Soz Präventivmed 1992; 37: 41-44

0303-8408/92/020041-04 $1.50 + 0.20/0

Editorial
Epidemiology and environmental risks

Within the animal kingdom the human species has an unequalled capacity to live and to breed in a wide range of environmental circumstances. We are able to maintain internal homeostasis in the face of very varied lifestyles and diet; and (until now, at any rate) our intelligence has enabled us to control our environment more efficiently than other species. But recently the pace of technological development has been producing rapid and unprecedented changes, affecting not only how we live but also the chemical and physical environment around us.

The net effect on health of these changes has been strongly beneficial: we are longer-lived and less subject to physical disease than ever before, and cancer trends generally are not alarming – despite our careless habits with noxious chemicals. Our towns no longer smell of sewage or industrial fumes, and when you fly over a city at night, the lights are not hidden by smoke.

Despite these impressive advances, the last decade has seen a remarkable loss of public confidence in our environment. Belief in the virtues of fresh air has given way to widespread alarm at the dangers of passive smoking, of too much (or is it too little?) ozone, and the unseen presence of radiation. We have lost confidence in the safety of our food lest of contain Listeria, or harmful additives. Riding on the back of all this public concern, environmental medicine has entered the arena. If you want your grant applications to succeed then this is the area to choose for your research!

It is not an easy field in which to work: science and emotion are intermingled. On the one hand there are serious scientific grounds for concern, and a need for objective evidence; at the same time neither the public nor investigators find it easy to be dispassionate. There is often a perverse preference for alarm rather than re-assurance. "They are poisoning us" is a favourite theme of the media, because that, it seems, is what people want to hear.

The Sellafield incident illustrates many of the difficulties. In our report we concluded that over a 20-year period there had been an excess of five cases of childhood leukaemia in the neighbourhood of a nuclear reprocessing plant. Many parents have concluded that they do not want to live there because the environment contains a hidden threat: both radiation and cancer set off loud alarm bells. In fact, the chances of survival for the local children are better than in many inner city areas, and the excess risk of death from leukaemia is probably less than the urban risk from road traffic accidents; but we are not very successful in explaining risks to the public in a way that helps decisions.

The Sellafield enquiry came about because the local television company, looking around for a story, discovered this little cluster of childhood cancer. It is scientifically hazardous to draw conclusions from data which themselves generated the question, but yet such reports have to be investigated. They are increasingly common. Mrs. X writes to me to say that two neighbours have just developed cancer, and on enquiry she finds that seven other cases of cancer have occurred recently in her street; and what am I going to do it? Some alert doctors found that in a little village in the middle of England there had been 12 cases of Crohn's disease. Those who encounter such clusters are naturally impressed; but we have to remember RA Fisher's remark, that "the one in a million chance will happen with no more and no less than its expected frequency, however surprised we may be when it happens to us".

The Sellafield experience suggested that there probably was a real local excess of childhood leukaemia, but confirmation had to await later similar reports from around other nuclear sites.

The problem of a time lag

Any enquiry into an environmental risk of cancer is likely to be looking at the effects of exposure many years ago, and no one can ever know the actual doses which individuals received. At Sellafield we were given information of the total radioactive emissions from the plant, but the exposure levels of the children were a matter of speculation. The radiation experts on the committee calculated "best estimates" and they concluded on theoretical grounds that these could not have caused any major excess risk: "it couldn't have happened, so it didn't happen". The epidemiologists on the other hand were pragmatic: "we can't explain it, but there is a problem here". (This contrast in thinking runs all through medicine.)

From experience at Sellafield and elsewhere I have become aware that in investigating the environmental health impact of large industries (especially if they have military interests) we are confronting the seat of immense economic and political power. Their natural reaction to threat is defence; and we doctors are no more than an innocent and ill-equipped David confronting Goliath, the well-armed and experienced giant.

The Sellafield enquiry left us with no explanation of how radiation could have caused leukaemia among local children, but new light has now been shed by the subsequent case-control study of Gardner. This links the occurrence of childhood leukaemia with paternal exposure to radiation during the months before conception. Regardless of whether this finding can be confirmed by further studies, it is a mind-widening hypothesis. It teaches us that the explanation of disease in one generation may need to be sought in the environment of the parents.

Where (as may have occurred at Sellafield) the risk originates with genetic damage to the sperm, then the relevant paternal exposure will have been in the few months before conception, since sperm do not live long. The situation is different if transmission is maternal, for the ova shed during reproductive life were actually formed when the mother herself was *in utero*. Thus, for example, the chromosomal derangements which cause Down's syndrome originated when the mother was herself a fetus; and if we seek an environmental component to its aetiology, then we need to look a the grandmothers's experience during her pregnancy.

The problem at Sellafield had been around for years before it was discovered. This was not through negligence but because routine statistics are not able to reveal the experience of small areas; and when the problem is very localised (as it was in that instance), the local effect may be drowned in the statistics of a larger area. This concern led us to create the Small Area Health Statistics Unit at LSHTM. In this unit we hold post-coded mortality, cancer, birth and congenital malformation data for the whole country. An elaborate computerised system relates this to the corresponding population data, so that we are now able very quickly to produce disease rates in specified zones surrounding any named point source. Recognition of a hazard to local residents should be more readily detected in the future. With this system you have only to name the map coordinates of a pollution source, and the diseases and time periods of interest, and it will swiftly produce observed and expected event rates for specified zones around the plant.

Our early experience with the new system has taught us three important lessons. (1) The number of events around a single site is generally too small to support any useful conclusion. This problem can be dealt with by aggregating the findings from a number of similar sites. (2) The problem of all epidemiological enquiries based on mortality or cancer incidence is that they tell us about the risks of a world which in most cases no longer exists, because industrial processes and regulatory controls are all changing so fast. The utility of our enquiries would be vastly strengthened if only we could obtain national morbidity data, post-coded. (3) We quickly discovered how little is known about small-area variations of disease rates. In particular, people who live around an unpleasant industrial site are not a random sample of the population, but rather those who have no choice. This demographic distortion means that many diseases are commoner in such areas, even apart from the effects of pollution. We have had to develop methods of adjusting for these local demographic characteristics, using small-area census data; and we are now evaluating the efficiency of our adjustments.

Weighing up risks and taking appropriate decisions is a part of everyone's daily life, as well as of medical practice. Curiously, the whole process tends to become more difficult when we are confronted with statistics. We find it easy to judge when to overtake another car on the road, but it would become harder if we were given a precise probability of incurring a fatal accident. People are not used to interpreting very low order risks, such as that of cancer in the neighbourhood of a radiation source: the nature of the risk then tends to be more influential than its size, which is not logical. We need to find ways of describing risk which carry more meaning than the jargon of epidemiologists.

Lung cancer in men exposed to asbestos and/or cigarettes, relative to the risk in the doubly non-exposed are increased in both non-smokers and smokers, but asbestos increases risk five-fold. However, the *absolute* increase in risk is many times greater in smokers. Asbestos is far more dangerous to smokers, but we would not have realised this had we only considered *relative* risk. All policy decisions should be based on absolute measures of risk: relative risk is strictly for researchers only. Unfortunately most aetiological research is content with measures of relative risk.

The distinction is important. For example, the cost/benefit ratio for building modifications to houses with a high radon concentration is likely to be far less favourable in non-smoking households.

In the great public health movement of the last century the emphasis was on prevention through action at the level of the community, but in this century the emphasis has shifted towards a concern for individuals. Aetiological research has been dominated by case-control and cohort studies, whose purpose is to discover how sick and healthy individuals differ: they identify risk factors, and this enables us to take preventive action in high-risk individuals.

An individual-centred concern is naturally attractive to clinicians, who deal with individual patients. It is also the focus of interest for molecular biologists and other laboratory workers, who investigate the mechanisms of disease in sick individuals. In the climate of today's medical thinking it has become more difficult to consider the wider viewpoint of public health action.

In environmental medicine attention has been concentrated on the microenvironment – the individual's local situation. Occupational physicians keep close watch on the heavily exposed; personal sexual practices are seen as the determinants of AIDS and cervical cancer, and they are the target of preventive action; coronary risk factors identify those who need help in order to avoid a heart attack; and so on.

The guiding principle of environmental control has been that no one should be exposed to an unacceptable risk. It is only individuals who can sue in the law courts – communities have no rights in law; and it is individual scandals which the news media like to headline. So, provided that no individuals are exposed to conspicuous or unacceptable risk, everyone can relax.

This viewpoint influences control policy in a number of critical ways. Doctors are more concerned about multiple or high-dose x-rays to an individual patient than about the total dose to their patients as a whole. Occupational physicians take steps to monitor and limit toxic exposure of individual workers. Factory chimneys are made tall enough for emissions to be spread thinly and widely, so that individuals will not complain. (Tall chimneys do not, of course, reduce the total emissions.) Environmental health experts identify "critical groups" of the most-exposed individuals (for example, the amount of radioactivity ingested by those who are very fond of shell-fish), and they ensure that their dose is not unacceptably high. But it may be the total population burden which is critical! The shape of the exposure-response curve is critical for planning a control policy

We are witnessing a proliferation of regulations which define the maximum level of exposures – for the workplace in industry, for food additives or contaminants, impurities in the environment or water supply, and so on. It is not always clear whether the standard is supposed to correspond to a threshold, below which there is no risk; or whether there is no threshold in the exposure-response curve and someone has decided what level of risk is acceptable.

We need to be more honest in admitting the limited power of our studies to identify these critical differences in the nature of the risk relationship. It was recently estimated that a case-control study, to distinguish whether the relation between radon exposure and lung cancer was linear or curved, would need 24000 cases!

The radiation experience of employees of the UK Atomic Energy Authority of cumulative life-time dose illustrates that the policy of 50 rems (500 millisieverts) as the upper limit of what any worker should incur, was in general excellently observed: few workers exceeded the limit, and only 8% of the total dose arose in this group. This looks reassuring.

Health policy in this area is based on the assumption that the relation of radiation exposure to cancers is linear and threshold-free. From this it follows that the distribution of doses also represents the distribution of radiation-induced cancers; and suddenly the whole implication has changed. The unacceptably-exposed individuals do indeed have a personal problem; but because there are so few of them they account for only a very small part of the total problem or radiation-induced cancers. Nearly all of this "public health" problem arises from the large numbers of workers with small exposure and inconspiciuous personal risk. This is one instance of a widespread principle: many exposed to a small risk generate more cases than a few exposed to a high risk. In all such situations it is the total dose falling on the whole population which determines the burden of health effects, and it is then the total dose which particularly needs to be controlled.

If it is only high doses that damage health, then a policy of preventing high individual exposures is sufficient; but if there is no threshold effect and even low doses carry some risk, then it is total emissions or total population exposure which matter, with quite different implications for control policy.

Despite the large size of our studies of radiation workers (40000 workers), the confidence interval around the risk estimates was very wide, ranging from zero at one extreme to an upper limit which would imply that the ICRP safety limit could be 15 times too low.

The lesson is unpalatable but important: the shape of the dose-response curve at low levels of exposure is critically important, but the power even of the largest studies is quite insufficient to determine it. This applies not only to radiation but also to many chemical exposures. We must therefore learn to live with uncertainty.

This uncertainty applies to many environmental policies. There is, for example, no substantial positive evidence that fluoridation of water supplies will cause cancer. Equally, if it did cause (say) 50 extra cases of gastric cancer annually in a country, there is no way in which that could possibly be detected. The implication of such uncertainties is not that we should never take risks: that would imply never using a motor car, or going to a doctor. Rather, when environmental policy decisions are debated, the balance-sheet of gains and losses should include the uncertainty limits of each major item, as well as allowing some place also for the unforeseeable consequences.

The dogmatic certainty of experts is unforgivable. After every environmental disaster the immediate reaction of the authorities is to re-assure the public – even before they know the facts. After the Chernobyl incident there were immediate reassurances from our government scientists that "This could not happen here". Further, the experts on nuclear power have issued precise predictions of the expected frequency of accidents leading to meltdown, implying a belief that all contingencies can

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be foreseen. They need to be reminded of the important dictum, that *you can't exclude the possibility you haven't considered.*

Nuclear power generation offers an attractive but threatening alternative to dependence on fossil fuels. Under normal operating conditions the health risk to employees and to local residents is extremely small, with damage to health and the environment being certainly much less than from mining and burning coal. The anxiety arises from two other directions, namely, disposal of radioactive waste and the possibility of a disaster.

National policies on building nuclear power stations were not restrained by any concern with waste disposal. The responsible approach would have been to limit production of waste to what could be safely disposed of; but this has never been the policy of the governments concerned, and so we now have the legacy of a large accumulation for which safe methods of disposal do not yet exist. Current planning envisages burial, using encasement materials (steel and concrete) which, it is thought, are unlikely to start leaking within the next 50 or 100 years. This shows scant regard for future generations, since the half-lives of some actinides are measured in hundreds or thousands of years.

Even more alarming is the extremely small, but still real, possibility of an immense disaster: in a crowded country such as England a melt-down in a nuclear power plant might make it necessary to evacuate the whole lot of us!

We are faced here with new kinds of issues in decision-taking. We are used to considering risks that are known, not very remote, and of comprehensible size. We must now learn how to take account of risks that are unquantifiable, and either cumulatively important but remote in time, or else of tiny probability but immense threat.

Doctors and other medical scientists are responsible for being constantly on the look-out for untoward effects of the complex and violent changes which our environment is now experiencing. From what we have seen so far, the picture is in the main surprisingly re-assuring; but important effects on health could easily be missed, and "have not noticed" must never be mistaken for "is not there". Medical scientists also have a key role in communication, by explaining and interpreting the evidence to an anxious – often over-anxious – public. That public has learned to mistrust authority, which is rarely disinterested; doctors should seek to earn a place as scientifically informed and impartial custodians of the public health.

Finally, it would be good if in the future the making of environmental policy took more notice than in the past of health issues. We should be the nation's expert advisers on this important component of its difficult policy choices. It is then up to society, through its chosen political representatives, to decide the balance of health versus social and economic benefits. Medical experts do not carry the ultimate responsibility for the nation's health, but at least we should seek to ensure that decisions which affect health are well informed.

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