Citizen's Science: What Activists Need to Know

Redressing the Balance: working towards environmental justice in Scotland

Friends of the Earth Scotland

CITIZEN'S SCIENCE: WHAT ACTIVISTS NEED TO KNOW

Redressing the Balance: working towards environmental justice in Scotland. Handbook 5

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1. Introduction

...why science for activists...?

Environmental justice demands no less than a decent environment for all with no less than our fair share of the earth's resources. What is it that prevents people living and working in a decent environment – pollution, dust, exposure to chemicals, damp housing, waste, pests, things which cause illness? Many of these things make scientific demands of activists – to understand what the problem is, to interpret the technical reports, to be able to debate with the 'experts' in the companies which are causing the problems or with the agencies who are charged with protecting the environment.

This is also true when trying to understand how we can live within our fair share of the earth's resources. How can we know the extent of the earth's resources - of water, oil, minerals, the fish in the sea or the capacity of the atmosphere? These are scientific questions and also social questions. Citizens are better able to make judgements on these issues if they have some knowledge of the science behind them.

Science is an interesting area of human endeavour. Peoples' reaction to science can be quite extreme. Many adults remember science at school as something which was 'too hard', or just for the egg heads. For some people science is the cause of all the ill in the world. Scientists are the people who experiment on live animals, invent bombs, steal the secrets from the earth and its peoples. For others it appears as a religion, having the power to explain everything and defining the purpose of life. Still others think of science in terms of the bangs and whizzes, coloured smoke and funny mirrors which some science shows continue to promote.

Scientists in our society continue to be regarded with a certain social status – they are brought onto television debates as 'experts' (even when their expertise is not in the issue that they are speaking about). Scientists are stereotyped as hairy, authoritative men or frumpy, eccentric women, always brainy, usually somewhat other-worldly. Fashions change, but drawing on science as an authoritative endorsement for a product is a theme in advertising. Advertisers continue to use the male scientist reassuring the female consumer of the trustworthiness of washing powder, food, pharmaceuticals, cosmetics etc. An advertisement for a perfume from the 1980s showed a man in a white lab coat on one side of the page and a glamourous woman on the other, each holding a bottle of the product. In 2003, adverts are still around showing a similar (possibly the same) product boasting the number of researchers who had worked on producing the beauty product which was being worn by the glamourous woman in the photograph.

There is an interesting dichotomy in society between the scientist as reliable and authoritative versus other-worldly and dangerous. Frankenstein's monster remains a powerful image of the kind of destruction that scientists can wreak from devotion to the endeavour for knowledge without considering the social implications.

Scientists are human beings – it is sometimes important to remind ourselves of this. There are good and bad scientists, cruel and kind scientists, progressive and conservative scientists. Scientists have careers, hobbies, religious faith, relationships, children, worries about the world and mortgages to pay. Despite all the mystification, science is an ordinary activity carried out by ordinary human beings.

Moreover, what scientists do is not so very different from what a lot of people do. In deciding which washing up liquid to buy, you might well notice a new brand that makes claims to wash dishes more effectively. You might decide to buy one bottle of it to see how it is, and whilst using it assess whether the claim is true. If you are impressed with its effectiveness you might start using this brand, if not you might revert to your usual brand. In doing so, you are conducting a scientific experiment – not a very rigorous one admittedly, but the process of thought whereby you assess a claim against the evidence in a comparable situation, is very like the process which a scientists follows. There is a lot of mystification in science, but really it is just well trained common sense.

How a research scientist goes about their work:

Reading current published articles / hearing about research at conferences
Coming up with an idea
Working out how to test the idea (experiments, surveys etc)
Getting the approval of their superiors
Applying for a grant
Receiving the grant with its conditions
[Recruiting staff or students to carry out the work]
Analysing the data
Writing the findings up as articles for publication
Submitting each article to a scientific journal
The journal shows the article to other scientists to assess its validity
Valid articles are published
Speaking about findings at conferences

Environmental justice activists need to know something about science. Science is not 'hard' any more than any other subjects, which if you study them enough, are not hard. The aim of this handbook is to introduce you to science in such a way that it is useful and relevant to your activities as an activist for environmental justice. The areas which will be covered are the following:

Chapter 2: Why do we need to understand science? The Glespin study shows a real life problem and the information and interpretation needed to understand which issues may be significant (and misleading).

Chapter 3: What is science? This chapter explains the activities which scientists do, and what is the process by which all the knowledge on which scientific claims are made are based on.

Chapter 4: "Science in the control of pollution" details how to access scientific information and find what you're after. This includes regulatory responsibilities and further contacts.

Chapter 5: Pollution and Health - what effect do pollutants have on human health? Why are they a problem? How do you assess health effects from environmental causes?

Chapter 6: Case studies whereby science has become a tool for the non-specialist. The chapter includes details of information and support centres for such activists.

Chapter 7: The handbook finishes with the example of the Womens Environmental Network, an organisation which has followed the process of addressing a scientific issue through from start to finish, a process which you may also follow too.

Pam Bochel lives in Nairn and works for Earthshare, an agricultural scheme based near Forres in the Highlands. In 2001 she was arrested for standing in a field in Munlochy in front of tractor that was about to sow a genetically engineered crop of wheat. Until that moment she had no previous knowledge of campaigning or being an activist, but persistence by herself and other Highland residents was probably the reason why GM crop trials will not go ahead in that region for the foreseeable future.

Bochel says her key resources in the campaign were Dr Kenny Taylor, Chairman of Highlands and Islands GM Concern, books by the international anti-GM activists, like Luke Anderson, and websites, including those of Friends of the Earth and Greenpeace, the Scottish Executive, the Institute of Science in Society and Five Year Freeze set up by group of wholefood suppliers.

"The science behind GM is very complicated and I would never claim to understand it all, but the best way around it is to find a scientist that you know and trust," said Bochel. *"Dr Kenny Taylor explained a lot of the complicated information that I needed to understand. It's important that you find someone that you can trust because some people can exaggerate things and get het up with issues and are not being fair and honest. Some people are against GM without even understanding it."* So she said, it's important to have an understanding of both sides of the story before taking your own stand point.

Networking is also an important part of both gaining and sharing knowledge. The Highlands and Islands GM concern Group, of which she had been a member since 2000, found that the most efficient and cost effective way to do that was through an email network which brought into the loop people from as far afield as South Africa, New Zealand and Canada.

She said books such as Luke Anderson's book on genetic engineering armed her with vital background, but the thing that really brought the GM trials in the Highlands to a halt was probably the high profile of theYurt (Mongolian Tent). This was erected at the edge of the trial field in Munlochy within weeks of the first arrests, while the arrests themselves put their plight on the front page of the newspapers.

"The success of our campaign on the Black Isle would have stemmed from the media coverage that we got and that, I think, resulted from the arrests. It was a good kick-start to the campaign. I would not suggest that anybody break the law for publicity but it certainly helped."

Pam Bochel was found guilty of aggravated trespass and fined £100 in March 2003. She has appealed the verdict. The Scotttish Executive has refused a request by the farmer who hosted the first GM trial for a second trial to take place in the Highlands.

Lorraine Mann has been an anti-nuclear activist since 1984 when spent nuclear fuel was brought into the port of Invergordon and transported to Dounreay near her hometown in Caithness.

"I asked Dourness what was in spent fuel and they sent me back a chart of nuclides. If you have ever seen a periodic table then that is what a nuclide table looks like," says Mann. 'They gave me that and a series of graphs which did not make any sense at all and told me to work it out for myself - so I did just that."

Mann says most of the knowledge she has gathered about nuclear physics came from good old-fashioned textbooks. Websites, the modern day activists tools, were not available in those days. She still now does not trust websites to provide a strong enough basis for a watertight argument. Greenpeace and Friends of the Earth's websites, in the early days, tended to "over egg the pudding a bit", she said.

"A report from them would be very lurid. The facts of the matter were bad enough but they wanted to put in that extra bit of spin and miss out the other side of the argument."

Since then she says things may have changed but the best way to get your facts straight is to look up the technical reports yourself. Either download them from the internet, write to the company for them and if the company refuses ask your MP to get it for you. The reports are vital because this is where the company puts most of its information and if you can get through these then you know where their arguments are coming from.

At major public meetings, such as those Lorraine Mann has spoken at, you can be faced with battalions of lawyers and if there is a piece of your information, which is not 100% reliable, then you will be "caught on the hop". Although she doubts the Internet has all the answers Mann was hooked into emails long before the rest of us had PC's. In 1989 she was part of the Rural Development Network, a kind of email conference system for people working in research and development, Mann's job.

Lorraine Mann's tips for activists include check the facts and check them again. Do not take what anyone has told you by other campaigners to be true. Also make sure that you know what the industry's arguments are. Never assume you are the good guys and they are the bad guys because most of the people who work in the nuclear industry or the GM industry think they are the good guys. Some of them are hugely morally committed to the work they are doing.

Read journals such as the New Scientist, and plug into networks, read the bibliographies at the end of the technical papers. Keep the press interested by not giving them too much information, wait until you have got something to say.

"An enormous story can come out of nowhere recently when spent fuel from Georgia was due to come to the UK. I was doing radio and TV interviews from 3.30am to 1.30am the following morning and then for months and months there may be nothing newsworthy," she said.

At the moment Mann is waiting for Dounreay to be decommissioned but that doesn't mean her work is done. The Scottish Environmental Protection Agency, SEPA, has launched an investigation into Dounreay's activities, and will be looking into a possible prosecution, Mann explains, warming up her computer and reaching for the bookcase.

Thanks to Andrea Elderfield for providing the above two interviews.

Environmental problems are variable and tend to be complex. As such, this handbook is not going to try and explain specific details, but rather give an overview of how to understand the basics when faced with an issue involving scientific concepts. Lorraine Mann in the section above explains how you don't have to resemble a top scientist to be listened to, armed with knowledge and facts you can get your point across. With this ethos in mind, through the handbook we hope to direct you to sources of more information and be used as a reference manual. Basic information can give you the necessary background before embarking on the full picture.

2 Why science is useful to environmental justice activists

CASE STUDY

Glesbin is a village in Lanarkshire which has just seen the development of a new opencast coal mine on its doorstep. There are many opencasts in this part of Lanarkshire and the people of the area have been putting up with the noise, dust, dirt, heavy traffic and despoiling of the landscape for many years. The proposal to develop a new site was resisted by the local community who organised themselves into an action group. The community found hurdle after hurdle put in their way in trying to oppose the new development through the planning procedure and it became clear to them that North Lanarkshire Council was determined to give permission for the opencast mine to go ahead. Having failed in their attempts to prevent the development, the group is now looking at ways in which they can constrain the worst excesses of the mine operation, monitor for breaches to the conditions and for damage to the community, and seek to obtain whatever compensatory benefits for the community which might be possible.

One of the biggest concerns of the group is the effect of opencast mining on people's health. There is some scientific evidence which suggests that opencast mining may be associated with asthma and other respiratory diseases, especially in children and other vulnerable groups. However, it is often claimed that this evidence is inconclusive. Andy Robinson, a local activist and Friends of the Earth 'Agent for Environmental Justice' describes the problem:

"Developers will frequently attempt to reassure communities that there are no health risks associated with their industry. All communities living with open casting know that the activities are not improving their health. They see the dust clouds, they see the diesel clouds from the extractor exhausts, they know damage is being done. Needless to say, it is the elderly, the young and the infirm that are most at risk from these pollutants. There are no requirements for developers to carry out health impact assessments. This requires to be urgently addressed, if health inequalities against disadvantaged communities are not to be perpetuated. The people of Glesbin are demanding a scientific health study to discover the effects of this injustice."

This case study is a good example of an environmental injustice. There are claims in the account that peoples' health will be affected by the new opencast coal mine, through increased incidence of asthma, and the author argues that this should be tested by a scientific study. Claims that a scientific study would be useful to assess the effect on the ill health of a source of pollution are commonly made in environmental justice struggles. However, it raises some important questions about the nature of science.

.....to date, this study has not been carried out. But imagine that you are conducting such a study....

You would probably want to do one or more of the following exercises:

1. Compare the number of people with asthma in Glesbin with the number of people with asthma in a similar town without an opencast mine.

2. Compare the proportion of people with asthma in Glesbin with the overall average incidence of asthma for Scotland.

3. Measure the number of people in Glesbin who have asthma now, and again in a few year's time to see the changes.

Each of these involves the comparison of two numbers, and the difference between these numbers is what you would expect to be the effect of the opencast mine. The situation which is not affected by the mine would be called 'the control'.

2.1 Problems of control

Each of these approaches present practical and interpretive problems. For the first one there is the problem of finding a similar town without an opencast mine. How similar would it have to be? Presumably it would have to be about the same size, the same proportion of children and older people, the same balance of men and women, the same mix of social classes. You would probably want the control town to be the same as Glesbin in other factors which might have an affect on asthma - occupational groups, smoking levels, traffic on the roads, diet etc. And what about factors that are less obvious, but could have an unforeseen affect on asthma - ethnic groups for example, or access to telephones, or how long people have lived in the town. Basically you would be looking for a town which is as near as possible to identical in every way except that there is no opencast site. A scientist would say that you need to control all the variables except the one that you are interested in.

In reality, you will not be able to find a town identical in every respect to Glesbin so you will have to make assumptions about the comparison. If you compare the asthma incidence in Glesbin with the Scottish average, or compare the changes over time, you will still be faced with the problem of whether all the variables were the same with the exception of the presence of the opencast coal mine.

2.2 Problems of measurement

The second question which you might ask is, how do you measure the incidence of asthma in Glesbin? Asthma is quite a complex disease and can be measured in different ways, each of which might bring up a different problem. You might be able to get an incidence level from the local GP's surgery, but can you guarantee that each GP categorises asthma in the same way? Do you want to measure the number of people with asthma or the severity of their asthma? Do you want to concentrate on childhood asthma which is probably more sensitive to change? Would the use of asthma drugs be a better measure? Or what about directly interviewing people in the town to get their own perception of the severity of their asthma? Essentially, for something as complex as asthma incidence, you might be looking for a direct measurement, but more likely you will need to use an indicator of the effects of asthma. Whatever form of measurement you use might affect the outcome of your comparison.

Assuming now that you have decided on how you will measure the asthma and you have collected numbers of asthma sufferers in your experimental community and your control community - these numbers would be called the data (each record is a datum). How do you know if Glesbin is different from the control town?

2.3 Problems of interpretation

Suppose that you have discovered that 10% of children in the control town have asthma and 12% of children in Glesbin - does that mean that the opencast coal mine is causing asthma? It could be that the small difference is caused by the opencast mine, or it could be due to other factors which were not possible to control (there are many causes of asthma), or may even be due to the chance variation which you always find in populations. If you took at two towns that were identical in every way and neither had an opencast mine, you might still get a difference this big. All scientific data are likely to include a degree of chance variation and something as complex as asthma is more likely than most.

You need to be able to concentrate on the potential cause of the asthma, the opencast mine, and to do this you might want to look at other towns and villages both with and without opencast mines - ie you would need to replicate the experiment. The more towns you measure, the more reliable your result is likely to be.

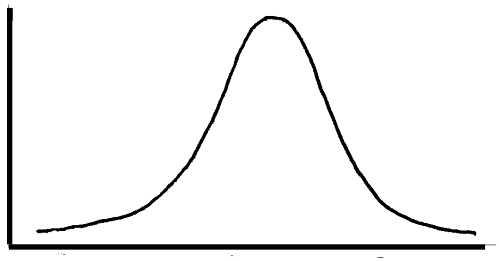
Suppose you measure five towns with and five towns without opencast mines, and you come up with the following data:

	percentage of children with asthma					**Average**
Towns with opencast:	**12**	**13**	**16**	**8**	**11**	**12**
Towns without opencast:	**10**	**12**	**9**	**8**	**11**	**10**

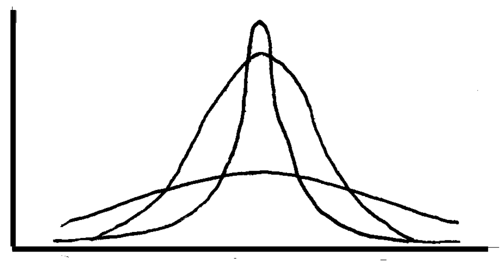
So this tells us that the overall average incidence for towns with opencast is 12% with a range from 8% to 16%, and for towns without opencast is 10% with a range of 8% to 12%. How confident can we be that the apparent increased incidence of asthma in the opencast sites is caused by the opencast mines themselves? Even if we can be confident, how are the opencast operators likely to interpret the results? It is because of the kind of messy data that you are likely to get from measurements such as this, that there are conventions which all scientists stick to in the form of statistics. These allow them to say whether the difference between the data sets is really caused by the experimental variable or whether it is not.

2.4 Statistics

In order to understand the role of statistics, we need to look at the data in a different way, to ask a different kind of question. Rather than asking whether the two data sets are different, we could test whether the two data sets are the same. This is known as the null hypothesis - in other words, in order to be convinced that there is a real difference between two data sets, we need to be convinced that they are not really the same but just variable by chance. We know enough about the chance variation in data to be able to gauge what is the probability of getting a measurement within that chance variation. Data usually varies according to the shape of a 'bell shaped curve'. Thus, for the incidence of asthma in the population we would expect a shape something like this:



In order to assess whether any new data set is the same as the existing one, it is possible to estimate the probability of getting that measurement within that data set by chance alone. The further from the average figure the new data set is, the less likely that it is caused by chance alone. The more variable the data are, then it is more likely that a different data set will be caused by chance alone. Look at the following, rather exaggerated bell shaped curves, which give an indication as to whether the new data set is different from the average by chance alone.



If the probability is very small that the difference between the data sets is caused by chance alone, then we will have to reject our null hypothesis because there is inadequate evidence to say that it is a chance variation. In this case we must look for an alternative explanation, for which we need to look at the differences in the context of the two data sets. In other words, what is the one variable which provides a better interpretation of the data than the null hypothesis? It is assumed that the null hypothesis (that the two data sets are the same) is the best explanation for the pattern in the data unless it is very unlikely that such a pattern is caused by chance. That 'very unlikely' is set by convention to be 5% or 0.05. In other words, if the probability that the two data sets are the same is less than 1 in 20, then it is conventional to reject the null hypothesis and claim that the difference is significant (the other conventions are that "a highly significant difference" is 0.01 or 1 in 100 and "a very highly significant difference" is 0.001 or 1 in 1000).

Suppose we know that the incidence of asthma in the population of Scotland as a whole, varies to some extent. The pattern of that variation will be fairly predictable according to the shape of a bell shaped curve, and the probability of getting any measurement will be predictable. We must assume that the data for Glesbin are the same as those for the population of Scotland within a predictable level of variation unless they are so different that the probability of getting such a value by chance is less than one in twenty.

It isn't necessary at this stage to understand how the maths is worked out, but simply to know that it is possible to calculate the probability of a value being caused by chance, and that that probability depends on the average and the degree of variability in the data. Significantly, it is important to recognise that science is conservative on this - it must be assumed that there is no difference unless the chances of the variation being caused by chance is very low. These conventions help to keep science rigorous in the sense that you would be unlikely to make a false claim (or 'type 1 error' – see section 3.4.2). Therefore the conventions are 'policed' by other scientists to ensure that the overall rigour of science is maintained, a process known as peer review. However, whilst these rather conservative and strict conventions lead to more reliable science, it does not tend to help environmental campaigners very much, who are more interested in type 2 errors.

In particular, when looking at environmental injustices, the following factors tend to make type 2 errors more likely:

- Environmental data are nearly always very complex with many environmental variables having effects on many other variables.
- It is very difficult to control the variables or even reach an agreed measurement or indicator of environmental damage.
- Even when the data are measured, environmental data tend to be very variable, so unusual values occur regularly by chance.
- The scientific method requires an assumption that there are no real differences in the data except by chance, unless this assumption looks very unlikely.

The trouble is, the assumption that opencast mining does not cause asthma is exactly what the opencast operators want to believe, so it often looks as though the scientific method takes sides with the polluter. The rigour of the null hypothesis might make a good scientific convention because you are unlikely to make false claims, but it does not make for a good precautionary principle.

3. What is science?[1]

Many answers are possible to this question. A simple, and wrong one is that science is a technique for proving what is true about the natural world. I want to suggest a rather more limited role for science, but one that still accepts it as an enormously powerful and effective enterprise in seeking truth.

3.1 Routes to knowledge

How can we know anything? At the risk of trivialising thousands of years of philosophical thinking, answers to this central question have usually fallen into one of three categories: through God, through logic and through our senses. God is beyond our scope here, which leaves the other two options:

Truth from logic: Deductive Reasoning
Deduction relies on making logically necessary conclusions based on assumptions, known as axioms. Classically, it takes the form of syllogisms, for example:

All reptiles lay eggs
Adders are reptiles
Therefore adders lay eggs

If the first two lines are correct, the deduction must follow. So perhaps using rules of logic like this (or more complex ones, using the language of mathematics for example) can one establish truth? This view has been championed in particular by thinkers worried about how information from the external world, mediated through our senses, might be unreliable. How do I know that your experience of the colour red is the same as mine? It won't be, if you are colour blind. But the problem here is obvious. If the axiom or the second statement is incorrect, the deduction will be faulty. All reptiles do not lay eggs; some, like adders, bear live young. We need a way of determining the truth of the axiom, and to do this we must refer to the real world.

Truth from data: Inductive Reasoning.
Inductive reasoning starts from the facts, as ascertained through our senses, and then tries to conclude theories about the world that explain them – it turns deduction on its head. One of the most famous clashes between these two modes of thinking occurred at the trial of Galileo, who claimed to have detected four previously unseen moons around Jupiter with his newly invented telescope. The Catholic Church ruled that the moons could not exist. The accepted assumption (the axiom) was that there were only seven heavenly bodies, and that these all had astrological significance. Since the proposed moons had no astrological significance, they could not exist. Galileo's

[1] Thanks to Mark Huxham for this chapter. Huxham lectures in Biology at Napier university in Edinburgh and is a board member of Friends of the Earth Scotland.

accusers refused to look through his telescope – they trusted their deduction more than their senses.

3.2 Science as a lie detector

Much of science now works by combining these two modes of thinking into what is called the hypothetico-deductive method. Central to this is the 'hypothesis', a statement or theory about how the world might be. The hypothetico-deductive method works as follows: propose an hypothesis (for example, all women are more compassionate and empathic than men). Now use deductive logic to examine its implications and induction to compare these consequences with the facts. For example Margaret Thatcher is a woman ...... therefore Margaret Thatcher was more compassionate and empathic than her male colleagues. Since there is little evidence to support this deduction, we have to conclude that the hypothesis is false, and hence revise or reject it.

But what would have happened if our initial observations supported the hypothesis? Consider a different example, the hypothesis that *a moving object requires the application of some force in order to keep it moving*. We could test it by deducing that a bicycle being ridden is a moving object, and therefore it requires force to keep it going. Observations would seem to support this (if the rider stops pedalling, the bike stops). And observations on any moving object (cars, thrown stones, bullets etc) would all produce the same conclusion. So does this imply that our hypothesis has been proved? Absolutely not! We know that this hypothesis is false (objects moving through space, without friction to impede them, continue moving indefinitely). We could make thousands of observations that appear to support the hypothesis, without proving it; a single observation in space that contradicted it would show that it was false.

This demonstrates a fundamental feature of scientific knowledge. Science cannot absolutely prove things. Instead, it makes progress by disproving or falsifying hypotheses. The definition of a scientific hypothesis is that it can, in principle, be disproved (in contrast to non-scientific hypotheses such as 'God exists' as it is not possible to conduct an experiment which could conclusively disprove this statement). So science acts as a lie detector, weeding out the hypotheses that may be true from those that are not. But even the most established and well-supported hypotheses and theories (such as Einstein's theory of relativity and Darwin's theory of evolution) remain unproven and therefore provisional.

3.3 Doing Science: A beginners guide

Although most scientists subscribe to a philosophical approach such as that described above, there is no single scientific method. What scientists actually do in their working days, varies enormously between disciplines. However, there are some general methodological principles that apply to most types of science, and which help to distinguish between scientific studies that are likely to be reliable, and those that produce more provisional (or downright false) results. These principles are particularly important in subjects – such as ecology and epidemiology – which are usually concerned with looking for general trends in populations where there are many exceptions to the 'rule'.

First a word about the nature of data. Data are the collection of observations, they are the stuff which we know about the world through our senses. One thing about data is that they vary, and much of the variation is a result of things which are nothing to do with our hypothesis. The subject matter of the ecological and social sciences is even more variable than that of the chemical or physical sciences, but there is variation in all data. If you collect data, it is possible for there to be patterns in it purely as a result of chance, but there may also be patterns as a result of some factor that you are interested in. So, when a scientist looks at data, he or she is keen to ascertain whether any patterns in the data are the result of some factor of interest, or the result of chance. For this, scientists use statistics (see section 2.4 on environmental justice and science).

3.3.1 Sample size

Suppose you wanted to test the hypothesis that British men are taller than British women. On average, this hypothesis is true (or rather, it has not been falsified). But typically for biological data, there is a great deal of variability around the average; many women are taller than many men. So it is quite possible that if you selected five men and five women at random, and measured their average heights, then you might find that women were taller than men. However, if you selected five thousand men and women and calculated average heights from them, there is a vanishingly small probability of finding a bigger average height for women. So the laws of probability dictate that any scientific statement based on the measurement of average values (and most science works this way) will depend for its reliability on the sample size measured.

photo credit - Queen Margaret University College

3.3.2 Power and effect size

As suggested above, the smaller the sample you have to work with, the harder it is to detect any effect. A related phenomenon is that of *effect* size; the smaller the suggested effect is, the harder it is to detect. For example, showing that a toxic chemical leaching from paint increases your chances of cancer by 200% will be much easier than showing it increases your chances of cancer by 20%. Sample and effect sizes work in opposite directions; the bigger the proposed effect, the smaller the sample size needed to show it, and vice versa. These considerations mean it is often impossible for scientists to convincingly show an effect, even when it is really there. For example, if a small local community believes that a nearby toxic waste dump has contributed to a slight increase in stillbirths in their village, they might well be right. But given the small number of people and small proposed effect size, it will be difficult to distinguish what has happened from the effects of chance. In this case, we say that any study of this local population has *low power*, meaning it has a small chance of detecting a real effect.

3.3.3 Confounding effects

A study in the journal Nature (Pawlowski et al. 2000) compared the average heights of men who had fathered at least one child with those of men who were childless. Some of their results are given in Table 1.

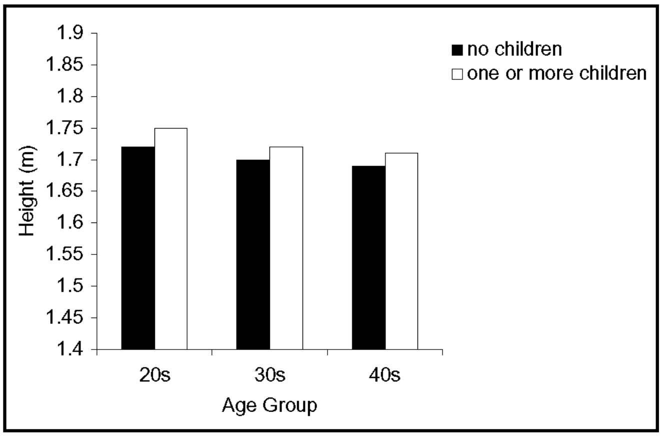


Table 1 - The effect of height on mens' chances of fatherhood

What do these results suggest? The implication is that taller men are more likely to father children, perhaps because they are more attractive to women. But can we really conclude that male height is causing this higher chance of fatherhood? What we have here is a correlation between two sets of data (height and fatherhood). However, correlation does not imply cause. There are actually four possible interpretations of this pattern in the data:

1. height in men increases the chance of fatherhood
2. fatherhood causes an increase in height of men
3. the apparent correlation is caused by chance
4. the correlation is caused by a third factor which affects both father hood and height in men

A central problem here is that there are many other things that might be related both to height and to the chances of fatherhood. For example, better nutrition, arising from higher income, produces on average taller people. So perhaps it is differences in wealth, rather than height, that is causing the observed effect? In this case, we would say that wealth is a confounding factor in this study: a factor which is related to those actually studied (height and chances of fatherhood) and which may be what really matters. Scientific studies need to be very carefully designed to avoid being fooled by confounding effects (Pawlowski and colleagues, for example, used careful statistical analysis to avoid the effect we've discussed). Often we are unaware of factors that may be confounding, and so it is hard to take them into account.

Confounding factors are usually thought of as a feature of studies which show some effect; this effect is then suspected to be due to a factor other than the one that is studied. However, they can also operate when no effect is found. Consider the hypothetical hypothesis that mobile phones cause cancer. You may conduct a survey and find no higher rates of cancer in mobile phone users. However, we know that many cancers are related to poverty, and it may be that mobile phone users are richer on average than those without them. So the combined effects of the mobile phones (cancer enhancing) and relative wealth (cancer reducing) could produce no difference in cancer rates compared with the general population.

3.3.4 Experiments vs surveys

Scientific experiments involve actively intervening in a situation to manipulate factors of interest. Surveys involve looking at the differences that exist, without intervention, and drawing conclusions from them. For example, suppose you were interested in testing the effects of sex education on rates of teenage pregnancy. You could establish an experiment with groups of children who received sex education ('treatment groups') and compare pregnancy rates with groups who received no such education ('control groups'). Alternatively, you could conduct a survey that compared the levels of sex education received by children, not from you but from teachers, parents and others, with their chances of becoming pregnant. There are strengths and weaknesses in both approaches (see table 2 below).

	Strengths	Weaknesses
Survey	• Can often achieve large sample sizes • Uses data from the 'real world', rather than the often artificial situation of an experiment.	• Will probably involve many confounding variables, which can be difficult to control for. • The data are often collected by others (e.g. census data) and thus you may not be confident of its quality
Experiment	• Allows you carefully to control the treatment, applying the same one to all of your treatment individuals or groups. • Good design means you can avoid or control for confounding variables. • Can be repeated, at different times and in different places.	• Often impossible to do because of ethical or practical constraints. • Usually restricted to small sample sizes. • May involve the unwitting introduction of 'experimental artefacts' which confuse results.

Table 2 - A Comparison of Surveys vs. Experimentation

The ideal situation is to be able to combine both approaches. But this is rarely possible. Studies dealing with human beings (especially health effects of industry and lifestyle) are usually restricted to survey methods because of ethical and cost constraints – so there is usually the possibility of confounding factors.

Because they are such a fundamental constraint on interpreting many scientific studies, let me give another example of possible confounding factors. Imagine you want to study the effects of disturbance by people on the success of nesting sea birds. You could measure how many chicks are reared successfully in nests close to human disturbance (for example, on relatively accessible grassy slopes), and compare this with the numbers reared in inaccessible nests (such as cliff ledges). But of course, these sites will differ in many other ways; if humans can reach the nests, then so can other animals such as foxes. To avoid this confounding, you would ideally conduct an experiment in which you prevented human disturbance at certain sites.

3.4 Uncertainty, Error, Ignorance and Bias

There are known knowns, there are things we know we know.
We also know, there are known unknowns…we know there are some things we do not know.
But there are also unknown unknowns, the ones we don't know we don't know.
Donald Rumsfeld (US Secretary of Defence)

Science can give answers that are uncertain or that are wrong. It can also answer the wrong question or give no answers at all. These limitations are inevitable in a human enterprise, and they can arise for a number of different reasons; it is useful to distinguish four categories of limitation:

3.4.1 Uncertainty

Uncertainty in scientific predictions usually arises because of the natural variability in the world; the 'probabilistic' nature of many phenomena. We have already discussed this in the context of average height of men and women. Another example is the firm scientific prediction, declared on UK cigarette packets, that 'smoking kills'. Everyone seems to have known an uncle or granny who smoked 20 a day since their teens and lived into their eighties. This does not make the statement wrong, it merely reminds us that most scientific predictions deal with average values. In data with a normal distribution, there will be as many values above the average as below. So half of all smokers will live longer than the average reduction in years of life would suggest, and a few lucky smokers will live much longer. Although we can be very certain that, on average, smoking reduces lifespan, any predictions about the effects of smoking on any individual will be very uncertain.

Some uncertainty may arise from ignorance. For example, if we knew much more about the genetic predisposition of an individual to cancer, we may be able to make much more accurate predictions about the likely affects of that person smoking. But in other cases, further knowledge and understanding can increase uncertainty. Take for example the latest assessment of the likely impacts of pollution on global temperature by the IPCC (Intergovernmental Panel on Climate Change). This body, consisting of hundreds of the world's best climate scientists, is charged with trying to understand and predict climate change. Its initial estimates for temperature increase over the next century ranged from 1 – 3.5°C. The new estimates range from 1.4-5.8°C (Schneider, 2001). In the six years between the two predictions, much work had been conducted and a greater understanding of the climate had emerged; despite this, the uncertainty has clearly increased. In many cases (and climate change may be one) we cannot eliminate uncertainty – it is an inherent part of the way the world works. This is one reason why environmentalists stress the precautionary principle – if in doubt, play safe (see Merritt and Jones, 2000).

The climate change example demonstrates the extent to which certain kinds of science depends on models. Scientific models are much like any other kind of model in that they resemble the real thing in several important respects but do resemble it in other significant respects. A model aeroplane is similar in shape and colour to the real aeroplane, but differs in size and the materials it is made of. Scientific models tend to be mathematical but in other respects are like other models. So the IPCC model resembles the real climate in many of the parameters but not in others. However, although its outputs can appear to be like the real climate, it is entirely dependent on the assumptions of the mathematical formulae and the data fed into it. No matter how good the model is, it will always be a model and subject to uncertainty.

Reporting Uncertainty

Because uncertainty is routine and expected, there are standard scientific ways of reporting it. Two of the most important are confidence intervals and P values: Confidence intervals - usually reported as, for example '….the height (mean ± 95% C.I.) of men in our sample was 1.7 ± 0.15 m'. To produce this result, the researchers will have measured the heights of a certain sample of men from the group (or population) of interest. Perhaps they were interested to know the average heights of all British men, in their forties, with no children; because they could not measure all men in this category, they would have chosen some sub-sample of this population. But how do they know that the average height of this sub-sample is representative of all such men? The confidence intervals are derived from statistical theory, and mean that we can be 95% confident that the average height of all relevant men lies somewhere in the range 1.55 – 1.85 m. So the bigger the confidence intervals, the more uncertain is our estimate of the true figure.

3.4.2 Error and 'Significance'

In everyday language, 'error' is synonymous with 'mistake'. Scientists, like everyone else, certainly make plenty of these kinds of errors. It is a dangerous illusion to suppose that those with a scientific or technological training will be less susceptible to 'human error'. Spock, from 'Star Trek', may transcend human weaknesses, and symbolise the cool rationality of the scientist, but in real life gaining a science PhD does not transform the recipient into a Vulcan. A recent survey of incidents at Japanese nuclear plants showed that most were caused by a simple failure to tighten the bolts correctly (Hirotsu et al, 2001)

But in formal scientific (or rather statistical) language, errors consist of two main types. Scientists talk about finding 'significant' effects in their studies; for example, they might claim that eating oily fish significantly reduces the chances of suffering a heart attack. What does this mean? It is not the same as the use of the word in normal language (simply meaning that the chances are reduced 'quite a lot'). Instead, it reflects the use of statistical methods to allow a precise estimate of the chances that the statement is wrong. Because of uncertainties such as those described above, there is always the possibility that the statement about fish reducing heart attacks is in error – if that was the case, and oily fish really had no effect, we would say that the scientists had made a Type 1 error. A type 1 error is when a named effect is believed to be due to a specific cause whereas in fact this is not the case. By convention, scientists usually claim to have a significant effect only if they stand a 5% chance or less of making a type 1 error (and most statistical tests are designed to estimate the level of this chance). But note that the 5% level is entirely arbitrary, and should always be judged in the context of particular studies and situations. For example, imagine you were faced with taking a drug for arthritis that was known to have serious and unpleasant side effects. You would want to be very sure that it would actually help you – so you might want a 1% or 0.1% chance of a type 1 error in the clinical trials that tested it. Alternatively, if the drug presented your last hope of a cure for a terminal condition, you might be willing to accept a 50% level.

The opposite of a type 1 error is a type 2 error – this is the chance of stating that something does not have an effect, when in fact it really does; it is closely related to the concept of power, discussed above. Most scientists have traditionally been concerned with type 1 errors, because their reputations depended on not claiming dramatic effects if no such effects occurred: they are professionally conservative. This concern is reflected in most commonly used statistical techniques which focus on type 1 error. But often it is type 2 errors that are more worrying for environmentalists, health campaigners and communities. If scientists and regulatory agencies have stated that an incinerator is safe, but have made a type 2 error, then the health of local people will be put at risk. The chances of type 2 error increase as the power of a study declines.

3.4.3 Ignorance

Scientists expect uncertainty and error, which is why there is such a rich statistical language with which to describe them. But you cannot anticipate the effects of factors about which you are totally ignorant – Rumsfeld's 'unknown unknowns'. Two good examples, CFCs and radiation leaks, are given in Sumner, 2000 (p 48):

'Chloroflurocarbons (CFCs) became popular as refrigerants and propellants in aerosol spray cans because they were cheap to produce, non-toxic, and (it was thought) relatively inert. Unfortunately, once released to the atmosphere, they are slowly transported up into the stratosphere and broken up by sunlight. Chlorine is released, which through a series of chemical reactions destroys stratospheric ozone. This process was not predicted, because we were ignorant of the pathways involved… The cause, or causes, of childhood leukaemia around Sellafield remain unclear. The estimated radiation doses, obtained from complicated models, are too low to account for the excess leukaemias. But perhaps there are pathways that haven't been included, pathways that (at present) we are completely ignorant of? An example of this occurred in early 1998, when feral pigeons contaminated with radioactive material were discovered in the village of Seascale, near the Sellafield reprocessing plant. The pigeons were congregating in large numbers at a small bird sanctuary in a private dwelling. Levels of man-made radionuclides measured across the garden at the bird sanctuary were up to 800 times the typical concentrations for the region, and the dose to residents of the bird sanctuary more than ten times higher than the doses from man-made radionuclides to average inhabitants of the village'.

How to deal with ignorance is a political and philosophical, not scientific, question – science cannot tell us whether to be pessimists or optimists about a future full of 'unknown unknowns'.

3.4.4 Bias

The fourth main way in which science produces answers that are wrong is through bias. This can come from deliberate fraud, or for subtler and often unconscious reasons.

Fraud
Sometimes scientists just make things up. This might be for political reasons, for commercial reasons or for reasons of personal prestige. The USSR famously supported the geneticist Lysenko in his erroneous work, because his conclusions were politically acceptable, and also under-reported the number of whales it caught to allow illegal whaling. In 2002 Jan Schön, a leading physicist, was shown to have simply invented data in dozens of his papers, which were published in the most prestigious journals (Brumfiel, 2002). This kind of fraud is probably more common than most scientists would like to admit, but is likely to be exposed if the research is high profile, contentious or of significant political importance.

Commercial pressures
More important than outright fraud are the impacts of funding decisions on what science gets done and published. More than half of all research conducted in the UK is now funded by private companies, who are, of course, interested in the pursuit of profit rather than of abstract notions of truth. This can create many conflicts of interest. For example, Stelfox et al. (1998) reviewed 70 scientific articles on a type of drug used to treat heart disease. 96% of the studies that supported the use of the drugs were written by people with financial relationships (such as research support) with the drugs' manufacturers. For publications deemed critical of the drugs, the figure was only 37%. So people are right to be suspicious when groups with obvious vested interests fund science, such as when oil companies fund research casting doubt on climate change.

Another, and possibly more influential, form of commercial control of research occurs through the exercise of what kinds of research can be funded (rather than published). Areas of knowledge which do not promise large returns to private companies will not attract funding, even when they are very important. Two good examples are organic farming and diseases of the third world. In the former case, research expenditure is tiny compared with the sums spent by agribusinesses on intensive techniques and GM technology. In the latter, diseases that kill thousands of poor people (such as schistosomiasis) receive less research funding than natural conditions that irritate the rich (such as skin wrinkling and hair loss).

It can be seen there are a great deal of factors which influence what type of scientific research is completed and the way in which this is done, and how it is interpreted. An example of this "political epidemiology" is shown below from a study in Teesside. It is apparent you have to always consider the wider picture when looking at scientific studies and not necessarily accept them at face value because they have been completed by professionals.

The Teesside Studies -from: Phillimore, P (1998) Uncertainty, reassurance and pollution: the politics of epidemiology in Teesside. Health and Place vol 4 no 3 pp 203-212

In a series of epidemiological studies in Teesside, Professor Peter Phillimore and his colleagues identified potential health impacts from industrial pollution. Phillimore compared rates of illness and death in the populations of Middlesborough on Tees, and Sunderland on Tyne. These two cities have similar populations in terms of class and poverty and other social factors, but Sunderland lacks the polluting industries of Teesside. Moreover, Phillimore contrasted the health of different communities within Teesside, on the basis of how near to industrial sites they are.

The researchers found that “the most persuasive evidence for a link between industrial pollution and health was in relation to death from lung cancer ..and.. other respiratory diseases.” However, despite this evidence there are also inexplicable patterns in the data (as is typical for epidemiological data) and alternative explanations.

In a more anthropological paper, Professor Phillimore reflects on how various groups in society have responded to this persuasive but inconclusive evidence, and how discussion of health effects of pollution have been sidelined and excluded throughout the region’s industrial history. Tactics for exclusion range from modifying minutes of meetings and the sacking of off-message professionals, through to shifting the focus onto traffic, smoking or overseas causes, or simply arguing for more research before taking action. Through both direct political influence of industry, and the indirect effects of promoting economic development and inward investment, authorities (including some health professionals) have adopted what Phillimore calls a “narrative of reassurance” which serves to stifle public debate.

The interpretation of the same data as evidence of harm, is no more ‘right’ epidemiologically than as inconclusive distraction. What this work illustrates however, is that the interpretation of evidence is necessarily political, and as such vulnerable to being represented in a dominant narrative as reflecting powerful social interests.

3.5 In Summary: How to Look Science in the Eye

‘There is no form of prose more difficult to understand and more tedious to read than the average scientific paper’.

Francis Crick.

How do you know if the science that you are reading, using or contesting is any good? Remember that all science is provisional, so even the most firmly grounded scientific laws and generalisations may prove to be inadequate or wrong. But as a first guide, look for the characteristics in Table 3.

Table 3: Reliable Science – What to look for

Characteristic	What is it?	Why is it important?
Peer Review	Scientific journals (the so-called 'primary literature') use two or more subject specialists who decide – usually anonymously – whether a submitted paper is suitable for publication. Good referees will scrutinise a paper for any mistakes in methodology and assumptions, and may advise the editor of the journal on how important the results are.	Top journals, such as Nature, reject up to 95% of the papers submitted to them. This means that most published papers are carefully scrutinised by people who know the field well, and should not contain obvious errors and biases (although this does still happen). Without this quality control process, the non-expert often cannot judge if a paper is reliable. So sources which are not peer reviewed – such as the press and most web sites – should be treated with caution.
Sample size	As discussed, most science relies on making statements about averages. Average values become more reliable with larger samples taken. The number of observations taken, individuals surveyed etc is often given the short-hand of 'n = ..'	When data are variable (think of average height of men and women) it is easy to take small samples that are unrepresentative of the whole group. When suspected effect sizes are small (e.g. there is a small increase in the risks of cancer from a chemical) they will require large sample sizes before detection is possible.
Repeatability	Has the reported result been found in similar surveys or experiments?	Even with good experimental design and large sample sizes, errors can occur. If a result can be repeated, then confidence in it can be greater.
Simplicity	Much of science relies on models (verbal, mathematical and computer simulations). Simple models contain only a few key variables and parameters	If a model is highly complex, with many different variables, it will be 'data hungry', requiring much data to be fed in. This increases the chances of false assumptions and erroneous data being used.
Independence	Do the scientists involved have any commercial or professional links with vested interests?	Although taking money from an industry does not automatically undermine a scientist's independence, it does raise legitimate concerns.
Control	Can the effects of the 'treatment' (e.g. chemical exposure) be compared with a proper control group which is unexposed?	Detecting an effect relies on isolating it from other possible confounding factors. If no proper control can be found, showing the effect will be much harder. For example, demonstrating the damage the fishing does on North Sea fish communities is difficult, because there are no controls that have been left unfished.

4. Science in the control of pollution

One of the main areas in which environmental justice activists encounter scientific information is when accessing information on pollution. Put simply, pollution is the unacceptable release of a substance or activity into the environment. Obviously there is a great deal to explore here, such as what do we mean by unacceptable, and which substances and activities are included. However, the point here is that we need to know something about the substances and activities, the environment in which it is released and the impact which it has. Such information requires scientific knowledge but it is more than science itself - it also requires an ethical judgement.

Chapter 4 deals with pollution in four parts:

• In 4.1 we look at sampling, literally what issues are involved in going outdoors and collecting an amount of soil, water, air or living tissues for analysis and what sort of questions you should be asking yourself about the data.
• Section 4.2. details the policy and regulations in place, how these are determined and why they are important.
• In section 4.3 we see who is responsible for ensuring that the regulations in place are not exceeded for different parts of the environment.
• When searching for environmental information you need to know where to look for what. The final section, 4.4 explains what information is available and where you would expect to find it.

4.1 Sampling and Preliminary Investigations

When faced with a particular polluting industry or site, it may be that in some cases the regulations and monitoring established to protect the population are not sufficient. By virtue of the environment being an inhomogeneous medium in a constant state of change, no monitoring can ever be 100% effective. For this reason, when, how and where sampling occurs is usually decided upon by a number of factors to obtain a 'best guess' or representative sample.

For example, if you were faced with a football field area in which you suspected there was an area of contamination, you would not dig up the whole field to a depth of 1m and bag up all the soil for analyses. You would have to approach the problem in a systematic manner, compile as much background information as possible, and use this to make an educated guess as to where you might expect to find the 'hot spot' or the distribution of the contaminant.

Likewise, a multitude of other factors can determine the given concentration of a contaminant found in the air, water, soil, vegetation or tissue. These include:

Degradation
Organic pollutants will degrade rapidly when they enter the environment. Inorganic pollutants like metals won't degrade but may alter their toxicity, whereas polychlorinated byphenols (PCBs) are called persistent pollutants as they hardly degrade at all.

Transport
The movement of pollution within air, soil and water. For example, gaseous NOx and SOx may travel vast distances though may be deposited near the source emitter whereas pollution to water courses can equally be dispersed downstream or collect in sediments.

Accumulation and Bioaccumulation
If pollution is not degraded or transported then pollutants may accumulate in soils, vegetation and living organisms. Bio-accumulation is the magnification by living organisms of particular pollutants, where animals at the top of the food chain may have much higher levels of contamination than the lower chain organisms (see Chapter 5.4 on ecotoxicology).

....so what is the real concentration and what does this mean....?

Every discharge situation will be different and therefore should be approached differently. For example it may be that short-term high level of exposure to a contaminant may be more harmful than long-term low levels. If an air-monitoring device was to take a sample every 24hrs at 8am, this may miss a significant pollution event. As described by the case study in section 6.5, the residents of Contra Costa County, California, became aware of this shortfall in the monitoring so decided to do the work themselves. Through consultation with experts they established a scientifically valid method of sampling and used this to be able to monitor more regularly their local area and 'catch' the pollution event.

This chapter is not going to try to give you the information to be able to go out and take a sample which can then be waved in the face of a polluting industry. Sampling techniques and the equipment used vary considerably and many confounding effects (see section 3.3.3) can lead to invalidation of samples. Rather, it is about understanding the pollutants released to the environment and their effects on human health, as well as the monitoring process and determining the potential shortfalls within this process.

Some pertinent questions to ask regarding a particular concern could include:

• *What are the issues…. Are you primarily concerned about direct health problems or the levels of pollution* (this will determine which angle you start your investigation from). *Is there a prevalence of a particular illness within the community?*
  - Look at table 4

• *Do you know what the source of pollution is?*
  - What industries operate in your area?

- All industries require a licence to discharge certain substances to the environment. Some industrial processes require authorisation by the regulatory bodies (see section 4.4 for accessing information).

- Background and historical information can suggest possible sources of contamination. This can be found in public libraries in trade journals, map libraries, council records, regulatory bodies including envi ronmental agencies and environmental health departments.

- *What are the polluting agents and what effect do they have on human health?*

  - Look at the process itself and determine what the outputs could be, again this should be available from local authority environmental records and see table 4.

- *What monitoring is in place at present and carried out by whom?*

  - See section 4.4 for access to monitoring records.
  - What type of monitoring is it?

  Continuous monitoring – this can be long-term or an intensive period of short term monitoring.

  Grab sampling- a sample taken from the air, soil or water, and then transported to a laboratory where it is analysed.

  Extractive sampling - Water or air samples passed through an extractive column on site that is then sent for analysis.

- *Do they monitor the relevant compounds at the relevant concentrations and is this on a continuous or sporadic basis?*

  - Are there any harmful products, which could be produced and are not being monitored?
  - Is there sufficient information about sampling locations and regularity?
  - What are the gaps in the monitoring knowledge?

- *What are the recommended levels of exposure given by the authorities?*

  - See table 4 and www.sepa.org.uk/data/eper/pdf/annex_a1.pdf

From this preliminary analysis, it will then give you a better idea of how to address a monitoring issue. It will often not be feasible to take the sample yourself due to limitations of finance, expertise, and access to sample area and equipment.

Sources and related health effects are detailed in table 4 overleaf. This is by no means an exhaustive list. For further information see the end of the chapter.

4.2 Pollution policy

For an activist to be able to access information about pollution and to make sense of it, there is a context which needs to be understood; both the scientific context and the context of why certain things are measured and how. Regulations structure the reasons why pollutants are measured, and the main piece of legislation to govern this is the Environmental Protection Act. There are many other pieces of legislation which will be introduced later, but the value of starting with the Environmental Protection Act is that it illustrates the approach to pollution control and monitoring which has been adopted in Scotland as led by the European Union.

Table 4 - The more common pollutants of air, water and land.

Pollutant	**Source**	**Health effects**
Particulates	Products of combustion. Can combine with other pollutants such as PAHs and heavy metals.	Inflammatory effects upon the lungs and the respiratory system and delivery of toxins into the body.
Metals -arsenic, cadmium, lead, mercury, selenium, thalium, chromium, copper, nickel, zinc	From a wide range of industrial processes. Particularly metal processing. They are often found in particulate form but can also be gaseous.	Each metal has a different chemical behaviour and toxicity.
Volatile Organic Chemicals (VOCs)	VOCs are emitted as gases from certain solids or liquids. These include a variety of chemicals, some of which may have short- and long-term adverse health effects.Examples are benzene and short chain hydrocarbons	Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans.
Polychlorinated biphenyls (PCBs)	PCBs were historically widely used as ingredients in a number of industrial materials, predominantly used to make coolants and lubricants for certain kinds of electrical equipment, including transformers and capacitors. Highly persistent within the environment.	PCB exposure has been associated with breast cancer and known as an endocrine disrupter and a disrupter of the immune system.
Polycyclclic aromatic hydrocarbons (PAHs)	PAHs are a group of over 100 different chemicals that are formed during the incomplete combustion of carbon based fuels; hence industrial plant and motor vehicles produce the largest quantities.	Many of them are confirmed or suspected carcinogens.
Dioxins and Furans (PCDDs and PCDFs)	Dioxins and Furans are mainly produced by combustion but are also produced as by –products in production of some chemicals. Dioxins and furans can travel long distances in the atmosphere.	Animal tests indicate serious health effects that occur include weight loss, skin disorders, liver problems, birth defects and cancer. Dioxins have been shown to have endocrine disrupting, anti-oestrogenic effects.
NOx and SOx	Produced mainly by combustion processes. These are acidic gases and main contributors to acid rain.Dioxins and furans can travel long distances in the atmosphere.	Asthmatics are particularly badly affected by these pollutants

The 1996 European Union Directive on Integrated Pollution Prevention and Control (IPPC) has set out the approach required by member states to control pollution. The emphasis here is on integration. Pollution often does not fall into separate categories. For example, substances released into the air might also then be absorbed into water and might have different effects on each. Therefore, the management of pollution needs to be integrated and must be the responsibility of a single agency.

The IPPC Directive defines pollution as:
'the direct or indirect introduction as a result of human activity, of substances, vibration, heat or noise into the air, water or land which may by harmful to human health or the quality of the environment, result in damage to material property, or impair or interfere with amenities and other legitimate uses of the environment'.

4.2.1. Controlling pollution at source

As interpreted in Scottish law, the control of pollution is primarily the responsibility of the Scottish Environment Protection Agency (SEPA). The object is to control pollution at the point where it could be released into the environment. This point-source approach to controlling pollution has the advantage that it is precautionary – it aims to prevent pollution before it is actually released at the source. However, because some pollution is released in small amounts by many sources, the cumulative effect of diffuse sources of pollution also need to be controlled. This is most clearly seen in urban air quality where the main source of the pollution is from motor vehicles (see 4.2.3)

Where there is a point source of pollution, such as a factory, industrial plant, waste management facility, quarry, fish farm etc, it is the responsibility of the operator of that facility that their emissions into the environment do not cause pollution – i.e. does not cause harm. They therefore have to consider all emissions to air, water, land and waste before they start operating, and they need to receive SEPA's permission to emit anything potentially polluting into the environment.

SEPA therefore gives to companies the authorisation to emit substances up to a given level, in the form of a license which itemises the emission consents. This then raises the question of how much of which emissions should SEPA give consent to. The spirit of the legislation is to avoid harm to the environment but not to constrain economic development. The level of the consent is a trade off between the conflicting pressures of economic development and the protection of health and the environment. However, whilst SEPA is the supposedly neutral agency which gives the consent, the pressure for economic development is kept up by the companies. The public and environmental organisations have a limited role in being able to keep the pressure up on health and the environment.

4.2.2 Best Practicable Environmental Option

How does SEPA ensure that the business is not unnecessarily constrained but at the same time the environment is protected? There is a system known as Best Practicable Environmental Option (BPEO) which aims to ensure that this decision is reached through 'technical' means. Of course, decisions about pollution, health and risk are never entirely technical because, as we saw in Chapter 3 they all require some degree of judgement.

To assess the BPEO, the operator assesses the options of available technologies for the process which they wish to conduct. For certain kinds of operations that carry a potential higher level of risk, they are also required to carry out an Environmental Impact Assessment (EIA). This EIA identifies potential impact on all aspects of the environment, and takes into account background concentrations of different substances, dispersal patterns, combination of pollutants, interactions with different media such as air, water, soil and also potential health impacts and damage to the natural environment.

Of the range of technologies available for the process, the one with the lowest impact on the environment is considered to be the BPEO. In other words it is possible that the BPEO may continue to lead to damaging concentrations of pollutants in the environment. In that case additional technologies need to be employed to capture or prevent these emissions, or to render them harmless, and to ensure that any emissions do not exceed statutory or existing standards. Such remedial, or 'end of pipe', technologies are covered by the formula BATNEEC, or Best Available Technology Not Entailing Excessive Costs.

The requirement not to entail excessive costs is clearly an area where there is conflict between industry and environmentalists. It has been claimed that BATNEEC is often replaced by 'CATNIP': Cheapest Available Technology Not Involving Prosecution! Again, it is an area where the public has limited leverage on the negotiations between SEPA and the demands of industry. However, after the determination of the BPEO and the identification of BATNEEC, there is an opportunity for consultation with interested bodies and the public.

At the end of this process, SEPA will grant a license to operate under the conditions detailed and will identify an agreed monitoring procedure which should be carried out by the operator (or by consultants hired by the operator). The data collected during this monitoring is made available to SEPA, who also have the right to inspect the site, if necessary without notice. If the operator identifies any emissions which exceed the authorisation consent, then they are required to inform SEPA of the nature of the breach and the mechanisms put in place to remedy it. These pollution incidents are in the public record – see section 4.4.

4.2.3 Controlling diffuse pollution

Where pollution is caused by diffuse sources it is difficult to control at source, so additional mechanisms are put in place. For example, air pollution as a result of traffic is covered within the Environmental Protection Act's Local Air Quality Management. Whilst SEPA retains overall responsibility for such air pollution, the monitoring and management is implemented by local authorities. National Air Quality Standards will be set by 2010 for eight airborne pollutants: Sulphur dioxide, Nitrogen dioxide, Ozone, Particulates, Carbon monoxide, Lead, Benzene,1,3-Butadiene.

Local authorities are required to identify areas at risk of exceeding National Air Quality Standards (NAQS), monitor these areas for the appropriate pollutants and take action to maintain these standards.

4.3 Who is responsible for controlling pollution?

SCOTTISH ENVIRONMENT PROTECTION AGENCY
www.sepa.org.uk
SEPA

As identified in the Environmental Protection Act, and various other pieces of legislation, the implementation of pollution control regulations in Scotland is primarily the responsibility of the Scottish Environment Protection Agency (SEPA) and local authorities.

SEPA is responsible for:

- Regulating emissions from major industries including power stations, chemical works and incinerators via the Pollution Prevention and Control (PPC) regulations.

- Controlling pollution from waste management activities. This includes both licensing the storage and disposal of waste and regulation of landfill sites.

- Regulating installations which use radioactive materials including nuclear power stations, oil rigs and hospitals.

- Regulating discharges to rivers, lochs, estuaries and coastal waters from sewage works, fish farms and septic tanks.

- maintaining and providing public access to registers of authorisations, consents, licences and resolutions and also of applications, any enforcement actions taken and samples analysed.

- Under the terms of the Environmental Information Regulations 1992, SEPA has a duty to provide reasonable public access to all environmental information, such as sampling and survey results and reports.

Scottish local authorities also hold powers relating to the control of pollution within their areas. These powers include:

- Ensuring that national air quality standards are met. Where these standards are not met local authorities are expected to take action to improve air quality, for example by tackling traffic pollution or working in conjunction with SEPA to reduce emissions from industrial sources.

- Identification of areas of contaminated land, ensuring clean up of sites posing environmental or health risks.

- Dealing with the collection, recycling and disposal of domestic waste and working alongside the Scottish Executive and SEPA to reduce waste and increase recycling.

- Responding to (and taking action on) statutory nuisance concerns for example noise and smell and acting to deal with litter, clean graffiti and tackle dog foul.

• Environment and pollution issues are also assessed as part of the land use planning system to control development.

4.4. Accessing scientific information

The question many people find themselves asking, is "what are the likely pollutants arising from a particular process, and what effect do they have on human health?". Of the numerous industrial, manufacturing and agricultural processes which occur throughout Scotland, nearly all may be found on the SEPA website with their potential contaminants of concern.

The public in Scotland has a general right to access all environmental information (including scientific information), with a few exceptions, under the Environmental Information Regulations. These are being updated to bring them in line with new European legislation and the Scottish Freedom of Information Act. This requires public bodies, and other bodies which carry out a public function, to respond to public enquires for environmental information within a set time and at only a minimal charge to the enquirer. Information can only be withheld in the public interest for reasons such as defence and commercial confidentiality. SEPA is the principal body responsible for providing information on pollution and other emissions.

4.4.1 A Pollution Inventory for Scotland

SEPA is currently developing a comprehensive pollution inventory. It shows emissions from sites across Scotland, allows you to search for emissions in your area and highlight the progress of measures taken to reduce industrial pollution. The full inventory is due to be complete in August 2005 with information coming on-line in stages. (see http://www.sepa.org.uk/spi/index.htm).

The pollution inventory is an internet-based searchable database of pollutants released in Scotland. The database enables the user to search their local area on a map, or by postcode, to find out which companies/factories etc. release which chemicals, in what quantities and what the effects of such releases are (see http://www.sepa.org.uk/data/eper/search.aspx)

This information lets you understand the health of your local environment and enables both communities and pressure groups to identify particular companies and sites which emit harmful pollutants. The release of this information will also provide incentives for the companies themselves to clean up their act.

The first stage of the inventory went on-line in May 2003 as part of the European Pollutant Emission Register (EPER). The EPER is an inventory of chemical emissions and sources from across Europe. It reports on emissions from 50 chemicals, 26 for releases to water and 37 for releases to air (some chemicals are released to both water and air). The EPER will report on emissions in 2002, 2004 and 2007 with annual reporting likely to start from 2007 (see http://www.sepa.org.uk/data/eper/subst_all.aspx)

The table below is an example of the information EPER provides. It highlights the top ten biggest polluters in Scotland for 2002.

Table 5 - Scotland's top ten carbon dioxide emitters (2002)

Company	Location	million tonnes CO_2 pollution
Scottish Power	Longannet power station, Kincardine	11.1
Scottish & Southern Energy	Peterhead power station	3.4
Scottish Power	Cockenzie power station, East Lothian	2.7
BP Oil	Grangemouth	2.3
BP Chemicals	Grangemouth	1.1
Grangemouth CHP	Power station	0.8
Lafarge	Cement works, Dunbar	0.7
ExxonMobil	Mossmoran, Fife	0.7
BP Exploration	Grangemouth	0.5
BP Exploration	Sullom Voe, Shetland	0.5

There are some forms of information that are not (or not yet) covered by the pollution inventory. To obtain this information you need to contact a SEPA office or other public body.

4.4.2 Authorisations

SEPA grants authorisations to operate and such authorisations control the means required for integrated pollution control (IPC). These are public documents, although may be somewhat technical, and can be viewed at SEPA offices.

4.4.3 Air

Emissions into the air from around 2000 industrial sources in Scotland are regulated by SEPA under Local Air Pollution Control (LAPC). In addition, around 200 of Scotland's larger and potentially more polluting industrial sites are regulated via Integrated Pollution Control (IPC). Data collected by local authorities on the pollutants covered by National Air Quality Standards are available from the local authorities environmental services department directly. In some cases they are published on the LA website.

4.4.4 Water

SEPA is responsible for setting water quality objectives and issuing discharge consents to all bodies of water. The new Water Framework Directive requires SEPA to publish quality standards and improvement targets for all rivers, lochs and coastal water.

Public water supply is monitored for several chemical and biological contaminants by the water authority at the reservoir. You will be able to obtain these records by contacting the relevant water authority directly, or from their website. This does not apply to private sources of drinking water.

photo credit - Digital Vision

Local authorities are responsible for the water distribution system and will monitor for lead. You should be able to obtain these records from the environmental health department.

4.4.5 Contaminated Land

Both the Local Authority and SEPA issue remediation notices for sites proven to exceed allowable levels. All local authorities are undergoing a process of registering the contaminated land in their area. They have been required to publish the strategy of how they intend to inspect and register this land. Local authorities will be at different stages in this process, but when the register is in place it will be available to the public, and normally available at the Council Headquarters or environmental services department.

4.4.6 Waste

photo credit - Digital Vision

SEPA issues waste management licences, registration of activities exempt from waste management licensing and of waste carriers and brokers. The Local Authority deals with issues such as litter control area orders and municipal waste disposal.

4.2.7 Environmental Impact Assessments (EIAs)

Major developments require an EIA which are conducted by the developer of a new operation. These EIAs are held by SEPA and are public documents. They tend to be large and fairly technical.

4.4.8 Radioactivity

SEPA holds registrations and authorisations for storage,accumulation and disposal of radioactive substances.

4.4.9 Others

Local authorities hold consents for hazardous substances, applications for planning permission and measurements taken in noise abatement zones

photo credit - FoES

Up until May 2003, the only on-line register of environmental pollution in Scotland was for bathing water quality (www.sepa.org.uk/data/bathingwaters/). Information on air quality was, and still is, contained within registers which can be viewed in SEPA's larger offices.

4.5 Pollution Laws

Although much environmental protection legislation has been incorporated into the Environmental Protection Act, there is a range of different regulations covering several specialist pollutants or contexts. The box overleaf is a list of some of the laws controlling pollution in Scotland at present. Full details of this and other legislation can be found on the following websites:
www.europa.eu.int/eur-lex/en/lif/ind/en_analytical_index_15.html (European)
www.legislation.hmso.gov.uk/ (UK regulations)

Water directives

• Bathing Waters Directive – sets limits on indicator bacteria concentrations at the 60 identified bathing waters in Scotland.
• Control of Pollution Act – controls discharge of poisonous, noxious or polluting substances to controlled water in Scotland.
• Dangerous Substances Directive (and 'daughter' Directives) - set concentration limits in fresh and marine waters for trace metal and trace organic substances.
• Nitrates Directive - controls the pollution of controlled waters by excess use of fertilisers on agricultural land and the Freshwater Fisheries Directive requires compliance with certain standards to protect waters designated to support healthy fish populations.
• Urban Waste Water Treatment Directive - sets out timetables for the implementation of appropriate treatment for sewage discharges.
• Protection of Groundwater Directive - to prevent pollution of groundwater.
• Shellfish Waters – to protect quality of coastal and brackish waters designated for protection or improvement to support shellfish populations.
• Water Framework Directive – extends environment protection for point and diffuse pollution sources and impacts associated with water abstraction and engineering works.

Air directives

• Directive on Combating Air Pollution from Industrial Plants - aims to minimise pollution for a specific range of substances (e.g. hydrocarbons, heavy metals, chlorine).
• Large Combustion Plants Directive - sets out a monitoring plan for all plants of greater than 50MW capacity and sets emission limits for sulphur dioxide (SO_2) and oxides of nitrogen (NOx).
• Local Air Pollution Control (LAPC) – regulates emissions to air for c. 2000 industrial sources in Scotland.
• Municipal Waste-incineration Plants Directive - provides limit values for gaseous temperatures and dust content and carbon monoxide concentrations in the emissions.
• Sulphur Dioxide and Suspended Particulates Directive – prescribes sampling and analysis methodologies and sets limit and guideline values for atmospheric concentrations. Similar requirements are made under the Nitrogen Dioxide Directive, the Ozone and the Lead Directives.
• The World Health Organisation (WHO) also publishes guideline values for acceptable atmospheric concentrations of ozone, radon, lead, nitrogen dioxide, sulphur dioxide, and particulates.

Waste directives

• Disposal of Waste Oils Directive - requires the registration of collectors, promotes regeneration, prohibits discharge to water and soil, and sets emission limits on disposal by combustion.
• Framework Directive on Waste – imposes a requirement for competent authorities to be established for the planning, organisation, authorisation and supervision of waste disposal operations and also requires them to prepare disposal plans. The Amendment reinforces the need for waste minimisation, for disposal to be locally provided, and for adequate process control.
• Producer Responsibility Obligations (Packaging Waste) Regulations – used to implement requirements of EC Directive on Packaging and Packaging Waste.
• Special Waste Regulations - insists that the disposal of such waste must be identified and recorded and separated from other wastes. Hazardous wastes are defined by a lengthy list including substances (e.g. pigments, resins, biocides, etc.), constituents (eg cadmium, phenols, ethers, etc.) and properties (e.g. flammable, toxic, mutagenic, etc.)

Contaminated land directives

• Environment Protection Act - local authorities and SEPA are required to establish public registers under Part IIA of the EPA.

Radioactivity directives

• Directive on the Health Protection of the General Public against the dangers of Ionising Radiation - sets thresholds above which member states must implement systems of reporting and authorising the production, handling, use, holding, storage, transport and disposal of radioactive substances. Dose limits are set for a range of exposed workers and for the public, and some management practices are specified.

Further information

The Scottish Environment Protection Agency - SEPA
SEPA has a network of local offices which can be contacted for specific queries. Contact details can be obtained from the website or from their Corporate Office in Stirling on 01786 457700.

• www.sepa.org.uk
• European Pollutant Emissions Register: www.sepa.org.uk/data/eper/mainpage.htm
• The Scottish Pollution Inventory: www.sepa.org.uk/spi/index.htm
• SEPA's 24hr Pollution Hotline 0800 80 70 60 (for reporting accidents or incidents requiring an urgent response)

SEPA Corporate Office, Erskine Court, Castle Business Park, STIRLING FK9 4TR

Local Authority:
The Convention of Scottish Local Authorities (COSLA) has contact details for all local authorities on their website or can be contacted on 0131 474 9200
www.cosla.gov.uk

Friends of the Earth Scotland
Pollution and Industry webpage: www.foe-scotland.org.uk/nation/iandp.html
Bonnington Mill, 72 Newhaven Road, Edinburgh EH6 5QG (0131) 554 9977

The Environment Agency
Part I of the Environmental Protection Act 1990 (the Act) and the Industrial Pollution Control (Northern Ireland) Order 1997 establish a UK wide pollution control system for industry under which any person carrying out a prescribed process must obtain an authorisation from the environmental regulator (www.environment-agency.gov.uk/netregs/sectors)

Information on legislation, technical guidance and compliance notes (www.environment-agency.gov.uk/business)

Scorecard- An information service provided by the USA Environmental Defence Fund. Scorecard makes it easy to find information about toxic chemicals: where they come from. A comprehensive online tool for monitoring and taking action on chemical releases and other forms of pollution nationwide (www.scorecard.org)

The Toxics Release Inventory (TRI) is a publicly available USA Environmental Protection Agency database that contains information on toxic chemical releases and other waste management activities. This inventory was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and expanded by the Pollution Prevention Act of 1990. (www.epa.gov/tri)

The International Agency for Research on Cancer (IARC) is part of the World Health Organization. Extensive databases of cancer related information for chemical substances, agents and mixtures. (www.iarc.fr)

5. Pollution and Health[1]

By its very nature the environment we live in is not something we can escape from. Even if we remove ourselves from the airborne pollutants of the "outside" world, they will simply follow us in. On a daily basis we are exposing ourselves to other contaminants in the food that we eat. There are a variety of ways that we can become exposed to pollutants but perhaps the two most frequent ways are via what we breath in and what we eat. The purpose of this chapter is to look, briefly, at the two body systems affected in this way, namely the respiratory and gastrointestinal systems, and then discuss the affects of various pollutants on these systems.

5.1 The Respiratory System

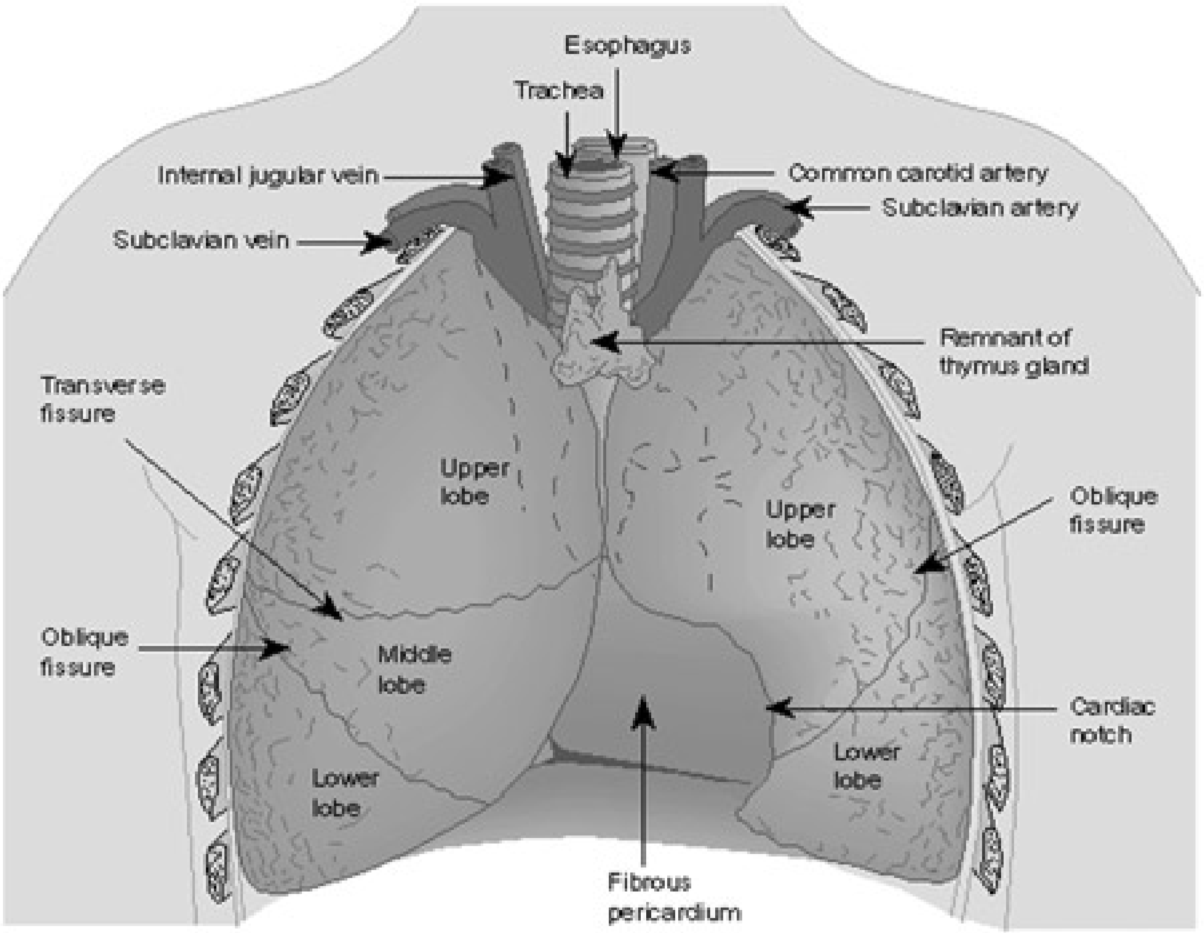


Figure 1 - The Respiratory System, figure taken from 'The Human Physiology Illustration Resource' of Oxford University Press (see http://www.oup.co.uk/best.textbooks/medicine/humanphys/illustrations/ch16/)

[1]Dr. Douglas McBean, Senior Lecturer in Physiology & Neuroscience, School of Health Sciences,Queen Margaret University College, Edinburgh

The respiratory system is one of the most critical systems within the body since, working with the cardiovascular system, it ensures that all the tissues receive the oxygen (O_2) that they need to function properly. Any impairment of the respiratory system will restrict the amount of O_2 entering the blood and have serious consequences on body function.

When we inhale, the air enters the respiratory system either via the mouth or nose and passes into the trachea, which then divides into two bronchi, one supplying each lung. The airway divides up like the roots or branches of a tree into smaller and smaller airways (bronchi _ bronchioles _ terminal bronchioles _ alveolar ducts _ alveolar sacs _ alveoli) thereby ensuring that all of the lungs are filled with air. At the smallest level of the airway the alveoli come in to close contact with the small blood vessels. It is at this level that the O_2 leaves the lungs and passes in to the blood that has come back from the tissues of the body via the heart. The blood, now oxygenated, is pumped back to the heart and circulated round the body supplying the tissue again with O_2. At the same time as O_2 passes from the alveoli to the blood, carbon dioxide (CO_2, a waste product of tissue O_2 use) is passed from the blood to the alveoli to allow it to be cleared from the body during exhalation.

5.1.1 Airborne Pollutants

Airborne agents including bacteria, viruses, smoke, pollen, gas or dust cause most of the lung diseases in the developed world. Since these agents are airborne they enter the respiratory system with relative ease and, as a result, the majority of respiratory disorders are caused by pollution or contamination of the air we breathe. The view could be taken that almost everything in the air, other than the O_2 we need, is a pollutant. The term pollution, however, is normally used to cover the noxious material given off by cars, manufacturing, etc. The very nature of this type of pollution means that it can simultaneously affect a large percentage of the population, or be localised to a particular room in the workplace. For the purposes of this chapter we shall be looking at pollution in the wider sense as it affects the general population.

Air pollution can be subdivided into 5 broad categories:
- Carbon Monoxide
- Particulates
- Sulphur oxides
- Hydrocarbons
- Nitrogen oxides

Carbon monoxide (CO) is perhaps the best known pollutant emanating from the car engine. It enters the body via the respiratory system and passes in to the blood in the same way as O_2. Once in the blood it combines with haemoglobin, which normally carries the O_2, and displaces O_2 from the blood. As a result the blood travelling round the body is not supplying enough O_2 to the tissues, which at low doses of CO can cause a general tiredness, but at high doses can result in death.

Particulate is the general term for a mixture of solid and liquid particles, which are produced by various industrial processes. Examples include minute particles of soot and ashes blown from incinerators or industrial

smokestacks.
Sulphur oxides are the foul-smelling, corrosive, poisonous gases that come from burning sulphur containing fuel such as coal and oil. The sulphur is commonly found as an impurity in the fuel. The combination of these airborne gases with the moisture in the air is what results in "acid rain".

The inefficient burning of fuel, mainly petrol, forms hydrocarbons. Hydrocarbons are not very themselves harmful, however when they react with sunlight they form smog. Smog is less of a problem than it used to be, but it can still be found in significant quantities in large cities with high traffic levels and large amounts of sunshine.

Nitrogen oxides (including nitric oxide - NO, and nitrogen dioxide - NO_2), are produced when fuel is burned at very high temperatures in cars, electric utilities, metal fabricating plants and chemical plants. NO_2 is a yellow/brown gas that can that can be a component part of both smog and ozone (an agent that can be irritant to both the lungs and the eyes).

5.1.2 Effects of Air Pollution

When investigating the effects of airborne pollutants it is important to divide the population into two distinct groups: healthy people and those with an existing chronic respiratory or cardiovascular conditions. Another group particularly susceptible to investigate independently would be the elderly.

A significant number of epidemiological studies have been carried out in a variety of countries in the industrialised world, including the United States, Canada and the United Kingdom. These studies have allowed epidemiologists to show a causal link between air pollution and the following:

- an increased hospitalisation rate of both children with a prior history of asthma and people from the general population with acute respiratory distress,
- a reduced function in the lungs of children compared to those in non-polluted areas,
- a rise in the death rate compared to non-polluted areas.

Following the British Clean Air Act of 1965 there was a marked decrease in mortality and morbidity from bronchitis. The Pollution Standard Index (PSI, see table 6) scale ranges from 0 to 500 and is based on the air pollutant with the highest concentration at the time the test is done. Five major pollutants are measured at various points throughout the area: nitrogen dioxide, sulphur dioxide, carbon monoxide, photochemical oxidants (mainly ozone), and particulate matter. The PSI was originally developed by the US EPA to provide consistency in reporting on air quality. The PSI is published every morning in large city newspapers or is available from your local pollution control agency.

It is obvious from the above information that the elderly or anyone suffering from an underlying cardiorespiratory condition should avoid air pollution as much as possible. However, it will not always be possible for an individual to move house or change job for a variety of reasons, including personal or financial.

Table 6 Pollution Standard Index (PSI)

PSI value	Situation
0 - 50	Clean air
51-100	Moderate pollution
101-200	Unhealthy level - may cause problems in people with an underlying respiratory or cardiovascular problem
201-300	First stage alert - very unhealthy
301-400	Second stage alert - very hazardous and everyone should avoid outdoor activity
401-500	Third stage alert - a level of pollution that it may actually cause death in the elderly or those with a respiratory or car diovascular condition.

There is a significant amount of data available showing the link between cigarette smoking and respiratory problems, however it should be noted that there is no similar body of data proving conclusively the cause and effect link between air pollution levels and specific respiratory diseases. That said, there is no real reason to doubt the link between high levels of air pollution and respiratory distress, therefore it is likely that repeated exposure to these pollutants could lead to specific respiratory disorders.

5.1.3 What Respiratory Disorders Are Likely?

Asthma is an occlusive respiratory disorder and is often referred to as Reactive Airways Disease. In asthma the airborne irritant causes inflammation of the bronchial passages, which in turn leads to increased mucous production, inflammation of the bronchial membrane and a tightening of the smooth muscle around the airway. These three events lead to a narrowing of the airway, thereby minimising the airflow.

Bronchitis is referred to as a hypersecretory disorder and it is the increased mucous production that causes a narrowing of the airway. The irritation caused by the excess mucous results in the patient having a cough which is productive of sputum.

Emphysema occurs when there is a dilatation of the terminal air spaces (alveoli) of the lung with destruction of their walls. Since the alveoli are involved in gas exchange there will be an obvious reduction of O_2 entering the blood. The condition is not obvious from the onset and there can be a gradual progression of the problem over a period of 10 to 40 years.

5.2 The Gastrointestinal (GI) System

Subdivisions of the GI System

The Oesophagus

Food enters the mouth, mixed with saliva as it is chewed, swallowed and passed down to the stomach via the oesophagus (esophagus in US spelling). Due to the variable consistency of the material swallowed the oesophagus has to be protected from potential damage. To this end it has a double protection mechanism. Firstly, it has a lining, which protects from traumatic damage and, secondly, it has a layer that secretes mucous to ease the passage

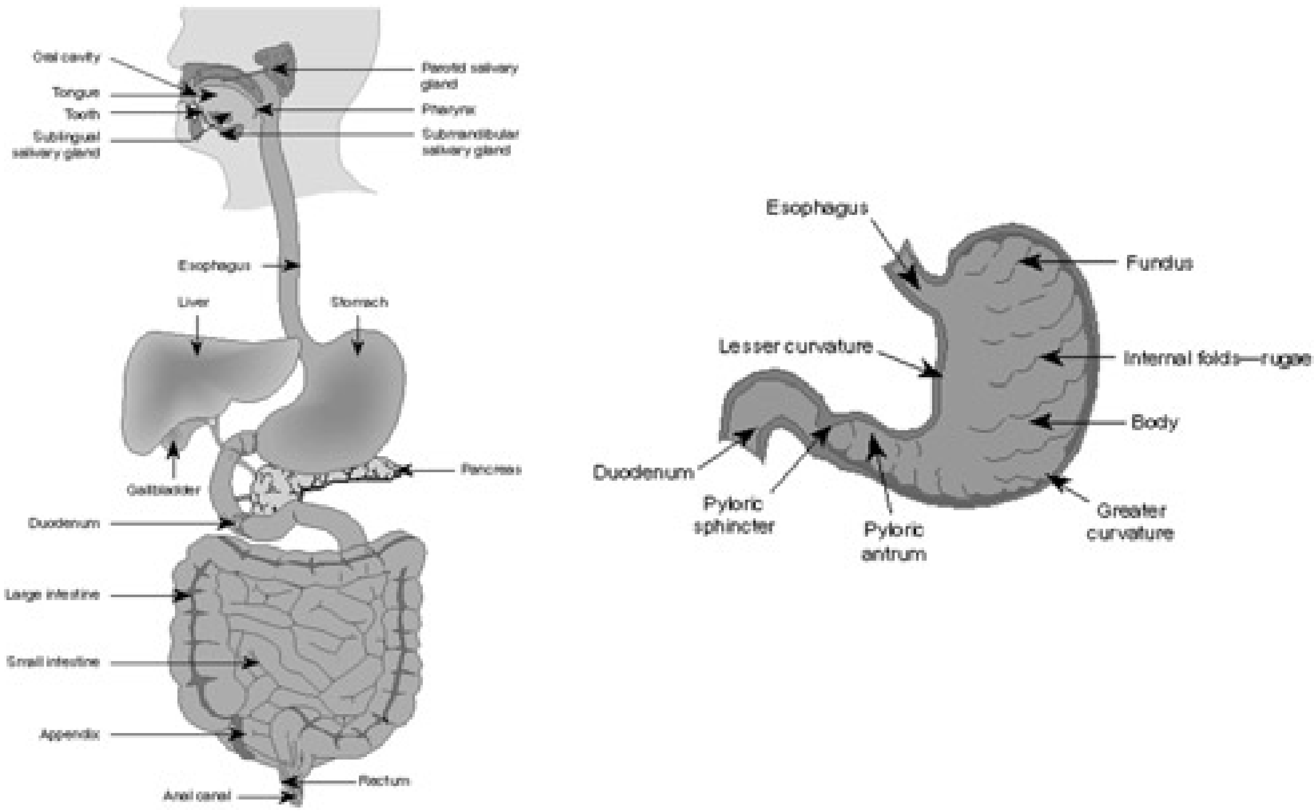


Figure 2 - The Gastrointestinal System, figure taken from 'The Human Physiology Illustration Resource' of Oxford University Press with the stomach detailed on the right (see http://www.oup.co.uk/best.textbooks/medicine/humanphys/illustrations/ch18/)

of the food. Additional to these protective mechanisms the oesophageal walls are surrounded by smooth muscle which contract and "squeeze" the food to stomach using waves of contraction known as peristalsis.

The Stomach

The stomach is a 'j'-shaped organ, with two openings (oesophageal and the duodenal) and four regions (cardia, fundus, body and pylorus). Each region performs different functions; the fundus collects digestive gases, the body secretes pepsinogen and hydrochloric acid, and the pylorus is responsible for mucus, gastrin and pepsinogen secretion. The purpose of the various agents secreted is to aid digestion of the solid food particles.

The stomach has five major functions;

- temporary storage of food
- to control the speed of food entering the duodenum
- secretion of the necessary acids, coupled with an antibacterial action
- to liquidise or fluidise the contents
- first stages of digestion using pepsin, lipases etc.

The Small Intestine

The bulk of both the chemical and mechanical digestion takes place in the small intestine. The small intestine is also the main site involved in absorption of all the useful materials from the digested material, and to this end the wall of the small intestine is lined with a mucous layer appropriate for absorption. Smooth muscle, in two layers, also lines the small intestine and peristaltic

movement occurs to move the digestive products through the area. The small intestine consists of three main components:
• the duodenum which acts to neutralise the acidic gastric contents (called 'chyme') and to start further digestion
• the jejunum and the ileum are the greatly coiled parts of the small intestine, and together are about 4-6 metres long; the mucosa of both of these sections is highly folded which markedly increases the absorptive surface area

The Large Intestine
The large intestine removes the water from the digestive products remaining, since the nutritionally important components have already been removed. This results in a partially solid faeces being expelled from the body via the rectum and the anus.

5.2.1 Pollution and the GI Tract

In order for water to be considered polluted it has to be judged unsafe for its intended use, or be likely to have an impact on public health or ecological factors. Various criteria can be used to monitor the levels of pollution (biological, chemical and physical). The purpose of this section is to discuss the main forms of water pollution. When organic matter (waste or otherwise) is added to water, the process of decomposition will start. Since decomposition requires O_2 this will result in the depletion of O_2 levels in the water. Subsequent low levels of O_2 can obviously be harmful to fish, aquatic plants and many organisms. The amount of O_2 used in water by this bacterial activity is referred to as the Biochemical Oxygen Demand (BOD; measured in mg/l @ 20°C over a 5 day period). Obviously, the more BOD utilising waste in the water, the larger the problem caused by depleting the O_2 levels. When water is polluted with organic waste and matter the number of disease carrying micro-organisms (e.g. faecal coliform bacteria) in the water increase. Cholera and typhoid are two of the main waterborne diseases and both are very common in less developed countries. Table 7 on the following page outlines the main disease-linked organisms found in water:

5.3 Epidemiology

The "father" of epidemiology was the late John Snow (1813-1855) who, at the age of 14, became a surgeon's apprentice in the north-east of England. Having been an unqualified assistant during the 1831 London Cholera Epidemic, he later graduated with an MD at the age of 31.

In the mid 19th century it was widely accepted that cholera was no different from all other diseases and that it was spread through the inhalation of contaminated air. Snow published "On the mode of communication of cholera" in 1849. In it he put forward the idea that cholera was spread through contaminated food or water, a theory which at that time he had no way of proving.

With the further outbreak of cholera in London in 1854, Snow set about to prove his theory. He started to mark on a street map the exact location of each death from cholera. At that time London water was supplied by two separate companies which drew their water from opposite ends of the

Table 7 Diseases commonly found in polluted water
©Department of Geography, Okanagan University College – used with permission

Disease	Infectious Agent	Type of Organism	Symptoms
Cholera	Vibrio Cholerae	Bacterium	Severe diarrhoea, vomiting: fluid loss of as much as 20 qts/day, causes cramps and collapse.
Dysentry	Shigella dysenteriae	Bacterium	Infection of the colon causes painful diarrhoea with mucus and blood in stools, abdominal pain.
Enteritis	Clostridium perfringens other bacteria	Bacterium	Inflammation of the small intestine causes general descomfort. loss of appetite, abdominal cramps and diarrhoea
Typhoid	Salmonella typhi	Bacterium	Early symptoms include headache, loss of energy fever; later, a pink rash appears along with (sometimes) haemorrhaging in the intestines
Infectious Hepatitis	Hepatitis virus A	Virus	Inflammation of liver causes jaundice, fever, head-ache, nausea, vomiting, severe loss of appetite; aching in the muscles occurs.
Poliomyelitis	poliovirus	Virus	Early symptoms include sore throat, fever, diarrhoea, and aching in limbs and back; when infection spreads to spinal cord, paralysis and atrophy of muscles
Amoebic Dysentry	Entamoeba histolytica	Amoeba	Infection of the colon causes painful diarrhoea with mucus and blood in stools; abdominal pain
Schistosom-iasis	Schistosoma sp	Fluke	Tropical disorder of the liver and bladder causes blood in urine, diarrhoea, weakness, lack of energy, repeated attacks of abdominal pain.
Ancylostom-iasis	Ancylostoma sp.	Hookworm	Severe anaemia, sometimes symptoms of bronchitis.

Thames i.e. one from upstream and one from downstream. Snow noticed that a greater percentage of the cholera cases were found in the parts of London supplied by the "downstream" water company, whose water was more likely to be contaminated by sewage. As well as observing that detail Snow also realised that there seemed to be an area of London at the junction of Broad Street and Cambridge Street where there appeared to be a larger number of deaths - 500 in 10 days. The simple removal of the handle from the Broad Street pump that supplied the water to this area resulted in the containment of the epidemic. Mapping has become a widely used research method in epidemiology, although data is expressed in relation to population (e.g. deaths per 1,000 population) to allow for differences in population density.

Epidemiology is the study of the pattern of a disease i.e. who is affected, the severity of the resultant condition, and the reasons for it. When investigating a disease the epidemiologist is not so concerned with the effect of the disease on an individual, but rather on a population or group of people. As a result, the majority of epidemiological studies are field studies where the disease is investigated in the environment in which it is occurring. This differs from traditional, laboratory-based science where conditions can be strictly controlled. In a field study it is highly unlikely to find exactly the same conditions twice, therefore epidemiologists only have one chance to investigate a study population under any particular set of conditions. Since epidemiologists are unable to study the same population under the same conditions more than once they attempt to minimise the impact of this by investigating a number of different populations over a range of situations to try and draw some general conclusions. This approach has allowed epidemiologists to understand a significant amount about the incidence of various diseases and their causes.

5.3.1 Investigation Criteria

To determine whether a specific risk factor can cause a disease epidemiologists utilise three criteria: temporality, consistency and dose response.

- Temporality - exposure must come before occurrence of the disease
- Consistency - same type of effect seen in a variety of studies
- Dose-response - the greater the level of exposure, the greater the health effect.

5.3.2 Study Design

4 main study types are utilised in epidemiology are as follows:

• Cohort study
This type of study will follow a group of people, who have had varying levels of exposure, over a period of time to assess their health status. This is a good study design because exposure can be recorded and evaluated before eventual health status is known. On the negative side it is an expensive and time consuming design and can be a logistical nightmare, trying to keep track of all the people in the study over time.

• Case control study
This type of study looks at a group of individuals who are suffering from a particular condition and assesses their prior exposure to the proposed causal agent. Normal, unaffected individuals also have their exposure looked at, thereby acting as a control group. This allows the investigator to carry out a smaller scale study using fewer people over a short period of time. As a result it is cheaper to run than the cohort study.

• Occupational epidemiological study
This type of study can be carried out using either of the previously mentioned designs, but selecting people who work in a particular job, with a particular exposure, as the study subjects. This study has the advantage that workers, due to their close contact to any exposure, usually have a higher level of exposure. As a result this increases the chances of identifying any link.

• Cross-sectional study
This design compares groups in terms of their current health status and exposure status and tries to identify any similarities. This design is a particularly easy type to carry out since the investigators do not have to wait for health to deteriorate or do any retrospective analysis of exposure. However, the design also has one major disadvantage - cause can not be inferred since only current exposure and health are being looked at.

Great care must be taken when designing an epidemiological study to choose the correct design. This will increase the "believability" of the result and reduce the risk of those parties with a vested interest minimising the impact of the findings.

5.4 Ecotoxicology - Jennifer Batty (Centre for Human Ecology)

What is ecotoxicology?

Ecotoxicology is the study of the impacts of chemical pollution on animals and plants. Toxic chemicals can have major effects on living organisms, sometimes at very low concentrations, but even chemicals of low toxicity can have negative effects if a large amount is present. The salt used to de-ice the roads can be toxic to tree roots, but salt is an essential component of all living organisms.

Ecotoxicology involves not only looking at the effects of chemicals on individuals and populations of organisms but can also include how these effects impact the functioning of the whole ecosystem. For example, a chemical may be very toxic to insects, and the insect population may be decimated. The whole ecosystem will be affected through additional indirect effects. For example birds that rely on insects for food will also decrease, as will the predators of these birds.

What sort of questions do ecotoxicologists ask?

- *Where are chemicals going to in the environment?*

It is important to understand where toxic chemicals go to in the environment and whether they will break down into other more or less toxic substances. For example, are the polluting chemicals deposited in the bottom sediments of a lake where they may be causing little harm, or are they dissolved in the water and being taken up by fish? If fish are accumulating toxic compounds then other organisms will also be affected, from the fish eating birds, such as herons, to us, humans, who might also go fishing in the lake. Many chemicals that are fat-soluble don't remain in the sediments or in the water but tend to be readily accumulated by many organisms, including fish. Such chemicals are described as having a high bioconcentration potential. These concentrations can then be biomagnified up the food chain by, as in the example above, of the fish being eaten by birds.

- *How persistent are the chemicals?*

Toxic chemicals in the environment can be broken down i.e. degraded by the action of sunlight or chemical reactions with water. Breakdown of substances specifically by living organisms, such as soil bacteria, is known as biodegradation. Some substances are very slow to degrade in the environment. The degradation time of these 'persistent' or 'recalcitrant' chemicals is described by their half-life. This is the time it takes for half of the substance to degrade in the environment. For example, if an insecticide with a 2-year half-life is sprayed onto a field, 2 years later half of the pesticide will have degraded, and after another 2 years half of the remainder i.e. a quarter of the original will still be present. (In reality, the field pesticide levels will probably fall faster than this because of loss through rain effects and crop harvesting). Some chemical pollutants are not degradable, and can be continuously toxic to organisms. Metals such as mercury can contaminate lake ecosystems for very long periods and dredging the sediments may be the only solution to the toxic problem.

- *What are the toxic effects on the organisms?*

Effects can be of two types: lethal and sub-lethal.
Deaths of organisms – lethal - are relatively easy to see and major pollution incidents involving fish deaths are usually quickly reported to SEPA who act to find the source and take appropriate action.
Sub-lethal effects are more difficult to spot early on, but may lead to far more significant effects on fish populations and on the community structure of e.g. a river (community structure refers to the number and types of other species present). For example, some chemicals can inhibit reproduction in fish but have no apparent effects on the survival of adults. Adult fish may be caught for some time after a pollution incident and only gradually does the impact of the pollutant becomes apparent. Clearly a fish population no longer able to produce eggs or young will decline very rapidly.

photo credit - Digital Vision

- *What is the best way to investigate a contaminated area?*

The techniques used (not surprisingly) depend on the site or area (river, loch and forest) and the nature of the concern such as human exposure and illness, declining bird populations, or the loss of fishing opportunities.

A typical series of steps taken to investigate reduced fish populations in a loch would include:

- Desktop studies-this involves checking past records of fishing catch, range of species etc, as well as looking at potential sources of pollution from agricultural run-off, location of industrial complexes, history of use of the area etc. Sources of pollution may be diffuse, e.g. atmospheric deposition from many sources or point source pollution for e.g. an industrial effluent pipe (in this case, there will also be some checks as to whether there has been over-fishing).
- Comparison of the lake flora and fauna (plants and animals) with other similar lochs. This gives an idea of what might be expected to be found in the loch.
- Surveying the fish in the loch, looking at the range of species as well as the developmental stages of the fish.
- Surveying food availability. Declines in fish may not be because the fish are being directly affected, but due to lack of food availability (which itself may be pollution related).
- Measuring the concentration of specific chemicals in, for example, sediment samples and fish tissues. Likely 'chemical candidates' for measurement will probably have emerged from the desktop study.
- Detailed study of the condition of a few specific species might be undertaken. For example examining the reproductive condition of the fish, or looking for tumours or deformities.
- To confirm a 'suspicion' about the role of a particular chemical, laboratory exposure experiments may be carried out, and effects under controlled conditions investigated. Alternatively, experiments may be carried out in the loch with fish in cages and the impact of exposure to the lake water observed.

What happens next?

Once the likely causation of the problem has been identified then remedial steps can be taken. In some cases where a point source of pollution is involved removing the source of pollution may be possible. However, many problems of pollution are due to both point and diffuse sources and reducing the pollution input to a site can be a prolonged exercise.

What about the polluted loch? The long term future for the imaginary polluted loch described here will depend on stopping or reducing the source of pollution, letting degradation processes clear the pollutants from the loch to perhaps other processes such as sedimentation leading to the pollutants becoming non-bioavailable.

6. The Citizen and the Scientist

Through the previous five chapters, we have seen how to approach scientific concepts, how to interpret them and what the consequences and regulations involved could be. This chapter describes practical ways by which science has been brought closer to those people who are striving to understand it bettter. Various academic institutions find different ways of making their expertise relevant to the wider community.

6.1 The Agents of Environmental Justice project

Friends of the Earth Scotland

The Agents for Environmental Justice project is a Community Fund supported initiative within FoE Scotland, providing popular education to community activists fighting for environmental justice. The project draws on the tradition of community agents who, in the Indian subcontinent, and increasingly in rural Scotland, have been local activists who are supported by development agencies to mobilise for community development and action in their own localities (Albee & Boyd 1997). In this case, 16 agents were recruited and provided with support for their local action; financial support in the form of honoraria, bursaries or reimbursement of expenses; printed resources; opportunities for networking; and centrally, a Higher Education Certificate in Environmental Justice through popular education methods, validated and accredited by Queen Margaret University College.

The agents are drawn from urban, rural, semi-urban and minority ethnic communities and are involved in struggles against opencast mines, road developments, quarries, fishfarms, GM crops and substandard housing; on Black and refugee issues; alternative economic development and sustainable waste management. The course, seeks to be relevant to these local issues and develop a curriculum which aims to understand not only how to change the specific issues in the agents' locality, but also a wider process of political change which builds intragenerational and intergenerational environmental justice.

This project aims to take a self-consciously popular education approach to making academic and other knowledges relevant to the struggles of communities involved in promoting environmental justice. Figures 3 and 4 demonstrate how adopting this popular education approach differs from traditional university education, including those which have adopted innovative equal opportunity approaches, such as the Open University. Traditionally, academics are employed to generate and keep up to date with changes in a body of knowledge which is the peer reviewed academic knowledge. These academics select from this body, that which is regarded as suitable for a course on a particular subject, and then deliver this knowledge (or in the case of the Open University, compile the course and employ tutors to deliver this knowledge) to the individual learner. Through being educated, the learner is engaged in a process of change which is akin to apprenticeship into the knowledge and conventions of academia.

The agents for environmental justice project moreover, operates in a less linear and, hopefully, more dialectical way. Knowledge is selected from the body of academic knowledge by professional academics employed in the university. Knowledge is also selected from the body of knowledge of 'environmentalism', by community educators or mobilisers, employed by the NGO, and a negotiation occurs to derive a curriculum from these two sources. It is on the basis of this curriculum that the validation of the course is approved. The Friends of the Earth staff then work with the agents, who are community activists and bring with them a selection from another body of knowledge, which is derived from the experience of living in a community with, say, an opencast mine on the doorstep, and being involved in a struggle against it. The negotiation then occurs between these forms of knowledge (and indeed others) in the educational process, which ensures that the learning is relevant to social action.

In this process the main objective is that the community's reality is changed by the social action leading to an improved environment for the community. It also changes the NGO since the interests and struggles of local communities are incorporated into its campaign priorities, and ultimately contributes to the body of environmentalism. There is even a sense in which the academic institution, Queen Margaret University College is being changed as the academics involved are given the opportunity of working with alternative methods of delivering and validating knowledge. The extent to which this occurs is set by the flexibility of the institution, allowed for in the policy environment of widening participation, but interpreted by the staff involved in a creative way.

There is also a hope that the wider higher education community may look at the example provided here of an approach to widening participation with adult students drawn from communities under represented in universities and see the value of engaging with communities in struggle as an effective and legitimate approach. Of the 16 students recruited half are without previous higher education experience, 4 are from geographically isolated communities. People with disabilities and from minority ethnic communities have a higher representation on this programme than in the student population as a whole. In addition to residential teaching weekends, the students/agents work within their communities as part of their course, and their community activism is given equal legitimacy to intellectual study and comparable rigour is expected. In their communities, they are providing a positive message to their families, neighbours and others – university is and can be for them. This also provides an example of the 'external' model of access and participation, one in which social interests outside the academy have access to its intellectual resources and the academy itself is able to participate in the life of communities and social movements around it (Crowther et al. 2000).

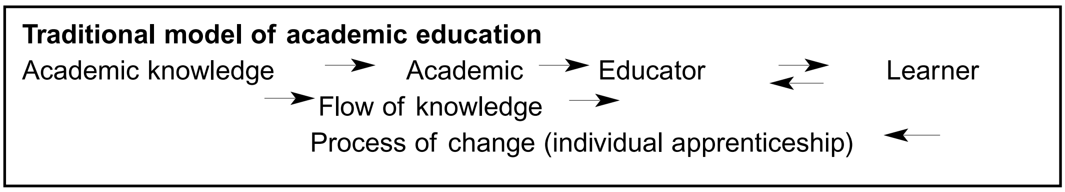


Figure 3

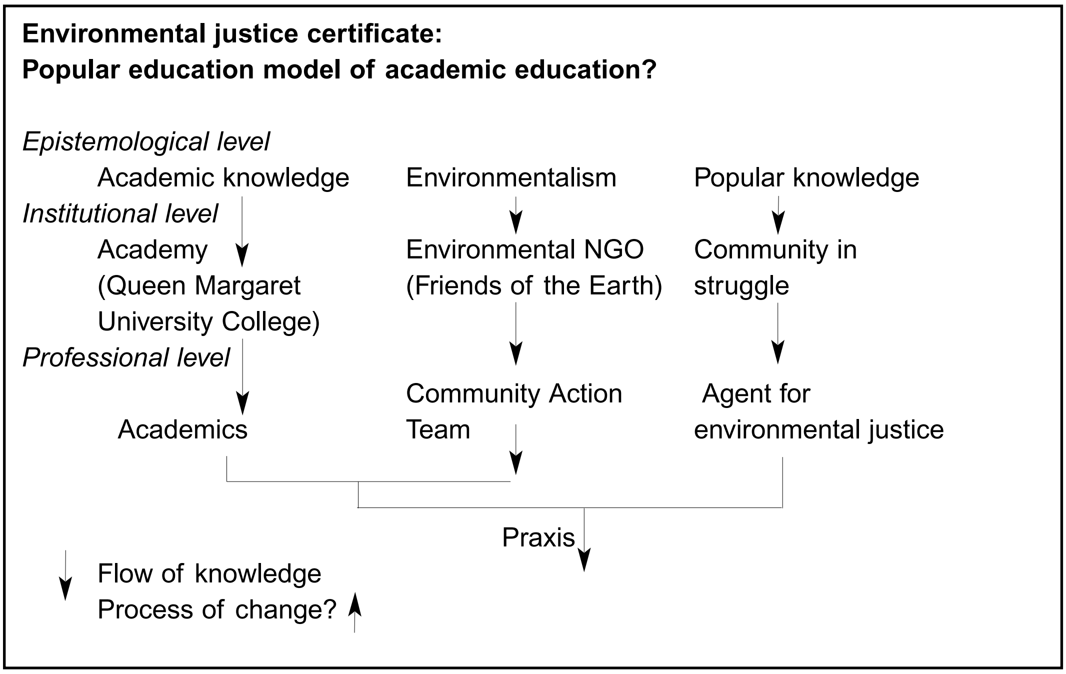


Figure 4

6.2 Science Shops

In the 1970s, a number of scientists in Universities in the Netherlands set up what became known as science shops. These consisted of shops, run by the University, but which could be accessed by the general public. They were open for access by community groups, tenants' groups and trades union branches, indeed any group of people who were involved in improving their quality of life through organising in their community or their workplace, and who might encounter problems of a scientific nature.

The way in which science shops work is that an activist from the group goes to the shop and meets with the staff member on duty, usually an academic with time allocated to running the shop. The activist explains to the academic what the problem is, which could range from explaining technical information about a chemical used in the workplace, through advice on what to do with asbestos in public housing, or how to conduct a survey of health problems in their community, to concern about smells coming from an old dump site.

The academic may be able to access the information needed then and there or explain the meaning of some technical information. More likely however, there will be more work required to work through the understanding of the problem or to carry out further research. The science shop would therefore link the activists up with a relevant department or individual scientist within the university and arrangements will be made for the two to work together to solve the problem. Sometimes some original research would be needed, and the scientist and the activist together would plan the project and, where possible carry it out. A student might be allocated the task of conducting the work, in which case the student would be given credit for this towards their degree or postgraduate qualification.

The purpose of the science shop is not simply to provide answers to technical problems encountered by groups, but also to demystify the science, so that the activists in the community groups and trades unions are better able to take on problems which have a scientific element. The activists will learn something about how science is conducted as well as finding out the information which they need, thereby making sure that the knowledge is really of use to their campaign or activities. If lay people were simply to go in to get the expert information, this would serve to reinforce the way in which science is used to make people less powerful. The science shop process is designed to be empowering to active groups.

Moreover it is also a challenge to the University. By allowing time for academics to do work for the science shop, and giving credit to students for carrying out research, even submitting applications for funding for work with community groups, so the science shop serves to make the research carried out in the university more accountable to those people in communities and workplaces who are struggling to improve their health and their environment.

Many science shops focused primarily on chemical issues, and indeed some were identified as chemistry shops. However, others were able to draw on scientific expertise from across the university and in the social as well as the natural sciences. Whilst originating in the Netherlands, they soon spread through Denmark, France and other European countries, including the UK.

A science shop is based in Belfast in Northern Ireland, and is run jointly by the University of Ulster and Queens University Belfast. Below is an extract from their information.

What is the Science Shop?
The Science Shop is a point of contact between community groups and University of Ulster and Queen's University Belfast. We connect community groups who require research with students or staff who might be able to help.

How does the Science Shop Work?
* a community group suggests a research topic or
* a student proposes a community based project

The Science Shop staff act as mediators, identifying appropriate resources for each group. If a student is interested in a project a meeting is arranged with the commissioning group. At the meeting the needs of the group and student are discussed in detail. If the student takes up a project an agreement is drawn up outlining the responsibilities of both group and student.

Students can help you with:
* Social Science Research
* Health Science Issues or Policy
* Environmental & Geographical Questions
* Historical Research
* Educational Issues
* Information Technology

Who can use the Science Shop?

* Groups of people rather than individuals
* Groups with no commercial aims
* Groups who will use the research for further development

MORE INFORMATION........

w: www.ulst.ac.uk/scienceshop

University of Ulster
Claire Mulrone
Magee
Northland Road, Londonderry.
BT48 7JL

Tel: (028) 71375448
Fax: (028) 71375652
Email: scienceshop@ulst.ac.uk

Queen's University Belfast
Eileen Martin or Emma McKenna
75 University Road
Belfast
BT7 1NF

Tel: (028) 90332620
Fax: (028) 90240656
Email: science.shop@qub.ac.uk

6.3 Action Connection

Action Connection works to bring together the needs of students (mainly of the University of Edinburgh) and the wider community, by providing opportunities for students to work with community groups and voluntary organisations on research questions and topics relevant to both. Many local groups and national charities have questions and concerns they would like to address fully, but lack the staff, time and other resources to do so.

Action Connection works with such organisations to frame questions which can become student dissertation topics or equivalent. In addition, Action Connection will try to help students with a particular area of research interest to find an organisation with whom they can work to mutual advantage.
At present, Action Connection is in contact with some 70 local community organisations and national charities, representing the diversity of the voluntary sector and the people it seeks to serve.

Situated in Bristo Square, a university complex located close to areas of the city currently designated as qualifying for Social Inclusion Partnership funding, Action Connection is well placed to provide students with experience of working with local community initiatives and to help rebuild the concept of a university as a community resource and to enable students to forge meaningful links with their chosen community of place.

The Action Connection process for community groups
Action Connection may be able to help any community group or voluntary organisation which has a question or area of concern which could become an appropriate topic for a dissertation or equivalent.Very often, community and voluntary organisations find it difficult or intimidating to access specialist information resources. Once an organisation has framed a question, a meeting is often arranged to help refine the question so as to make it more possible for the question to be taken up as a dissertation topic.

Once this is done, contact is made with appropriate university departments or students for whom the question might be appropriate, a further meeting is arranged, providing an opportunity for a prospective student researcher to meet representatives of the requesting organisation. The purpose of this is to mediate a research agreement between the requesting organisation and the student researcher, a meeting to which the student's academic supervisor is always invited and at which the Project Research Officer of Action Connection is always present. An agreement outline would normally define the nature and limits of the research to be undertaken, the methodology which will be employed, and the projected timescale of the project. Any particular requirements of any party would also be defined at this point. The Action Connection Project Research Officer will maintain contact with the student through the life of the research project and the student's academic supervisor kept informed.

Community Link - is Action Connection's sister project, acting as a volunteer exchange for students and staff of the University of Edinburgh and those living in the South Side and Old Town areas of the city, offering voluntary work opportunities with around 200 charities and community-based organisations.

What types of project does Action Connection help to make happen?

Examples of past Action Connection facilitated projects include:

• working with the Water of Leith Conservation Trust to measure and record illegal dumping of refuse in the Water of Leith and making recommendations in the light if this,
• work on land in-fill,
• the impact of wind farms on a Scottish island,
• helping an Edinburgh-based group teaching traditional Indian dances to develop into a membership based organisation.

Projects currently available include identifying reasons why ex-offenders find it difficult to sustain tenancies and revert to criminality and looking at possible systems for accrediting voluntary activity overseas.

What types of group can work with Action Connection?

Action Connection works with groups rather than concerned individuals, although it is willing to help senior honours or post-graduate students find appropriate organisations to work with. The service is free at the point of delivery, but Action Connection can only work with groups which are recognised Scottish charities or awaiting recognition and are not profit-making, political parties or advancing a particular religious belief.

MORE INFORMATION........

Bill Dunlop
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5/1 Bristo Square, Edinburgh EH8 9AL
tel. : 0131-650-9471 fax : 0131-650-8115
Email actcon@staffmail.ed.ac.uk

6.4 ScienceAid

Linking Communities and Scientists

ScienceAid makes it easier for community groups to access the scientific advice, information and explanations they need. Using a database of scientists willing to make their expertise freely available to community groups we can link communities with the right scientist.

ScienceAid aims to support communities to participate actively, effectively, and with appropriate scientific awareness in situations such as:

- planning inquiries regarding new industrial, waste and extractive developments;
- land management in rural areas;
- liaison groups of potentially polluting industrial plants;
- negotiations over coastal fishfarm developments or within national parks;
- reporting polluting incidents to regulating industries;
- housing improvements;
- transmitter mast erections etc.

ScienceAid is run by the Centre for Human Ecology (CHE) in collaboration with Friends of the Earth Scotland (FoES). CHE is responsible for encouraging scientists to offer their services, and for developing and managing the database. FoES is the first point of contact for community groups and, if necessary, helps them work out what sort of scientific information or advice they need. Using the database and in discussion with CHE, FoES puts the community group and an appropriate scientist in touch with each other.

ScienceAid also provides advice and training to community groups so they can make best use of the scientists' help, and also to scientists so they can best meet the communities' needs.

ScienceAid is a pilot project with initial funding from the Committee on the Public Understanding of Science.

MORE INFORMATION.........
from the Centre for Human Ecology

w: www.che.ac.uk/scienceaid
e: scienceaid@che.ac.uk
t: 0131 624 1972

6.5 The Bucket Brigade

The bucket brigades were started in 1995 by attorney Edward Masry (of Erin Brockovich fame) when both were made ill by fumes from a petroleum refinery he was suing on behalf of citizens of Contra Costa County, California. When he called the local, state and federal environmental authorities, they told him that their monitors detected no problem. This so angered Masry, whose clients were being exposed to these toxic releases daily, that he hired an environmental engineer to design a low cost device, the "bucket", which the community could use to monitor their exposure for themselves. This set in motion a movement which would give communities living near refineries, chemical plants or other toxic air emitting sources, a chance to take on indifferent regulators and corporations who were telling them that there is no problem with the air they are breathing while they are choking and dying.

Photo credit - Denny Larson

Denny Larson demonstrating the bucket to local residents at Grangemouth

The "bucket" is a low cost $75 version of the $2000 Suma canister used by government and industry and is simple to use. Suspect air is drawn into a Tedlar bag inside the bucket. The bag is then sealed and sent to a laboratory for analysis. The lab analysis is the most expensive part of the operation. For about $500 per sample, the contents of the bag are run through a GCMS (Gas Chromatograph Mass Spectrometer), which compares the "fingerprints" of the sample with the fingerprints of about 100 toxic gases in the computer library. The bag is non-reusable and cost about $15. In practice, much of this cost has been borne by charitable and government grants.

Working closely with Masry, Denny Larson proceeded to promote the use of these buckets in other communities exposed to refinery and other toxic air emissions. Larson hired a student intern to re-engineer the buckets in order to produce a community manual to educate fenceline neighbours so that they could build and operate their own air monitoring systems. When completed, the manual helped spread the buckets throughout the refinery belt of Contra Costa County to 7 communities.

The biggest hurdle was getting the authorities, who belittled the idea of citizen bucket brigades, to accept the results. Larson met with EPA Region 9 officials, including the administrator, Felicia Marcus, in 1996 and asked the agency to approve and fund bucket air sampling. To its credit, EPA Region 9 invested in a quality assurance evaluation of the bucket results and ended up accepting them. With the EPA acceptance, Denny was able to work with grass roots groups around the country to launch local bucket brigades.

Denny Larson explains that typically there are no monitoring devices in industrial zones. They are often 10, 20 miles away and even upwind of the sources. Thus, when the public complains about bad smells and choking fumes, the regulatory authorities and industries scoff and ask for their data. With just a few air samples, Larson explains, the community can collapse the house of cards built by the government and industry that pollution doesn't cross the industry's fence line.

Although started in California, the greatest success of the bucket brigadiers has been in Louisiana. The largely African-American community of Moossville in Calcasieu Parish is home to over 53 industrial factories, more than forty of which are located within a 10-mile radius. Tired of being the victims of lackadaisical government enforcement, which tolerated frequent accidental toxic releases, in September 1998, Mossville residents of "fenceline communities" formed a bucket brigade and began taking samples. Even though publicised in advance, 2 of the 5 original samples found violations of Louisiana standards for vinyl chloride, EDC and benzene. Subsequent samples were even worse. One later sample found carcinogenic benzene in excess of 220 times the States standard.

This got the attention of the press and the enforcement authorities. The EPA Region 6 Administrator made a publicised tour of the area. By 1999 the bucket brigades had spread throughout the cancer alley of Louisiana, leading to the formation of a new non profit Louisiana Bucket Brigade (www.labucketbrigade.org). Region 6 moved in with their own high priced monitoring devices that confirmed high pollution levels even higher than the buckets had detected. Fines were levied and state-of-the-art fenceline monitoring devices were required of some polluters. The Regional office has since given grants to community groups to continue bucket monitoring. Pollution has been significantly reduced, all of which stemmed from a few citizen activists with their buckets. Bucket brigadiers have been active in California, Ohio, Louisiana, Pennsylvannia and Texas with a proven track record of effectiveness.

In September 2003, local activists in Grangemouth, Central Scotland and in Grangetown, Teesside, learned how to make buckets from components sourced in the UK for use in their own local areas. Grangemouth is the site of BP's major Scottish refinery of North Sea oil, and Grangetown is nestled against the Walton site in Teesside. Both refineries have also spawned a range of related petrochemical manufacturing companies.

Activists in Teesside have been building capacity for some three years, getting to know the companies and regulators, and in Grangemouth collecting stories of local people, records of flaring and smell incidents. Through this process of capacity building they have started to overcome initial local feelings that nothing can be done against the polluting giants which provide significant (although decreasing) employment in the areas.

Local people from each area also learned the trick of sampling and took their first air samples of refinery air. Looking out for whiffs of chemicals from their neighbouring refinery flares, chimneys or leakages, they learned how to identify the best place to sample where the concentration of chemical is likely to be strongest. This is usually in the centre of the plume and as near as possible to the refinery fence, when the smell is at its most strong.

In contrast with sampling by passive mechanisms or even active sampling by companies and regulators, the bucket technique identifies gas emissions when they are at their most concentrated. The sampling method does not concentrate the sample however. It aims to capture the air at a point when it is most concentrated with pollutants and avoids diluting it with air at times when the pollutants are not there. The lungs of the people present at that time will also be absorbing the pollutants at that high concentration.

7. Conclusion - The Womens Environmental Network Scientists

Women using and making science - problems encountered and lessons learned[1]

The Campaign

In 1995, the Women's Environmental Network (WEN) organised a meeting at the House of Commons. Women were invited to attend to discuss their concerns about the heavy toll on women's lives from breast cancer . Straight hard official statistics showed (and still show) ever-rising numbers of women getting this disease, and, even with a recent welcome improved survival rate, an unacceptable death toll. The trigger for the discussion was the information then circulating that the use of the organochloride pesticide, lindane, (now banned in the North), was associated with significantly raised rates of breast cancer, and the knowledge that it was to be found in chocolate (and still is)! The breast cancer rate was 40% higher than the national average in Lincolnshire where lindane had been extensively sprayed on sugar beet crops (for more information see WEN's lindane briefing sheet at www.wen.org.uk).

The women were from different backgrounds, women with a wide range of knowledge and skills, - women who were interested and concerned about the effects of our environment on our health and included cancer survivors, health workers and scientists. The women were aware that many scientists were claiming that breast (and other) cancer was largely a preventable disease. They needed more knowledge to enable them to ask the right questions and to try to convince government and society in general that action must be taken to stop what has become a world-wide epidemic. While there was agreement that we must campaign for the best possible treatments to be available for all, it was thought necessary to find out the following, all of which needed further exploration:

- why so many women were getting this disease,
- why the rates kept increasing year on year,
- why there were certain patterns of incidence.

There is a very simple question to be answered: if so many substances and practices which can cause lethal diseases have already been identified, why are we still being exposed to them? It took nearly 100 years from the first report expressing concern about the lung damage that asbestos could cause, for action to be taken to ban it in this country. We will not wait that long.

There is no lack of research material and the WEN team scanned vast amounts of literature. Within it, there are conflicting and inconclusive reports. WEN had to learn which to trust as they would wish in turn to be trusted by the women taking up this campaign. They were careful only to

[1] using the example of WEN's Breast Cancer Campaign. Opinions are Morag Parnel's and not necessarily WEN's

consider reports and papers from reliable sources, those which were clearly referenced and, where possible, peer-reviewed or confirmed by further research, and were thought to be trustworthy. All research starts with a proposal or a theory to be examined, so it is useful to ask some questions such as - *by whom* and *for whom* and *for what purpose* is the research being carried out. We need to know something of the background to the project, who funds it, and if there are any special interests being served. All theories start with underlying assumptions, and these are not value free. Also, all theories are only temporary, until they are confirmed by the test of time or disproved by further information and insights. Above all, it is important to

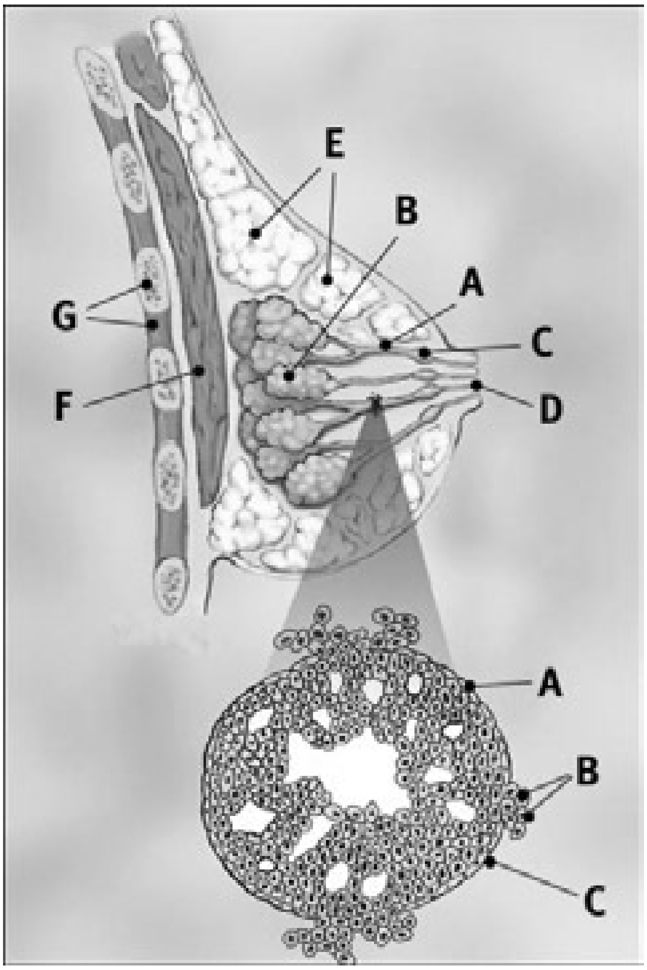


Figure 5 - Normal breast with invasive ductal carcinoma (IDC) in an enlarged cross–section of the duct.
(from www.breastcancer.com)

Breast profile:
A ducts
B lobules
C dilated section of duct to hold milk
D nipple
E fat
F pectoralis major muscle
G chest wall/rib cage

Enlargement:
A normal duct cells
B ductal cancer cells breaking through the basement membrane
C basement membrane

ask what it means to us in the context of our own lives, our experiences, our knowledge and our feelings. Is it relevant to what we need to know, - does it fit?

The breast cancer prevention campaign took off in 1995 with an 80,000 signature petition calling for primary prevention to be given a higher priority, and with Scottish Breast Cancer Campaign (SBCC) Post Cards to Members of Parliament. A National Cancer Action Plan was drawn up, with the support of MP Alice Mahon.

The next phase followed a joint meeting of WEN and the Scottish Breast Cancer Campaign, (SBCC) in Edinburgh. A woman in the audience questioned why she felt ill every time the crop fields next to her home were sprayed. Other women added similar tales and a decision to pool women's experiences was

taken. Thus 'Putting Breast Cancer on the Map' was born.
The objective was to ask women to draw their own maps highlighting possible links between their environments and breast cancer. While doing this we would build up a data base of information and resources, and create a grassroots network of people with a common goal. The ultimate aim is to have measures introduced that will lead to the primary prevention of breast cancer.

Women carried out their own research. They used their local knowledge to draw maps of their areas showing places, activities and installations which they considered to be possible sources of harm to health, along with known cases of breast cancer, where these could be collected. The mapping exercise was accompanied by a detailed questionnaire. Over 500 questionnaires and over 300 maps were completed and returned to WEN. Within this body of information is a real, alive and powerful message from women from Orkney to Land's End, showing concerns, perceptions, feelings, and essential and valuable knowledge of their environments and workplaces, and how they affect their lives. While WEN acknowledges the limitations of such a study, and it could only cover selected parts of the country where there were WEN members, nonetheless we should not underestimate its value. This kind of knowledge is too often wrongly dismissed by professionals and politicians. The findings certainly confirm that there is real cause for concern, and that we are right to press for further investigation and action.

WEN made a number of recommendations from the study on a) action to be taken, b) a range of proposals for further research and c) changes to workplace practices to protect women. It concluded that breast cancer is "symbolic of the state of our polluted environment" and that we need to "change attitudes of Government, the Medical Establishment and society at large to prevention, in the way that breast cancer is viewed, treated and politicised in the UK". The full report can be found on WEN's web site at www, wen.org.uk, along with the maps drawn by the women - entertaining, imaginative and informative! (see map 1).

This campaign is ongoing. WEN's researchers have covered topics from plastics to pesticides, carpets to cosmetics, toys to tampons, and much more, commissioning some of the research itself. Currently WEN is touring areas in the country with the 'Toxic Tour", passing on information of sources of toxic chemicals in personal care products, and holding discussions and workshops with women. Research for this was carried out by WEN along with US and Swedish women's organisations, resulting in the Report, 'Pretty Nasty', available from WEN's office, or from the WEN web site. Some things are indisputable: the fact that we all carry a body burden of more than 300 foreign chemicals, many of which are known or suspected of having serious consequences for our health and for the health of our children, and most of which did not exist before the 1950s. Of greatest concern are those that can be passed on to the developing foetus, and to the infant through breast milk. We must ask why, as this has been known for some considerable time, has it not long since prompted swift and effective action.

WEN's strength comes in no small measure from the way that women can come together and talk and share experiences. Women's concerns about their reproductive health and the health of their children are often the starting points for research studies and campaigns. The scope of these goes far beyond the original concern. In the case of the breast cancer campaign we can extrapolate the principles involved to include other cancers and other illnesses affecting men, women and children.

Confidence comes from working in collaboration with others and with other organisations who share our concerns. It is about making connections with people and between topics, and fitting it all into the big picture. We hope that WEN's Toxic Tours will be extended to other parts of the country.

Some specific obstacles encountered

In any campaign such as this one we will meet obstacles. The specific problems faced by the Breast Cancer Prevention Campaign are that while Government has readily accepted the role that personal lifestyle factors play in causing breast cancer, it has been reluctant to accept the major part played by environmental and occupational factors. In the Cancer Plan for Scotland, it is stated that *"prevention usually requires people to change their lifestyles"*, and that *"several forms of radiation and industrial chemicals have been linked with cancer. Most concerns in this area have been addressed and risks eliminated in terms of occupational or environmental exposure, such that their contribution to the overall cancer burden is now very small"*.

However, a small number of cancers related to such exposures still occur, for example mesothelioma as a consequence of past exposure to asbestos. Yet, depending on your source, environmental and occupational factors are variously quoted by researchers as giving rise to 50% to 90% of the risk, although one source put it as low as 6%. Personal and lifestyle risk factors are most frequently quoted as between 30% and 50%. These figures appear confusing and depend to some extent on what researchers include in these categories. When the 30% lifestyle figure was first publicised in the US, women took to the streets with banners saying "What about the 70%?". It is my belief that it is not so simple to separate personal and environmental risk factors. They are closely inter linked.

Also there is a tendency to confuse prevention with early detection, and to pass the responsibility for changing adverse lifestyle factors on to individual women themselves, with a bit of help and a lot of hectoring from professionals. Indeed, quite a nice little lifestyle industry has grown out of this. It by-passes the need for Government to challenge practices throughout the economy which are detrimental to health. We can therefore welcome the current European Parliament Draft Bill on Control of Chemicals, even with its shortcomings, as a significant step forward. It aims to deal with a few hundred toxic chemicals which can accumulate in our bodies, chemicals which we have been using every day and are known or suspected of causing cancers or of disrupting hormone systems.

Some general obstacles encountered

If we consider that science is about our knowledge of ourselves and our world and how the two fit together, then we can see that in different times, different places, different cultures, this body of knowledge will be different.

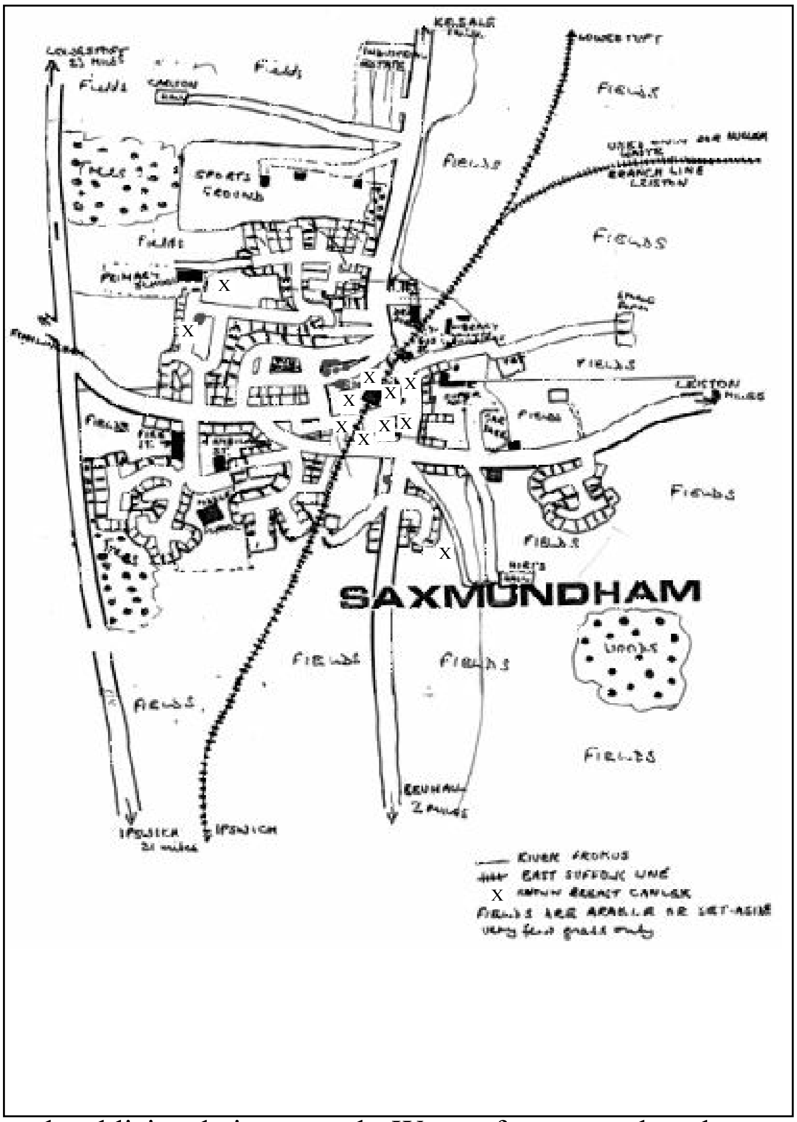
As it will have been acquired and interpreted in different ways, so it takes on a meaning that is relevant to the people concerned, for it is not just about objective external facts, but about our internal subjective interpretation of them. Science is heavily influenced by when, where and what kind of society it is that needs to ask and answer the questions arising. There are powerful pressures that will drive it towards promoting and serving the objectives of the current dominant groups in that society.

Within our Western culture, science has become more and more minutely specialised and fragmented, even within separate disciplines, so that not only do scientists not communicate easily with us, they often do not talk to each other across specialisations. This makes much of science more remote from us, and even from other scientists. It becomes difficult to fit it into, and find meaning for it, in the reality of our lives, and it fails to see the bigger picture. This has resulted in the seriously damaging side effects that we are all too aware of e.g. in nuclear technology, the chemical industry and genetic engineering technology.

We are led to believe that science is about seeking some kind of truth, and that scientists are authorities on a host of subjects. Indeed this is true of many scientists and their work, and where it is so, we get science that is valuable, exciting, captivating and beautiful. Science affects every aspect of our lives, yet we find that only carefully selected scientists are consulted on important political and ethical issues. Decisions that affect us all are made on the basis of their evidence, which may be very selective in what it presents, and may ignore or dispute other conflicting evidence. The kudos accorded to science also means that the views of such scientists can have a disproportionate influence on how we view the world. This would not be of such consequence, and would make it less difficult for us, if there was an open debate between scientists on the issues, but the field is far from level.

Mainstream science is supported, and increasingly controlled, by corporate and government bodies with access to most of the resources and publicity, and with an agenda too often driven solely by economic and political goals of 'wealth creation' and purely material gain. We were reminded recently by David Bellamy, speaking at the launch of the Independent Science Panel in London, of the Government White Paper of 1993 on Science Technology and Industry, of which Bellamy said *" Wealth creation became the acid test of relevance, seeing interaction on a much larger scale between scientists and businessmen in the day-to-day business of selling in a competitive market".*
We find more and more reports of interference in the conduct of science, in order to meet the demands of sponsors, funders and the market, to the extent of marginalisation, denying resources, pressurising to modify results, and even sackings of those scientists who will not compromise their integrity. While, without doubt, there have been some gains to some human beings from so-called 'instrumental science', it has left a legacy of serious problems as referred to above.

Fortunately, there are many independent-minded scientists with a holistic approach and outlook who make their work freely available to us, but they are being increasingly disadvantaged, and so have to work harder to pursue



Map 1 - Saxmundham

Over a hundred such maps have been collected, of how women view the environmental hazards in their areas and the links to breast cancer.

These maps can be veiwed on: http://www.wen.org.uk/health/Mapping/index.htm

This participant is making a connection between a cluster of breast cancers (X) and the adjacent railway line used for transporting nuclear waste.

and publicise their research. We are fortunate that there are still so many that we can turn to.

We can act now

We believe that we already have enough information to start to take action forthwith to clean up our environment and protect our health. However, we do need more research into the environmental and occupational factors in ill health, and we particularly need the great volumes of existing research information to be collected and collated, nationally and internationally.

The kind of research is important, and we can learn a lot from the inadequacies and disappointments of other studies, e.g. in the US, after years of campaigning by women, the government funded, ten- year long, $10 million, Long Island Breast Cancer Study Project left many women dissatisfied and angry. We can take heart from the achievements of the Women of Love Canal in their long battle to have action taken over their contaminated land and homes. We can see the advantages in the approach of the long-term Silent Spring Institute's Cape Cod breast cancer study, which works closely with and involves the community and those affected at all stages of the research programme.

We cannot wait for the 'proof' of cause and effect that some call for. In any case, when dealing with human health, it is neither possible nor ethical to conduct the trials or experiments to get this 'proof', even if we suspect that already we are all taking part in involuntary experiments without our knowledge or our informed consent. We must be prepared to act on the balance of probability and risk, and invoke the Precautionary Principle, and be Better Safe Than Sorry. There are too many examples of 'Late Lessons from Early Warnings' (publication of the European Environmental Agency).

We can take heart from the words of such as Albert Einstein and biologist Lewis Thomas. Einstein said that we should be on our guard not to overestimate science and scientific methods when it is a question of human problems, and not assume that only the experts have a right to express opinions on questions affecting the organisation of society. Thomas warned us that if we are to survive we need science, better science, not to manipulate and control, not even for more comfortable, easier or longer lives, but the kind of science that will increase our understanding of the world and our place in it.

7. References and Glossary

- Brumfiel, G. 2002. Misconduct finding at Bell labs shakes physics community. Nature 419, 419-421.

- Sumner, D. 2000. The limits and assumptions of Science, in Science and Environmental Decision Making Huxham, M. and Sumner, D. (Eds.) Prentice Hall, Harlow.

- Pawlowski, B., Dunbar, R.I.M. and Lipowicz, A. 2000. Tall men have more reproductive success. Nature 403, 156.

- Schneider, S. 2001. What is 'dangerous' climate change? Nature 411, 17-19.

- Stelfox, H.T., Chua, G., O'Rourke, K. and Detsky, A.S. 1998. Conflict of Interest in the Debate over Calcium-Channel Antagonists. New England Journal of Medicine, 338, 101-106.

- Merritt, J.Q. and Jones, P. 2000. Science and Environmental Decision Making: the Social Context, in Science and Environmental Decision Making

- Huxham, M. and Sumner, D. (Eds.) Prentice Hall, Harlow.

- Hirotsu, Y., Suzuki, K., Kojima, M. and Takano, K. 2001.Multivariate Analysis of Human Error Incidents Occurring at Nuclear Power Plants: Several Occurrence Patterns of Observed Human Errors. Cognition, Technology and Work 3, 82-91.

Glossary

Control - the part of an experiment or survey which attempts to keep all factors the same, for the purposes of comparison with what is being studied

Data - useful pieces of knowledge obtained by measuring or collecting (singluar = datum)

Directive - A piece of European Union legislation which, whilst having no direct power to implement, requires member states to implement their own legislation.

Duduction - A process of thought by which data are obtained from the world through the senses

EPA - Environment Protection Act

Hypothesis - An idea which appears to explain the data, which can be tested.

Hypothetico-deduction - A scientific method which involves a process of obtaining data, then suggesting an explanation, then obtaining more data to test the explanation

Induction - A process of thought by which data are obtained from logic, rather than through the senses.

LAPC - Local Air Pollution Control

Null hypothesis - An idea which appears to explain the data and can be tested, but which experiments are designed to disprove.

PPB - parts per billion (used for trace elements)

PPM - parts per million (also used for very small concentrations)

Probability - The likelihood of something occurring, in comparison to chance. Usually measured by a percentage of confidence.

SEPA - the Scottish Environment Protection Agency

Trace element - something which is found in minute but measureable quantities.