to day. Next look at the troughs. Overall do you think there is a strong pattern, a weak pattern or no pattern?

   (a) Strong pattern (b) Weak pattern (c) No pattern

8. The readings on the graph go up to 12.00pm (noon) on 19/05/04.
   (a) Predict the concentration for 1.00 pm.
   (b) Explain how you have made this prediction, and give an estimate for how accurate your prediction is. (In other words, what are the highest and lowest concentrations that you might expect to be possible at 1pm?)

Activity 3.3: Looking for patterns over time

Graph B shows nitrogen dioxide concentrations at Aberdeen for the week beginning (Wednesday) 19/05/04.



(Data obtained from The Air Quality Archive website at *http://www.airquality.co.uk/archive/index.php*

For graph B:

9. Are the peaks spaced out fairly evenly? If the answer is yes, look at the graph carefully and work out roughly at what time or times of the day there are peaks in nitrogen dioxide pollution. Write down the time or times.

10. Are the troughs spaced out fairly evenly? If the answer is yes, look at the graph carefully and work out roughly at what time or times of the day there are troughs in nitrogen dioxide pollution. Write down the time or times.

11. Now decide how strong the pattern of nitrogen dioxide air pollution is each day. To do this look at the pattern of peaks and decide if it is regular from day to day or whether there is a lot of variation from day to day. Next look at the troughs. Overall do you think there is a strong pattern, a weak pattern or no pattern?

    (a) Strong pattern (b) Weak pattern (c) No pattern

12. The readings on the graph go up to 8.00 a.m. on 25/05/04.

    (a) Predict the concentration for 9.00 a.m.
    (b) Explain how you have made this prediction, and give an estimate for how accurate your prediction is. (In other words, what are the highest and lowest concentrations that you might expect to be possible at 9.00 a.m.?)