CHAPTER 2

The Role of Science in Environmental Policy

A. STEPS TOWARDS A POLICY

Successful action on an environmental issue normally demands that four conditions be met:

(a) there is adequate qualitative and quantitative knowledge about its causes and trends or the means to obtain that knowledge;

(b) the issue is recognized as a genuine environmental problem and sufficiently important to arouse concern;

(c) there is social and technological capability to carry out essential action effectively;

(d) there is sufficient determination and resources within the community to make the action succeed.

It is evident from this analysis that while scientific information is essential, successful action demands more than science and scientists can alone contribute. This is recognized in the analysis of assessment of environmental risk prepared by SCOPE as a part of Mid-term Project VII.

The role of the scientist in this process is first to submit the problem to analysis, defining and clarifying its exact nature. A second step should be the quantitative prediction of the scale of the impact, both in environmental and social terms, and including a specific indication of uncertainty. A further logical step involves the development of alternative strategies for dealing with the problem and assessing the costs and benefits of each. This third step has three components:

(a) evaluation of available technology;

(b) statement of options;

(c) discussion of the implications of the options for environmental planning decisions.

Clearly the role of the scientific community is most important for the recognition and definition of issues and becomes less relevant in the final stage of executive action to carry out a management choice.

Environmental issues to which science can make profound contributions, may be grouped in three categories:

(a) those solved successfully by the application of existing scientific knowledge;

(b) those which existing knowledge could solve but where social or economic factors limit action;

(c) those requiring more scientific knowledge.

An example of the first category is provided by many communicable diseases. There are countries in which a number of these have been so successfully overcome that they are no longer regarded as environmental issues – even though they remain among the major problems of environmental health in other parts of the world. In many cases successful action has come not only from the direct application of biomedical knowledge but through higher standards of public hygiene and housing, as a more or less indirect outcome of social development or better nutrition. These improvements have made a major contribution to the solution of population growth problems. These diseases also illustrate another need: continued scientific vigilance to detect new hazards from the infectious agents involved, arising for example from modified resistance in man and other target organisms.

The second category includes many examples where the application of scientific knowledge has produced substantial benefits but on a limited scale. Wider and more beneficial action depends on social determinants and choices. For example, integrated pest control could be more widely applied, with consequent reduction in the environmental hazards due to excessive pesticide application, but is inhibited by the high costs and effects on patterns of industrial investment. Fluidized bed desulphurization can increase combustion efficiency in coal-burning power stations and reduce pollution, but is nonetheless being neglected because of the economic cost of converting existing installations. Many cities contain large blocks of high-rise flats having designs that offer a less than ideal social, ecological, and psychological environment for their inhabitants, but social and economic factors inhibit their demolition, and in many towns such blocks are still being built.

It is evident that the highest priority for further research should be given to problems where lack of scientific knowledge is the limiting factor. Among the areas which may merit priority treatment are the study of natural processes, which must be understood before one can begin to analyse processes perturbed by man; the search for new energy sources and more economic energy transformations; the development of more productive and efficient man-managed biological systems, without increasing the energy subsidy to them; the protection of soil from deterioration through misuse or pollution; the refinement of methods of improving the application of scientific findings; and the development of better methods of detecting, evaluating, and preventing risks to man, other organisms, or the processes of the biosphere.

It is equally evident from this analysis that it is wasteful to use scientific investigations, including basic research, as a 'displacement activity'. Many problems are capable of easement, if not of solution, using existing knowledge – assuming that socio-economic conditions allow the use of this knowledge and that the social will is there. If a Government is not prepared to act, but judges it expedient for some action to be manifest, there is a temptation to fall back on a scientific enquiry or study to explore those parts of the problem that are least well understood, or to 'reappraise' the whole. Such actions can be pointless and wasteful of expert resources. Before studies are undertaken, it is essential to assess whether the limiting factor is genuinely lack of scientific knowledge or a lack of social determination and response. If it is the latter the fault may lie in the systems of communication between scientists and policy-makers, and the onus may lie on the scientists not to do more research but to present their knowledge in a clearer format, suited to the policy-makers in the community. The scientist has a responsibility not only to acquire knowledge but to communicate it – to other components of the community as well as to his fellow professionals. This is the dominant theme of Project VII, in the Mid-term Programme of SCOPE.

B. THE RECOGNITION OF PROBLEMS

The sequence for solving environmental problems clearly demands collaboration between scientists, economists, legal experts, sociologists, health authorities, engineers, administrators, and the public. The essence of this co-operative process is communication. The efficiency of any problem management process must rest first on its being in touch with events in the natural world through monitoring and surveillance systems, and events in society through a monitoring of the channels of communications within the general public and within Government. Communication between the problem definer and other components of society is equally vital and at the end of the exercise, action on the problem has to be justified to those whose job it is to undertake the overall balance of social policy which must mix economic, environmental, technological, and other social factors. There are numerous examples of how this pattern has worked through in practice.

Very commonly, organizations that are expected to detect problems act largely in response to situations first made evident through unexpected environmental change (for example, through unexpected deaths among wildlife or unexplained sicknesses in communities) highlighted by the mass media. In the past this has been the predominant cause of problem recognition and the one producing most dramatic responses. Examples include:

(a) airborne sulphur and smoke, associated with 3,000 to 4,000 excess deaths in the London fog of 1952–53;

(b) methyl mercury as a cause of 'Minamata disease' in Japan;

(c) polychlorinated biphenyls involved in food poisoning from contaminated rice oil in Japan or associated with the deaths of about 12,000 sea birds in the Irish Sea in 1969; and

(d) persistent organochlorine pesticide residues associated with declining populations of predatory birds in Europe in the 1950's and 1960's.

It is important that scientific bodies such as SCOPE do not simply respond to requests from governments for advice and analysis, but act to identify prospective problems through the processes of search, recognition, definition, and analysis. Five separate ways of identifying problems have been noted:

(a) convening an expert meeting, the quality of whose results depends critically on the number, ability, and interactions of the experts present;

(b) feedback from experience, whether through national agencies or otherwise; it being recognized that action by a competent national agency is in itself an adequate testimony to the existence of concern;

(c) deduction from first principles by the scientific community: a highly desirable and insufficiently exercised process;

(d) observation of an unexplained event like the illness of people or the mass deaths of wildlife. It is undesirable that this be a main means of problem recognition but probably inevitable that it will recur from time to time however gifted the scientific community is in its logical deductions;

(e) deliberate definition of problems through research, the screening and testing of new products, and monitoring including the systematic monitoring of human health. This is a highly desirable way of recognizing problems, and a method which hopefully will increasingly prevail as new questions arise.

The five approaches cited above fall into two groups. Approach (c) is the theoretical one; (b), (d), and (e) together constitute practical means from which most comtemporary problem recognition comes. Commonly, approach (a) is used as a first stage in evaluation of issues noted through one of the other channels.

In the past, many organizations seeking to define environmental problems have indulged in cataloguing exercises. They have brought together groups of people with expertise in particular fields and in a relatively brief period have listed what seemed to those individuals as being of particular importance. Often such meetings involve the uncritical acceptance of the expertise of the individuals present because there is little time to test the assertions of any contributor by a studied debate, or to obtain endorsement by referring the potential problem to a wider circle of knowledgeable specialists.

Such current processes of problem recognition thus have certain potential drawbacks. They may involve conflicts of expert assertion. They tend to have a subjective element weighted to the standing of recognized authorities. It is difficult to quantify the process. It must be recognized that sampling problems are as acute here as in many other of the natural environmental fields. Very often a logical sampling approach has not been adopted. For example, if the expert meeting is to be used as a means of problem recognition, it would be sensible to set up a series of such meetings deliberately designed to define the variability of opinions, and more use could be made of scenario and judgmental methods which are in course of refinement. A stratified random approach could be made using the various groupings of scientists as units in the stratification. For example, one could select at random a series of members of various learned societies rather than invite those societies to nominate experts. One drawback of such a system would be that it would by-pass the traditional process of screening capability and knowledge.

The result of this traditional process is, however, the suppression of the variability in the views of the scientific world and its replacement by something akin to a weighted average, through the statement of the opinions of those in the national scientific community who happen to have at the particular time the greatest influence on established national thought. SCOPE might well take this whole question of the sampling of the views of the world's scientific community in problem recognition seriously and look at the techniques available, recognizing that it is at least as important to define the range of variation in opinion as to settle to an average view.

Stratification could similarly be achieved using the different international agencies which have been concerned in problem recognition. For example, there are groups concerned primarily with conservation which tend to adopt an environmentalist or protectionist view: examples include the Friends of the Earth, the Conservation Foundation, and the International Union for Conservation of Nature (IUCN). There are intergovernmental organizations in the developed world, such as the Organisation for Economic Cooperation and Development (OECD), the European Economic Community (EEC), or the Economic Commission for Europe (ECE). There are global intergovernmental organizations with varying degrees of specialization such as the United Nations Environment Programme (UNEP), FAO, the World Health Organization (WHO), WMO, or the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Finally, there are industrial groups concerned with particular aspects such as the petroleum or iron and steel industries. It would be possible to superimpose the lists of problems recognized by the different organizations and see how far they agreed. A recent study of this kind by the senior advisers to Governments on environmental problems in ECE suggests that there is considerable agreement, but the effect can only be to stress the recognized problems and under-reflect the cryptic ones. Ten years ago it is unlikely that this exercise would have revealed any potential problem over polychlorinated biphenyls or chlorofluorocarbons, yet both would occur on any listing compiled by this method today.

Until the recent sessions of the United Nations Governing Council on Environmental Programmes, international evaluations of environmental problems reflected, to an overwhelming extent, the experience of developed countries, although the environmental problems divined by developing countries inevitably differed. Many such countries not only have pressing local problems of a kind no longer acute in developed nations, but in consequence place less emphasis on slow and relatively ill-defined global changes. This has been one of the principal lessons to the world community from the Stockholm Conference, and has, incidentally, led to the inclusion in the SCOPE Mid-term Programme of a project on human settlement and another on the problems of arid lands irrigation, both of high priority in developing countries. The full range of problems of the environment will not be recognized, and still less solved, unless the diversity in man's approach to the environment is taken into full account.

The situation is aggravated by the imbalance in the distribution of the world's scientists. For example, at the International Botanical Congress held in Leningrad in 1975, it was noted that the tropics hold 70 to 90 percent of the plant species on earth, but 90 percent of botanical taxonomic work is done on temperate plants. Tropical species are becoming extinct before they are discovered, as forests are cleared for cultivation, with a consequent potential loss of important sources of food, fibre, or drugs.

At the same time, the natural preoccupation of developing countries with the immediate priorities of development should not lead to the neglect of the lessons which are apparent in countries which went through those processes of development at an earlier period. There is a need to put environmental planning on a sound footing in all countries. There are concrete examples showing that it would be very dangerous to overlook the environmental hazards, for example to soil fertility, that could result from unwise development.

C. THE EVALUATION OF PROBLEMS

Even after a list of potential problems has been compiled, relative priorities cannot be assigned without analysis and quantification. This is by no means easy, as a glance at the diversity of the problems in the priority areas defined by the United Nations Environment Programme (UNEP) shows. Each has a different socio-economic mix. SCOPE may be mainly concerned with the scientific components but cannot evade the blend of other considerations that intrude.

These components may be seen as a series of factors, sometimes varying quite independently of one another, sometimes highly interactive but always at some point on a scale from high to low. Each problem will be a combination of these. Among the criteria that can be recognized as important are the following:

(a) The nuisance scale of the problem. Is it capable of causing serious harm to individuals or populations at risk via sickness or death? Or is it less severe, but nonetheless a serious nuisance, e.g., noise or smells, or less severe still, e.g., visual ugliness. It is important to recognize that every society, depending on socio-economic or cultural considerations will scale problems differently because of inherently differing value-judgment systems.

(b) Perception of problems. At one extreme, the problem may be thoroughly and widely perceived, grading through to a problem which is being missed completely. Moreover, there may be differences in the perception of different sectors of the scientific community, and there is likely to be even more divergence within the general public, differently influenced by the communications media of press and television. The Government sector may well be at yet another point on the scale. The result is that there are many gaps in understanding. These may make each sector act differently, in response to their own particular level of perception of the problem. Funding for further work on the problem may be hard to obtain if the scientists are too far ahead of the public or government. The public may even appear to be complacent, e.g., over traffic accidents or smoking and health risks. Conversely, funds may be squandered on trivial problems or the scientific community may appear indifferent while the public is deeply concerned, e.g., over the medical significance of lead emitted from vehicles.

(c) Ease of recognition. Is the problem readily monitored directly by the human senses as in the case of noise or squalor? Or is the problem cryptic, requiring sensitive instruments and complex assessment procedures to recognize and define it, e.g., radiation hazards?

(d) Quantitative measurement scale. Some problems are easily measurable, e.g., many potentially harmful chemicals in air or drinking water. Others defy quantification, e.g., unpleasant tasting water or tainted air. The quality-of-life concept is a readily grasped reality, but at present it is impossible to measure on a scale common to all sectors of human society.

(e) Space-time scales. Is the problem global, regional, or local? Is it truly homogeneous or confined to separate 'hot spots' of greater or lesser frequency? Are these local problems increasing so greatly in number and extent that they are becoming regional or even global? Is it a long-term or short-term problem, and are its effects largely irreversible or evanescent when the causal circumstances are stopped? Conversely, how long is the response time after the causal circumstances begin to operate? These are very important considerations which separate very severe from trivial problems and may cause us to think carefully before taking an environmental risk.

(f) Ease of solution. Can the problem be solved readily or is it intractable?

These and similar considerations affect our assessment of what constitutes a problem and how much risk we attach to it.

The exact point along the scale will be different for each of the above criteria and often difficult to measure. A useful way of assessing the risk may be to get some idea of the range of risk by combining all the most unfavourable estimates for each criterion to give an extreme pessimistic assessment of the problem. Conversely, the most favourable forecasts added up, provide the most optimistic view. Within this range is placed the assessment derived from the most probable estimates for each criterion. Defining the range of uncertainty in this way helps us to avoid expensive management errors. Additionally, societies will weigh these component criteria differently and thus arrive at a result more responsive to their own regional environmental needs.

Many environmental observations are mis-interpreted because of an ignorance of environmental processes. For example, allegations of oil pollution on some coasts may in part be due to a confusion between oil scum on the rocks and the black, universally distributed lichen *Verrucaria* which is naturally present in just this situation. Similarly, a concern over oil in the marine environment is largely justified because of its impact on seabirds and not because of any demonstrated adverse effect on aquatic life, and yet the universality of oil pollution in the sea is widely taken as a threat to marine ecosystems. Appreciation of the significance of such substances as lead, mercury, or sulphur dioxide in the environment must depend on an understanding of the natural levels and cycles of these materials. Very often the detection of an environmental contaminant may be a reflection of the quality of the analytical techniques. It may also be valuable for the insight it gives into an environmental process rather than proof of a local hazard. The discovery of DDT in penguin fat was an admirable illustration of this since it is well below the level at which any adverse effect can be expected and because it established the global transport of organochlorine residues.

In the assessment of whether a problem is real, it is necessary to know about the natural or background situation, the sources of the effect which is regarded as posing a problem, the natural corrective mechanisms that would operate if the perturbation ceased, the additional environmental systems that might be disturbed if the problem remained, the responses of the various components of the environment being affected, and the scale in space and time. There is a particular role for science in the assessment of the risks resulting from any action that changes the environment. For example, to make such an assessment for a chemical contaminant, it is necessary to know quantitatively the amount transported from the point of release to the receptor through physical pathways and food webs and the probability of effects in the receptor per unit dose. By multiplying this probability by the size of the population at risk, an estimate is obtained of the total resulting harm. Analogous processes can be used to assess the likelihood of risk from physical alterations in the environment.

The evaluation of the significance of a problem is greatly aided by the existence of a monitoring system. This may be physical or chemical, measuring pollutants or indicators of land use patterns, or biological, following the distributions or performance of 'indicator species' which by their changes may alert us to hitherto unsuspected factors. Many monitoring systems have not been well designed in the past and much more attention could usefully be given to the sampling pattern they adopt. For example, many of the world's monitoring systems take measurements at points chosen for convenience rather than because they provide a network that adequately samples the range of environmental variation or the range in the variation of human activities within the area under review. The spacing of sampling in time is also very frequently insufficiently considered. All monitoring schemes should sample without bias the variation in environmental phenomena using, if at all possible, the same basic sampling philosophy so that the results of environmental, chemical, and biological surveys can be interrelated. Too many monitoring systems consider single variables in isolation, whereas it is the establishment of correlation between variables and organisms that is often the most valuable in suggesting the existence of a problem and also in defining the rate of change in a trend. The most important function of monitoring for pollutants is to obtain data from which the doses received by critical receptors may be calculated.

The final issue in problem evaluation inevitably involves weighting, value judgment, and social responses. These must take account of the fact that a problem in one country may not be regarded as of sufficient severity to justify action in another. For example, in many parts of the world, new land is being developed for agriculture using methods which would be regarded as inappropriate in more affluent societies, yet the pattern will be largely determined by economics, and local administration may have difficulty in recognizing that the current practices, which may be all that their socio-economic systems can sustain, create problems. Very similarly, the value that is placed on wild life is socially determined, and the attitudes which prevail in Northern Europe and North America may seem quite inappropriate to developing countries with no tourist industry and an urgent need to open up the forest for grazing and cultivation. The word 'problem' is itself emotive: what we are really dealing with is choice and the need to inform that choice scientifically. The costs and benefits of alternative actions are rarely absolute: even the development of fertile land for agriculture has disbenefits, and the important thing is to draw up the balance sheet in as dispassionate a manner as possible.

Inherent in problem definition are such concepts as 'acceptable risks' and 'the use of the environment as a resource'. It must be emphasized that all human activities which impinge on the environment are likely in one way or another to alter the pattern of factors which in turn determine human survival and happiness. It would be unrealistic to expect that absolute safety could be the outcome of any human policy – but relative safety and maximal longevity remain an understandable goal! What is needed is a balancing of costs and benefits of individual actions including environmental protection policies, so that the maximum net benefit accrues. It must also be recognized that these points of balance will differ from country to country. For example, in developing countries with a mean expectation of life of only around 40 years in some social groups and low standards of housing, medicine, nutrition, and sanitation, the chief concern will obviously be to increase the quality of human settlement and the standard of living of the individual. Such a community may well be willing to accept as a consequence of full employment the generation of environmental contamination which may curtail life toward the end of the human span. If the result of industrial development is to raise the expectation of living from around 40 to around 60 years some chronic effects that are not manifest until the late 60's may be tolerable in a fashion that would not prevail in North America or Western Europe or indeed in the developing country itself once it had moved forward from the first phase. Similarly, countries with the urgent need to improve the standard of human life may embark on programmes of environmental development which cause consequential losses in wild life and natural beauty that would not be acceptable to developed countries.

There is clearly a dilemma in this situation which is essentially linked to time scales. Countries that have become developed cherish many of the features which tend to be disregarded and have low value put upon them in the early stages of development and regret with hindsight the losses that occurred early in the process. It is predictable that similar attitudes will emerge in developing countries that may be inclined initially to sacrifice some of the luxuries of environmental quality for the necessities of adequate health and employment. The timing of environment protection policies needs consideration in relation to the timing of development and the ways in which the acceptability of risk changes as communities develop and priority goals are attained.

Linked to this question and involving fundamental biological properties is the extent to which environmental change is reversible. For example, the contamination of a freshwater body whether by excessive nutrients or by toxic substances leads to changes in its flora and fauna. These are rarely completely reversible, if only because the nutrient status of lakes tends to change as they become filled by sediment and receive inputs from the surrounding catchment. The process of eutrophication can thus be natural, and its acceleration by man is unlikely to be wholly reversible. Processes of removal of natural forest or loss of soil are only reversible on a long time scale, if at all. On the other hand, there are many examples in developed countries of the restoration and rehabilitation of degraded ecological systems, for example by reafforestation and erosion control. All such processes involve a considerable management effort and there are no models which at the present time adequately express the relative costs of rehabilitation as opposed to the cost of prevention of damage in various situations. It may be desirable for these to be developed.

There is another divergence of view between those who believe that it is normally wrong to allow any avoidable waste material to be discharged into the environment or any avoidable environmental change to take place and those who believe that the capacity of the environment to take in waste products and render them harmless is a natural resource which it is legitimate to use but not to misuse to the point where degradation follows. On the latter view the logical course of action is to consider, for any piece of the environment, the amount of sewage or industrially toxic waste or land use transformation that is tolerable and allow this to be attained but not exceeded. There is a very close relationship between this concept and the concept of acceptable risk: so far as the use of the environment as a resource to take in pollutants and undergo transformations is concerned the concept is really linked to one of 'acceptable standards'. The no-change philosophy, on the other hand, takes the view that any modification in the environment from the natural condition may be in the direction of lowered productivity, diversity, and 'health' and should be resisted to the maximum extent feasible. Where air is currently clean it should therefore not be allowed to become dirty and where rivers run pure, they should not be allowed to receive discharges of toxic waste.

Clearly there are intermediate positions. Generally speaking, it is evidently desirable to reduce heavily polluting industrial emissions by installing modern equipment operating to a standard, even if there are still some residual emissions, and the movement of industry to areas where its net impact is significantly reduced may be acceptable. However, there is a genuine problem in determining the extent to which the philosophies of 'acceptable standard' and of 'no acceptable change' should be implemented. In judging whether or not an environmental activity constitutes a problem, it is necessary to consider which standpoint is being adopted. The better the scientific understanding of how pollutants and wastes are dispersed and degraded in the environment, the easier it will be to make such judgments with confidence.

D. INFORMATION AND COMMUNICATION PROBLEMS

In the mid-nineteenth century, an educated man could know almost everything worth knowing about the natural sciences. Today, a person must spend several years of study beyond a first degree before reaching the forefront of knowledge in a single discipline, or even a part of that discipline. In the twenty-first century, the specialist may be able to communicate effectively only with other scientists in the same speciality, and there is a danger that science may collapse through compartmentalization.

As the number of scientists, the range of techniques available to them, and the body of accumulated knowledge has expanded, there has been a parallel escalation in the output of professional publications. Over the past three centuries the number of journals and of individual papers has doubled about every 15 years and in 1971 there were about 35,000 journals producing 2 million articles by 750,000 scientists each year, in about 50 languages (Harrison Brown 1971). What are now termed the 'environmental sciences' encompass some ancient disciplines such as astronomy and geology and some of recent origin like ecology. Interdisciplinary themes such as pollution, natural resource planning, environmental modelling, and conservation have grown with them. Many such 'horizontal' groupings are inevitably heterogeneous and they have sometimes become separated from the older, basic, sciences on which they must nonetheless draw and which have themselves developed new specializations (such, for example, as molecular biology). Inefficiencies in communication are already manifest in science. They are likely to grow as the literature expands. It is more difficult for the individual to sort out the important information he should master from the 'noise' he should not even scan. For the specialist, in a narrow field, the problem is less difficult for his publication needs are being met by the creation of more and more journals, each having a narrower scope than the previous one. The situation is worse for the environmental generalist. Should he be content with wide-ranging reviews which depend on basic papers he may not be competent to evaluate? There are many abstracting journals and services, but here too the problem may be not only a capacity to evaluate the reliability of the work to which they may lead the user but the sheer volume of information they reveal. Faced with this, the environmental scientist may need to consider alternative systems for data collection, analysis, and presentation – for example linkages, via a referral system, to data sources. The output of the environmental scientist may likewise be a body of data, deposited in machine-readable form, to which attention is drawn by a short summary.

To members of the scientific community who need to evaluate authoritatively the scientific results of many different specializations and to interpret these to non-scientists, this 'knowledge explosion' poses new problems. This is one reason for Mid-term Project VII, which is concerned with communication. We must recognize that scientists themselves have been guilty of contributing to the inefficiency of the information system by the formats they have used for communication. The traditional scientific paper is not the most appropriate vehicle to bring scientific evaluations to policy-makers, and scientific advisors cannot expect judgments to be accepted if they are not expressed in a form suited to the user – or in a way that defines their likely margin of error. Sometimes they may require the interposition of a scientifically-trained 'translator' between the scientist undertaking the research and the policy-maker using his results.