Geo Factsheet

Number 104

Freshwater pollution – a case study using the River Perry in North Shropshire

Water pollution has immediate social and economic consequences and, in some instances, can disrupt complex biogeochemical cycles. Contamination of water occurs in both the countryside (e.g. pollution discharges from farms) and in towns where much of the pollution is caused by industrial effluent.

What is pollution?

Pollution can be defined as:

The introduction by man into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structure or amenity, or interference with legitimate uses of the environment (Holdgate 1979).

With respect to pollution of freshwater, some 1500 substances have been listed as pollutants (Table 1). Some of the categories are not mutually exclusive, domestic sewage for example, may contain detergents, nutrients, metals and a variety of other compounds.

Table 1 – Freshwater pollutants

***Acids and alkalis** usually from specific points e.g. soda works. Not routinely released.*
***Anions**, e.g. sulphide, cyanide usually from specific points. Not routinely released.*
***Detergents** often from domestic sources*
**** Domestic sewage and farm manure/slurry***
**** Food processing wastes,** e.g. brewing, but also including processing on farms*
***Gases,** e.g. chlorine and ammonia*
***Heat,** e.g. that produced by a power station*
***Metals,** e.g. zinc, cadmium, lead*
**** Nutrients,** e.g. phosphates and nitrates – widespread from flushing out of fertilisers*
***Oil** – often from leaks*
Pesticides
**** = pollutants which are possible sources of organic pollution***

The effect a particular pollutant has on an organism or ecosystem will depend on its concentration and the time of exposure to it, i.e. the **dose**. Many freshwater pollutants, (excluding radiation) are **sublethal** in their effects, so they do not directly kill the organism concerned but may cause physiological or behavioural problems, for example - poor growth. The effects of pollution can be recorded in the loss of some species, or gain in others and generally a reduction in **diversity**.

Types of freshwater pollutants

Human sewage, animal wastes, silage and by-products of food processing are forms of **organic** pollution. These **effluents** contain unstable compounds which are broken down by bacterial action by using oxygen dissolved in water. Nitrate pollution from fertilisers is often referred to alongside organic pollutants as it has a similar effect, indirectly causing a reduction in oxygen levels in fresh water.

Pollution may enter a watercourse from a **point source** such as a pipe from a factory, in which case it is relatively easy to detect its origin. Alternatively, effluents may be dispersed e.g. nitrate run-off from agricultural land. This type of pollution is called **diffuse** and is more difficult to investigate spatially.

Why do we need to be concerned?

Water pollution is a complex topic. Most water courses receive a variety of potentially harmful substances via effluent discharges. But in many water courses the pollution is 'treated' leading to good standards of water quality.

Freshwater pollution is of concern for a number of reasons:

1. **Water supply.** In the UK, domestic water consumption is about 140 litres per person / day. Yet there is a discrepancy between water availability and use, i.e. disparity between areas of high rainfall (the North and West) and areas where water is needed in large quantities (the S.E in particular). Water is abstracted from rivers to make up this shortfall and such water must therefore be of an acceptable quality.

2. **Effluent disposal.** Domestic, industrial and agricultural users produce waste products and waterways provide a cheap and effective means of disposal. It is essential that the effluent discharged into a watercourse is of a high quality and the degree of pollution is such that the self-cleaning ability of the river is not overloaded.

3. **Managing pollution control.** Pollution control is costly and the benefit in resource terms may be far outweighed by the cost of control. Furthermore many rivers cross frontiers, e.g. the Rhine which rises in the Swiss Alps and flows through Germany to discharge into the North sea some 1300km from its source. If nation 'A' pollutes the river, nation 'B', further downstream, may experience the negative impacts of this contamination.

Monitoring freshwater pollution

Effective management of polluted waters requires a knowledge of:

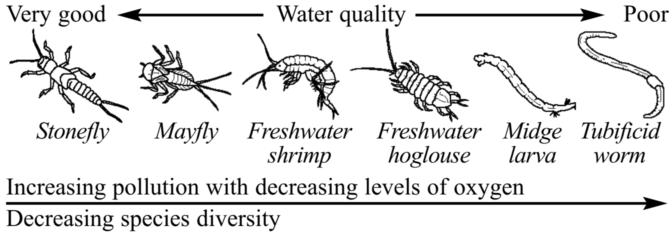
- *The substances entering the environment, their quantities, sources and distribution.*
- *The effects of these pollutants within the environment.*
- *Temporal changes in concentrations and the causes of these changes, i.e. changes over time.*
- *How far these inputs and effects can be modified and at what cost.*

Two main categories of techniques can be used to determine water quality:

Environmental: *A range of approaches can be used –*

1. *Animal and plants (biological indicators).* Some species of freshwater organism have a low tolerance to pollution. The types, numbers and distribution of these **indicator** species can be used to gauge the quality of water. There is usually a progressive loss of clean water animals the closer you get to the source of pollution, whereas the presence of certain organisms is an indication of pollution, e.g. sewage fungus and blanket weed. Biotic indices, e.g. the Trent Biotic Index, can be used to evaluate freshwater pollution. As the degree of organic pollution in a stream or river increases, the types of organisms tend to decrease in the following order: stonefly nymphs, mayfly nymphs, freshwater shrimps, water hoglouse and so on as shown in Fig 1.

Fig 1. Freshwater animals are useful as indicators of pollution levels



2. *Visual evidence.* Qualitative observations can be made such as smell, water discolouration, oil surface scum and presence of rubbish in the water and on the bankside.
3. *Turbidity.* This is a measure of the amount of suspended sediment present in a water sample. High suspended sediment loadings will give the water a turbid or opaque appearance and this may indicate high levels of organic pollutants. Turbidity can be measured using a Secchi disc.
4. *Temperature and circulation.* Temperature partly limits stream oxygen levels; the lower the temperature, the more oxygen that can be dissolved in the stream. Sometimes unusually high temperatures result from discharges from thermal power stations.

Chemical:

1. *Dissolved oxygen.* Oxygen is used by bacteria in rivers and streams to break down organic pollutants. This means rivers with low oxygen concentration may be suffering pollution, for example - from raw sewage, paper mills or food processing plants. This impacts on the fauna. Fish, for example, are high oxygen demanders, and will not be able to survive in streams with low concentrations of dissolved oxygen.
2. *Nitrate levels.* Nitrates are essential for plant growth, but levels of 50 ppm are the recognised upper limits for potable (safe to drink) water. Nitrates may enter from agricultural activities or from sewage and are associated with eutrophication (the nutrient enrichment of water through the accumulation of soluble residues, i.e. nitrates and phosphates which encourage algal blooms). Visual surveys can record the surface extent of algal blooms which appear as green slime on the water surface.

Other procedures are available for measuring river water quality, but these tend to be specialist and expensive and are usually only available at universities or through water companies.

Case Study – The River Perry

The River Perry is the most westerly of the rivers which rise in the low hills on the boundary of the North Shropshire sandstone plain and flow south to the Severn at Shrewsbury (Fig 2a). As Fig 2b shows, after about a third of its length, the Perry receives the first of its two major tributaries, the Tetchill Brook, from the north. It begins life as an artificial outflow from the mere at Ellesmere, created in Victorian times to regulate the lake level. Immediately after its confluence with the Tetchill Brook, the Perry enters the large depression of a basin known as Baggy Moor, where the gradient drops to 1m per km or less. After Baggy Moor, the river enters a narrow valley at Ruyton and then flows over glacial debris with the valley bottom becoming stony. Here it shows natural meander patterns and a pool-riffle sequence. The River Perry has been heavily modified. At Baggy Moor for instance, the land has been drained for agriculture. Severn Trent, a water company (and its predecessors) has extensively ***canalised*** *the main and tributary channels above Ruyton to cope with the extra drainage this change in land use has caused - modifying the hydraulic geometry, or channel cross section to make it more efficient and more 'canal'- like.*

Fig 2a. Map of rivers in North Shropshire

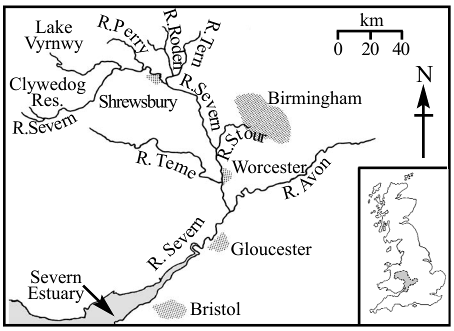
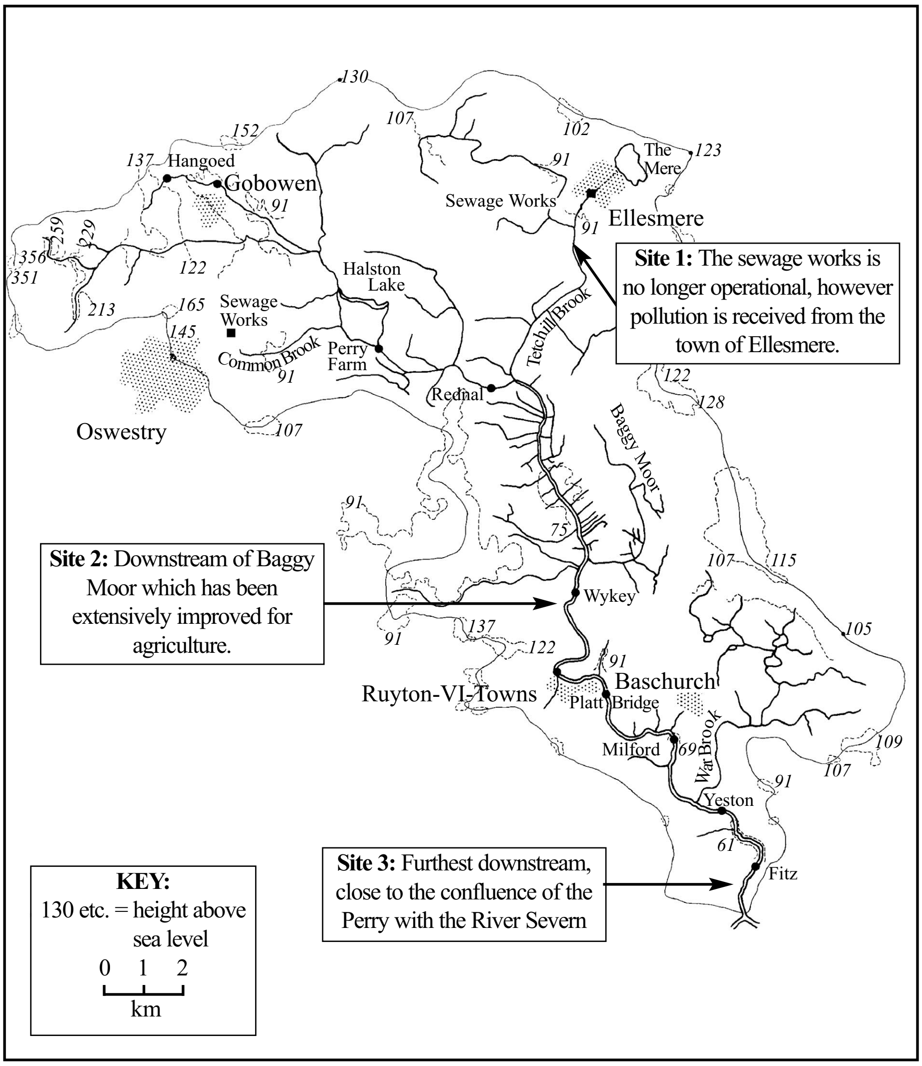


Fig 2b. Map of the River Perry



Case Study – The River Perry (continued)

Throughout its length, the River Perry is subject to treated and untreated organic effluents. Treated discharges come from sewage works and untreated discharges can derive from normal or careless agricultural practice (the latter tend to be a discontinuous source of organic pollution). In September 1985 for example, 200,000 litres of pig slurry were discharged into the river causing almost a total loss of fish life down to the confluence with the River Severn.

Exam Hint: Draw an annotated sketch map to show the main physical features of the River Perry catchment. Use Figure 2b as a base map. You should also label potential sources of pollution.

Water Quality Results for the River Perry - Field Based Results

The Perry receives organic pollutants from settlements such as Ellesmere and Ruyton and also outputs from farms throughout the course of the river. By sampling at locations along the river it is possible to identify the distribution and impact of such releases. Fig 2b shows the approximate locations of three sample sites, and Table 2 shows simplified results for invertebrate / aquatic plant indicators based on 'kick-sample' data collected by students on a field course in Shropshire. These results are shown as pie charts on Fig 3. Table 3 and Fig 4 also show chemical and environmental data from the same field course.

Interpretation of these figures reveals that Ellesmere is a likely point source of organic pollution.

- *Site 1 shows low **diversity** and is dominated by low-oxygen demanding organisms. Levels of dissolved oxygen are also low and suspended sediment concentrations are high. Further downstream, the river appears to recover due to dilution from additional tributaries which are bringing in clean water and also the breakdown of organic material by bacteria (resulting in the deposition of suspended solids).*
- *At Site 3 organisms which are high oxygen demanders are dominant and the dissolved oxygen level is highest indicating this site is experiencing the least signs of organic pollution. The evidence points to this being the cleanest site.*
- *Sites 2 and 3 show relatively high levels of nitrates (NO_3). This may be due to agricultural run-off of farm nitrates (especially from fertilizers and animal wastes) which are very soluble in water. Nitrates can come from domestic sewage, industrial wastes and storm drainage.*
- *Sewage fungus at Site 1 indicates high levels of organic pollution, whilst the presence of blanket weed at Site 3 verifies that the river is experiencing nutrient enrichment (from high nitrogen levels).*
- *Although Site 1 is the most polluted, there are actually more organisms sampled at this site in comparison with the other sites. This is because many species are unable to tolerate the low oxygen conditions, so there is a reduction in competition and predation so the midge larvae and tubificid worms are thriving in large numbers. The results achieved may also be part of a sampling problem.*
- *There is little variation in pH between sites, so, in this instance, pH is not a useful indicator of pollution. This again can be a common occurrence with pollution field work. You can survey a river and get very limited results. This is why it is necessary to use secondary data as a back up.*

Table 2. Results for invertebrate/aquatic plant indicators based on 'kick-sample' data collected by students from sites 1, 2 & 3.

Indicator Organism/Plant	*Site 1*	*Site 2*	*Site 3*
(1) Stonefly	0	1	39
(2) Mayfly	4	23	56
(3) Freshwater shrimp	8	58	39
(4) Freshwater hoglouse	24	17	3
(5) Midge Larvae	75	19	14
(6) Tubificid worm	92	24	21
Blanket weed	No	No	Yes
Sewage Fungus	Yes	No	No
Total high oxygen demanders	4	24	95
Total moderate oxygen demanders	32	75	42
Total low oxygen tolerators	167	43	35
Grand total	***203***	***142***	***172***

Increasing demand for oxygen i.e. 1 = cleanest water, 6 = poorest

Table 3. Environmental/chemical data collected from sites 1, 2 & 3

Environmental / chemical data	*Site 1*	*Site 2*	*Site 3*
Nitrate (ppm)	8	26	34
Oxygen (ppm)	5.4	8.7	10.5
pH	6.5	6.5	7.0
Suspended solids (ppm)	22	12	5
Observations - colour, smell etc.	Smell of rotting material	Clean, but cloudy in places	Clean. fast flowing

Fig 4. The graph shows environmental/chemical data from the 3 sites

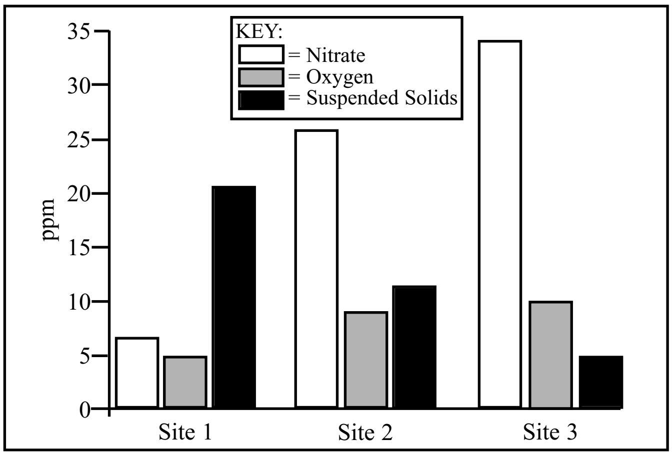
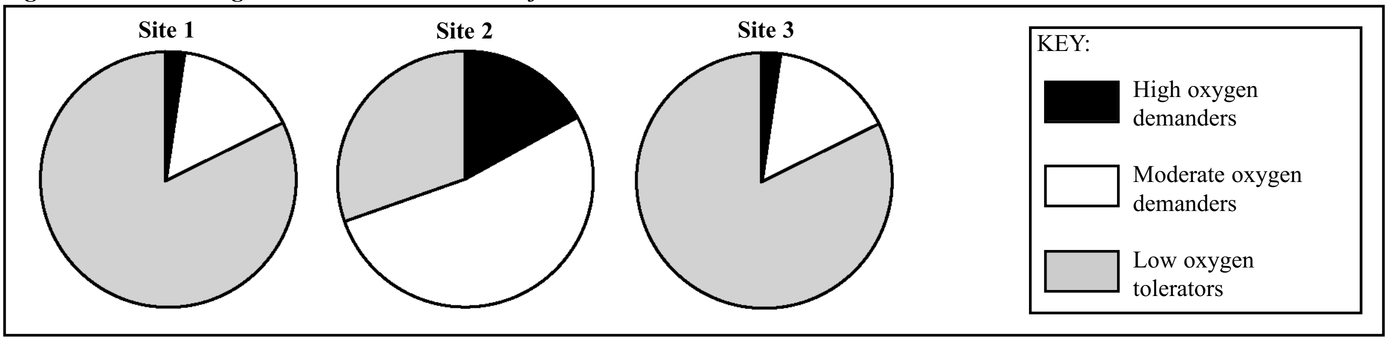


Fig 3. Pie charts showing environmental/chemical data from the 3 sites



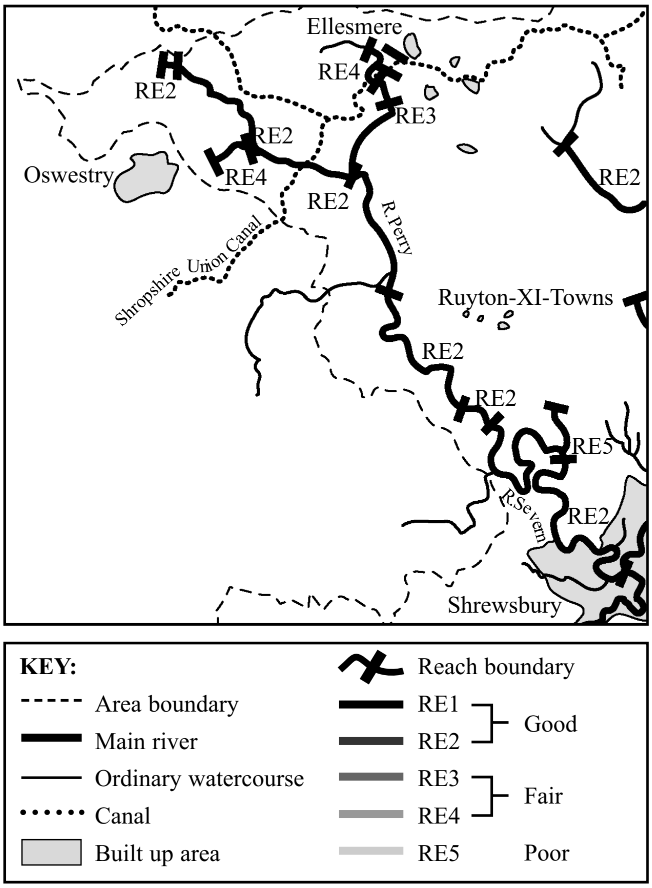
Case Study – The River Perry (continued)

Published data and Water Quality Objectives

Fig. 5 shows water quality results based on work carried out by the Environment Agency. This confirms the field based results with Site 1 classified as 'Fair – Poor' water quality (RE4) and Site 2 & 3 are described as 'Good' (RE2). The 'RE' (Rivers Classification) scheme comprises five quality classes which reflect the chemical water quality requirement of different types of ecosystems. For each designated stretch of water medium and long term RE targets are proposed.

For the R. Perry, long term objectives are for all the reaches to be RE2 or better with the exception of one problem stream near Shrewsbury. In 1999 improvements were made to the Tetchill Brook with an extensive programme of dredging and better management of the sewage outfalls and storm drain systems within Ellesmere. Recent water quality monitoring by students has revealed the impact the improvements are having with a return to a more diverse invertebrate ecosystem at Site 1.

Fig 5. Water quality of the River Perry.



Summary – Management of Water Resources

The primary task of the water industry is to manage the hydrological cycle for the benefit of users. Society produces a vast array of waste products and the water industry is responsible for ensuring that the disposal of wastes causes the minimum damage to resources. Water is not only used for potable supplies, but also recreation, amenity and fisheries, all of which have economic significance. Yet the management of water resources and the control of pollution is expensive and this may in turn have adverse effects on the shareholders profits. However environmental groups such as Greenpeace and Friends of the Earth have done much to heighten public awareness, and the same environmental pressure has also led to increased political cognizance and greater commitment towards environmental protection.

Exam Question:

1a Explain how you could use primary fieldwork and secondary sources to study pollution levels in a stream. (10 marks)

1b With reference to named river basin you have studied examine the reasons for variation in levels of organic pollution. (15 marks)

Answer:

1a For primary fieldwork expect details of visual summaries, turbidity, biological methods and chemical methods (e.g. sampling of nitrates, ammonia, and oxygen levels including BOD). Secondary research would include using water company and Environment Agency data, for details of pollution incidents and pollutants such as heavy metals. Also historic records – OS maps could be used to locate potential sources of pollution. A good candidate would discuss the need to measure discharge at the same time as carrying out field measurements of pollution.

1b A good answer would include an annotated sketch map to show causes of pollution with detailed comment on a number of sites for a range of point and diffuse samples. You would expect the use of precise statistics as the question specifically asks for variations in levels of pollution. These statistics could be located on the sketch map.

Useful references for further research

Holmes, D & Farbrother, D (2000) *A-Z Advancing Geography Fieldwork.* Geographical Association, Sheffield. Pages 96-97.
Lenon, B & Cleves, P (1994) *Fieldwork Techniques and Projects in Geography.* Collins Educational, London. See pages 74-76.
Mason, C (1981) *Biology of Freshwater Pollution.* Longman, Essex.
Williams, G (1987) *Techniques and Fieldwork in Ecology.* Collins Educational, London. Chapter 5 deals with water pollution.

www.field-studies-council.org - produces a number of user-friendly freshwater invertebrate identification keys. Also has a scientific paper on the pollution of the River Perry.
The Environment Agency *(www.environment-agency.gov.uk)* provides details of the results of various chemical analyses, monitors water quality and has on-line data for selected rivers, as will the water company for the area.

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