Assessing the environmental health impact: an expert system approach

by Martin Birley

In the future, health risk assessment, assisted by a computer, may contribute to improved planning and sustainable development.

WATER RESOURCE developments (WRDs) are difficult to plan and manage, requiring the co-ordination of a number of government sectors and the anticipation of a diverse range of problems. These problems are nowhere more acute than in the warmer countries, where the vectors of communicable diseases often breed in water. There is a growing recognition that vector-borne diseases cannot be controlled by mere chemical spraying or curative drug therapy. While these must remain a reserve line of defence, we should also look to environmental management to lessen vector breeding sites and reduce contact between people and the infective agent.

Environmental management is intricately linked to project planning. Whereas most health management is a response to existing health problems, WRD is a planned activity which can itself create health problems. Environmental management, in its broadest sense, is concerned with assuring that project design encompasses the need to safeguard health.

If health planning is to be incorporated in WRD, two basic requirements must be met. The first of these is political will. It should take the form of a strong and binding commitment by donor agencies and governments to finance only selected projects. These projects, whatever their primary aim, should also maintain public health and safety, care for the fragile environment and provide adequate resettlement for displaced communities.

Many government departments pursue a relentlessly efficient but vertically structured programme. They achieve their own goals at the expense of other sectors. Projects which lack an in-built health component simply transfer hidden costs to the health sector. In this context health is only one small part of a much broader issue in which the well-being of the individual may be ransomed for the well-being of the state. Often, such matters can only be resolved by public debate. Public debate is apparent where development projects involve the destruction of rain forests, the construction of large dams or the displacement of populations.

The second requirement is a rapid, cheap and simple procedure for determining whether and how the first requirement - for safeguarding health - can be fulfilled. The procedure should be widely available to those without specialist knowledge of health matters. Community groups will need to apply it. So will specialists in other disciplines: notably the engineers, economists, politicians and agriculturalists who are often the principal decision-makers in the water development drama.

Health issues appear to have been neglected in many development projects. Yet a recent survey of engineers ranked health fourth in priority out of 43 research needs, in connection with Third World irrigation projects. A distinction was made between the need for more scientific research and the need to crystallize existing knowledge and to improve procedures for its dissemination. Two recent PEEM publications are particularly relevant in the planning process: *Guidelines for the incorporation of health safeguards into irrigation projects through intersectoral co-operation* by Dr Mary Tiffin, and *Guidelines for forecasting the vector-borne disease implications of water resources development* by Dr Martin Birley.

Formal WRD starts with the identification of potential projects by negotiations between donor and borrower agencies. There follows a series of reports of increasing complexity and detail referred to as feasibility studies. These lead, finally, to project implementation, construction and operation, which may be accompanied by evaluation and monitoring. After many years of operation a new cycle may commence with a proposal for rehabilitation. All these steps form part of the project cycle.

Environmental health impact assessment should form one component of the feasibility studies. It is an activity which should not be confused with baseline surveys. In general, there will be neither the time, the staff nor the financial resources to undertake a detailed scientific survey of all the components of the natural environment and human community which interact to create a potential health hazard. Development disasters worldwide attest to the simple but sad fact that too little is done too late. Environmental health impact assessment in all but the richest countries must, then, concern itself with the art of the possible: forming rapid assessments of key issues with a minimum of reliable data supplemented by a maximum of knowledge and experience.

The project cycle

In the formal terms of the project cycle, health impact assessment starts with a rapid survey of existing regional information. Questions to ask during this pre-feasibility study include: which vector-borne diseases occur in the region; what is their relationship to water; what is the capacity of the existing health service? The results of the pre-feasibility study are used to specify Terms of Reference (TOR) for the more detailed feasibility study. It is vitally important that at least one among the many specialist studies which are specified by the TOR is explicitly about with public health.

The feasibility study will still depend on limited and inadequate data, but regional information will now be supplemented by more

Martin Birley is with the Knowledge Engineering Laboratory, Department of Medical Entomology, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA, United Kingdom.

project-specific information. There should be an opportunity for site visits and interviews with specialists from different sectors and representatives from affected communities. The 'PEEM Guidelines' suggest which questions should be asked at this stage.

Finally, each specialist group will submit a report of its assessment study to a co-ordinating committee. It is the task of this committee to appraise the reports and to determine where intersectoral linkages are weak and safeguards or mitigation measures are needed.

The assessment problem

Assessment consists of structuring a complex problem into smaller and more manageable components and then considering the interactions between these components. The general methodology employed is referred to as Environmental Impact Assessment or EIA. This may be defined as follows (PADC 1983:

> . . . any activity designed to identify and predict the impact on the biogeographical environment and on people's health and well-being of legislative proposals, policies, programmes, projects and operational procedures and to interpret and communicate information about the impacts.[1]

The problem may be structured by distinguishing three main sub-components: community vulnerability; environmental receptivity; and the vigilance of health services.

Community vulnerability

The human community associated with WRDs consists of a number of distinct groups such as current occupants, scheduled migrants, unscheduled migrants, relocatees and temporary residents. The susceptibility of each human group will vary according to the degree of prior exposure to each disease and according to their general state of health and well-being. People who are displaced from an environment with which they are familiar are subject to stresses which affect their well-being in many complex ways. For example, they may be short of food until the first harvest can be gathered. Contact with vectors or infected water sources will depend on the siting of settlements, the provision of domestic water supplies and sanitation, and the nature of work and social life. Each construction worker may attract as many as ten temporary residents who will supply goods and services and live in unplanned settlements. Scheduled migrants may be chosen from the young and most fertile segment of the population and the age structure of the settlers will diverge from the age structure of the larger community.

Environmental receptivity

WRDs can substantially alter the local environment, introducing new disease vectors and parasite reservoirs. The creation of large expanses of open water promotes the growth of aquatic and terrestrial vegetation, alters groundwater levels and attracts animals or birds. The forecast must indicate the main species of vectors, animals and plants which will be encouraged or discouraged by the project. The effect of human activity on the environment may be classified. Broadly speaking, if a vector occurs in the region and a favourable breeding site is created in the WRD then, sooner or later, that vector will colonize the site.

An abundant vector community is only important if it has contact with human beings. Contact between people and vectors may be increased or decreased by changes in the behaviour of either vectors or people, or by changes in vector abundance. Each species of mosquito has favourite locations and times for seeking a blood-meal. For example, human contact with malaria mosquitoes in South-east Asia is often restricted to the forest and the night.

The project should be designed so as to minimize contact with unsafe water. Contact between people and water containing intermediate hosts may be increased or decreased by changes in human behaviour or changes in abundance of the intermediate host. In a hot climate young children will bathe in water and so may increase the transmission of schistosomiasis.

Changes in community vulnerability interact with changes in environmental receptivity to produce a potential health hazard. There are changes to the ecological environment which affect the number of vector species and the size of vector populations; and there are changes to the human population which affect

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Health workers engaged in mosquito control. Over much of Africa, there is so much malaria that present methods of vector control are inadequate to check the disease.

susceptibility, exposure and prevalence.

Health departments are often the last to hear that a WRD is planned, and as a result there may be no health provision in resettlement villages or construction sites. Existing facilities in a previously underpopulated district may be stretched by the arrival of migrants without any advance planning of drug supplies or personnel. There may be no health inspectors available to advise on sanitation and no spray teams to protect temporary housing. Most importantly of all, there may be no environmental safeguards or mitigation measures incorporated in the project plans.

Forecast boundaries

The extent of the potential health problem may be confined by boundaries of time and space. Three phases of a WRD may be identified: pre-scheme; construction; and operation. Vector-borne diseases may be categorized according to the rate at which disease manifestations occur in the human community which is exposed to infection. Some vector-borne pathogens, such as malaria and arboviruses, may have a significant, immediate effect on the health of the community. Other diseases, such as schistosomiasis and filariasis, depend on a gradual build-up of vectors and intensities of infection over many years.

None of the diseases occur throughout the world and regional distribution maps provide a preliminary forecast. In South-east Asia, for example, *Schistosoma japonicum* is largely confined to the east of Wallace's line while Japanese encephalitis is largely confined to the west.

Within each region the distribution of diseases and vectors is limited by geophysical, biological or cultural variables. For example, many parasites cannot develop in the vector at cool, high altitudes while others are associated with specific humidity zones. It may be possible to overlay larger scale maps with zones of known disease prevalence. The relative position of the project site with respect to the prevalence zones may then indicate whether there is a health hazard. However, vectors have considerable power of dispersal and readily colonize newly created habitats.

PROJECT TITLE	
TYPE	Large hydro power
LOCATION	
DATE OF FORECAST	June, 1988
PROJECT PHASE	Early operation
COMMUNITY GROUP	Resettlement village

DISEASE	VULNERABILITY of community	RECEPTIVITY of environment	VIGILANCE of health services	HEALTH HAZARD
Malaria	high	high	good curative, poor preventative	high, increasing
Schistosomiasis	very rare	very low	good	very low
Filariasis	very rare	low	good	very low, decreasing
Dengue fever	moderate	moderate, increasing	good supportive	moderate, increasing
Encephalitis	very low	high	good	very low
Suggested ranks include	very low, high, rare,none, increasing, decreasing, none	very low, high, rare, none, increasing, decreasing none	good, bad preventative, supportive, neither, both	high, low, moderate, inceasing, decreasing, none

Figure 1. A summary assessment modelled on the PEEM Guidelines.

The summary assessment

Figure 1 illustrates the kind of summary assessment that the 'PEEM Guidelines' seek to provide. The three elements of vulnerability, receptivity and vigilance are scored, using simple terms such as high, low, increasing and good. The final health hazard, for each disease and each project phase, is scored by combining the three elements. The table is accompanied by a written summary which justifies the scores in terms of available information and necessary assumptions. The subjective nature of the procedure is acknowledged: other readers are free to reinterpret the scores as they wish until a final consensus is obtained.

The scores for each of the three elements are based on a checklist of questions which are ordered in a flowchart. The aim is to encompass broad issues which impinge on health. For example, in South-east Asia resettlement schemes are often established at the fringes of the forest reserve. Communities of subsistence agriculturalists are displaced from land holdings in valley bottoms to smaller plots on drier or poorer soils where they are encouraged to grow cash crops using inputs such as fertilizer. Despite the best intentions of government these communities often suffer economic stress which they relieve by harvesting forest produce and establishing new gardens. Such occupations may bring them in contact with malaria vectors and the prevalence of malaria may rise. Thus, a health hazard may be increased through the indirect effects of agricultural sector policies.

Assessment under uncertainty

Environmental health impact assessment is beset by great uncertainties, uncertainties which arise because knowledge of ecological and social processes is so limited. The normal scientific response to uncertainty is a proposal for extra data collection. In the context of development this would be a baseline survey. Such a proposal, however, reflects little understanding of the limited time and finance which govern development projects or the limitations of the scientific method. The donor agency often wants immediate advice and is not prepared to finance an expensive long-term study, so it is not surprising that many projects are planned without adequate health assessment or the provision of health safeguards and mitigation measures.

Under these circumstances one procedure is to employ an experienced health consultant who will produce a confidential report. The supply of consultants is limited; there are relatively few Schools of Tropical Medicine and Institutes of Medical Research dotted around the globe. Although this procedure is cheaper than the baseline study, consultants' fees are high and the cost of their site visit is considerable. Furthermore, many specialists would agree that without a much larger input of scientific research, subjective bias is unavoidable. Nevertheless, expert judgement may be the only available decision tool.

The qualities of the ideal consultant are, simply: knowledge of the subject; experience of the problems which are likely to arise in water development; understanding of decision makers' concerns; a desire to consult community leaders; and an ability to respond concisely and without specialist language.

Such a consultant may only be allowed one site visit and is then expected to produce a short, sharp report which addresses the main decision problems and suggests health safeguards and mitigation measures. In order to complete this task the consultant has available a mixture of formal and informal methods. Informal methods may simply involve note-taking during the field trip. The formal methods would include a selection of those described in manuals on Environmental Impact Assessment. Appropriate activities include checklists, map overlays and interaction matrices.

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Collecting larvae of the malaria-carrying anopheles mosquito for subsequent laboratory examination.

Knowledge

In effect, the ideal assessment procedure seeks to mimic the reasoning processes of the human expert. In order to do so, it is necessary to consider the nature of cognition and information in more detail. Two kinds of knowledge can be recognized: declarative and procedural. Declarative knowledge consists of facts, descriptions, classifications and measurements. This is the kind of knowledge which is stored in a database. For example, it is a fact that *Anopheles dirus* is an important vector of malaria in South-east Asia. It is also a fact that it often rests outdoors.

Procedural knowledge, by contrast, contains the rules, relations and reasoning which enable experts to combine facts in order to generate new facts or reach conclusions. An example:

There is no point in spraying the interior walls of houses with insecticide if the local vector rests outdoors, unless there is also a repellent effect.

The 'PEEM Guidelines' incorporate procedural knowledge by listing the heuristics or rules-of-thumb which an expert might use to assess the vector-borne disease consequences of water development. Some 200 rules-of-thumb were collected for the Guidelines and at least that number again are probably readily available.

Rules-of-thumb can be assembled into consecutive chains of reasoning and this holds great promise for the future development of assessment systems. For example, a chain of reasoning for a dengue fever health hazard could have five consecutive links, each representing knowledge from a different specialist domain: Water engineering; Social behaviour; Mosquito behaviour; Epidemiology; Medicine.

Within this framework there is no difficulty in crossing between domains. A specialist from each domain could be asked to list a hundred rules-of-thumb similar to the single rule in the example. The whole set can then be stored in a computer and the logical consequences can be inferred automatically. By sacrificing the apparent precision of functional relationships we gain a model which is rich in significance. In this manner rare expertise can be more widely distributed.

Expert systems technology

Computer programs capable of organizing and using rules-of-thumb are referred to as expert systems. They are a logical extension of the familiar database. Procedural knowledge is stored in a separate file referred to as a 'knowledge base'.

As yet, there are few functioning systems: the gap between potential and achievement is probably due to economics — the production of a complete system requires a considerable financial investment. Several prototype expert systems based on the 'PEEM Guidelines' have been built in Liverpool and elsewhere, and these have been used to explore the feasibility of the technology and have been demonstrated at a number of meetings.

Updating the database

Information about vector-borne disease is soon out-of-date and varies over quite small geographical distances so that both databases and knowledge bases require updating. However, the diminishment rate varies with the kind of information.

Knowledge, representing accumulated experience, remains valid over long timespans and large geographical distances. It may have either global or regional validity; indeed, the normal scientific process is to seek such generalizations, by induction, from project specific data.

The validity of data varies over smaller temporal and spatial scales than knowledge. For example, disease prevalence or insecticide susceptibility may vary between regions or districts. Consequently, some databases will require updating more frequently than others. One excellent example of such a database is the *Atlas of the Global Distribution of Schistosomiasis* (Doumenge *et al.* 1987). It is salutary to note that this monumental endeavour was completed without recourse to any computer techniques of database management or geographical information systems. Information technology would make the task of updating such an atlas a relatively trivial task.

Conclusion

WRDs change the environment and the human community, sometimes promoting contact with vectors and infection with pathogens. Our understanding of the dynamic processes involved is limited. We are uncertain about the functional relationships between ecological and social variables. Despite our uncertain knowledge, we need rapid assessments of health impact so that safeguards and mitigation measures can be incorporated in design and operation. A new assessment method has been described which uses an ordered series of questions to establish a basis from which impacts may be inferred. This method distinguishes declarative and procedural knowledge. Procedural knowledge can be expressed as rules-of-thumb. These can be ordered into logical chains of reasoning which capture the knowledge and experience of a diverse range of specialists. The limits of experience which can be represented in this way have yet to be determined. The potential for future development is exciting.

This sense of excitement should be tempered by two caveats. Firstly, environmental health risk assessment is still more of an art than a science, and is a tool for decision-makers, not scientists. Its objectives are modest: to improve perception of a complex problem where decisions have profound repercussions on both the environment and the community. Any method which is simple to use in practice, which improves perception and reduces unstructured guesswork should be given serious consideration. Finally, health risk assessments can only be of value if there is a serious commitment by both donor and recipient to safeguard health.

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1. PADC (ed.) 1983, Environmental Impact Assessment, NATO ASI Senes D: Behavioural and Social Sciences, 14, Nijhoff, Boston.