Health hazards in irrigation development: a strategy for improvement

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Certain kinds of irrigation development projects in hot climates have important adverse implications for human health. This article reviews aspects of such projects in relation to their effects on vector-borne disease; the specific diseases associated with these developments are discussed and tabulated. It introduces the concept of environmental management for disease control and this is discussed in relation to the various phases of project planning and establishment. It concludes by making recommendations for action to be taken towards ensuring the general acceptance and implementation of such techniques.

The development of irrigation schemes, especially in the tropics, has important implications for human health. The impact of such developments on health may be intentional and beneficial, as with most domestic water supply and sanitation schemes, or it may be unintentional and adverse, as is the case with many irrigation projects.

In view of the large amount of literature and case study documentation in this area it cannot be truthfully said nowadays that the adverse consequences to health caused by certain types of irrigation development are unexpected. Unless deliberate measures to avert these consequences are taken at planning, design, and operation and maintenance stages, then health problems are bound to occur. This much is clear from past experience, even if it is also clear that the prediction in detail of the effects of environmental change on disease and disease vectors is not simple.

Although human health has to be considered as a whole, especially the overall relationship of water to health, this paper is concerned with those diseases which require a vector or intermediate host for their transmission. It considers specific important diseases and specific case studies. A strategy for vector-borne disease control is proposed, using environmental management measures, and the need to train engineers in such techniques is discussed.

Health implications

Important facets. It has already been pointed out that it is those aspects of development that are not directly related to the improvement of public health which often have adverse health consequences. Two important facets are the physical aspects of the land developed for irrigated agriculture, with or without drainage, and the degree to which resettlement policy has attempted to reduce man-vector-pathogen contact and provide improved water and sanitation facilities.

Irrigated land. The development of agricultural land can constitute a very significant and sudden change to the physical environment which can affect the disease vector ecology. G. Surtees [1] mentions six general ways in which irrigation development modifies the environment and thereby changes the abundance and species composition of insect and other vectors. These are respectively simplification of the habitat; increased area of above-ground water; raised water table; water flow; modified microclimate; and urban development.

The observed result of such changes is to reduce (in the short term at least) the diversity, but to vastly increase the available number of vector breeding sites. Open canals, drainage ditches, borrow pits, and other areas of standing or slowly flowing water provide attractive sites for mosquitoes and snails in particular. The problem is exacerbated by poor maintenance of canals and ditches because weed growth slows water flow, encourages sedimentation, and thereby produces attractive breeding grounds for disease vectors. Uncontrolled settlement and urbanisation adds even more fuel to the fire, with its lack of water supply, storm water drainage, refuse disposal, and sanitation.

The extent of the impact of irrigation development on human disease is huge. Schistosomiasis is the disease most particularly associated with irrigation schemes in hot climates: numerous case studies demonstrate the greatly increased prevalence of the disease only a few years after irrigation developments have taken place. In the case of the Gezira Scheme (Sudan) the impact of schistosomiasis has been such that the scheme as a whole has been branded as a failure [2]. Even if this may be seen as overstating the case, there can be no doubt that the extent of the health consequences of irrigation developments throughout Africa and elsewhere is enormous.

Resettlement. Irrigation schemes often involve resettlement of rural communities, and usually an influx of human population. If resettlement is not carefully planned as part of the development project human health problems are sure to occur. Two important aspects of resettlement in the present

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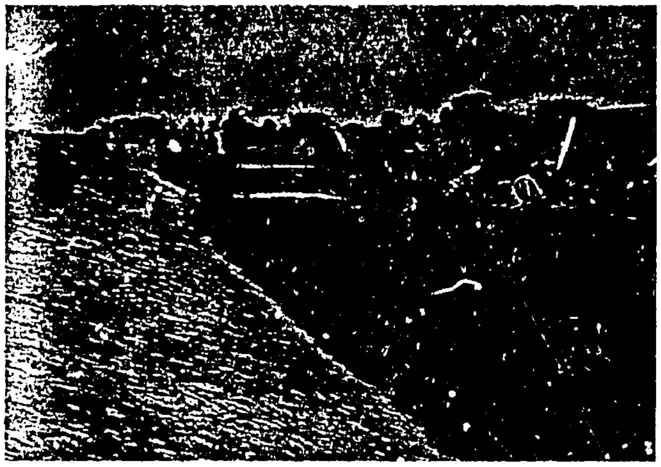

Figure 1 Children playing and adults washing in infected irrigation canal.

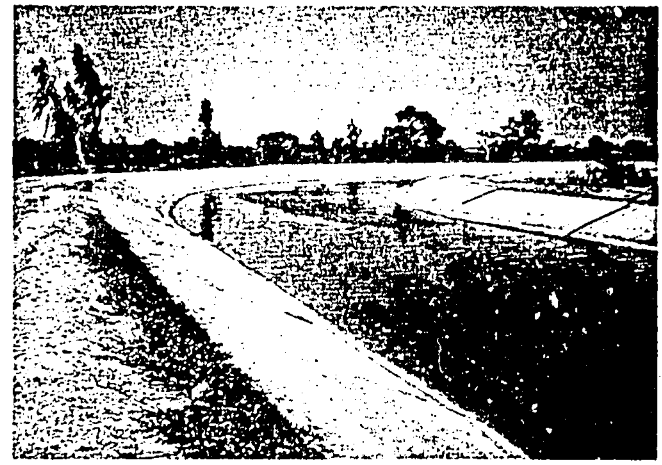

Figure 2 Lined irrigation canal, perhaps the best way of reducing risk of schistosomiasis.

context are the location of communities and the water supply and sanitation facilities available to them.

One facet of the concept of environmental management as discussed by WHO [3] and developed by PEEM (Panel of Experts on Environmental Management for Vector Control) [4] is that of 'modification or manipulation of human habitation or behaviour . . . to reduce man-vector-pathogen contact'. Where resettlement planning fails to take account of the dangers of human proximity to vector habitats (many of which are man-made) it is deficient. Uncontrolled resettlement near irrigation canals and other water bodies not only puts people in close proximity to insect vector habitats, but also encourages the use of the water for drinking, bathing, and washing, with consequent schistosomiasis and guinea worm hazard.

It is clearly desirable for new communities to be sited some distance from open water in order to reduce contact with the disease vectors. This is possible only if all the facilities which the canal supplied can be provided within the new settlements. This means among other facilities, the provision of good water for drinking, bathing, and washing, as well as adequate drainage and sanitation. It may also mean the provision of swimming pools for children and others who would otherwise allow transmission of schistosomiasis by their bathing habits (figures 1 and 2).

The essential factor, as D. J. Bradley [5] points out, is that there must be easier access to safe than to unsafe water, for whatever purpose. In the past resettlement policies have not adequately protected the new communities from the disease vectors whose habitats have been produced by some water resource development projects.

The diseases. S. Cairncross and R. G. Feachem [6] mention 37 diseases or groups of diseases that are water related and which, therefore, may be affected by water resource developments. A selection of the more important vector-borne diseases is summarised in Table 1.

A strategy for improvement

Environmental management involves physical modifications to, or manipulation of, the environment associated with the construction of irrigation and drainage works in order to limit human contact with water and to create unfavourable habitats for vectors.

Examples in the more developed areas of the world have shown this to be an encouraging approach. The slow, steady re-organisation of the environment, although pursued mainly for economic and social reasons, was a primary factor in the conquest of such diseases as malaria, plague, and yellow fever [3]. In the tropics too, there are strong indications that environmental management can contribute significantly to the control of vectors and hence to improved community health.

These techniques need to be introduced into projects at each stage of planning, design, construction, operation, and maintenance and—in the case of existing projects—rehabilitation.

Planning studies. For new projects, the early stages of development are of vital importance. The regional and reconnaissance studies establish the principal resources of a region and identify projects demanding more detailed investigation by feasibility studies. Where irrigation developments are to be incorporated in the regional plan a broad appreciation of their likely influences on community health is essei ..l. Problems identified at this stage can be tackled within the development plan. If delayed to a later stage they can be extremely difficult and costly to put right. Involving specialist entomologists and epidemiologists in the investigating team would ensure that due attention was given to identifying specific vectors; types and location of their habitats, and their behaviour and importance in disease transmission.

Design and construction. In these phases there is a wide range of physical works, referred to by several authors [7, 8], which can be incorporated into projects to assist in disease control. However, the relative importance of such measures cannot be considered

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TABLE 1 SOME WATER-RELATED VECTOR-BORNE DISEASES

Disease or disease group	Pathogenic agent	Vector or Intermediate Host	Vector Habitat	Geographical occurrence	Estimated No. of people affected worldwide	Actual or potential risk from dam and irrigation developments
Schistosomiasis (Bilharziasis)	Helminth (trematode worm) *Schistosoma* *japonicum* *mansoni* *haematobium* *intercalatum*	Snail Oncomelania spp. Biomphalaria spp. Bulinus spp. Bulinus spp.	Still or slow flowing water e.g. lake shores, canals, ditches	*S. japonicum:* Orient *S. mansoni:* Africa, South America Caribbean *S. haematobium* Africa, Middle East	300 million	Very high potential risk of substantially increased prevalence, based on past experience
Malaria	Protozoa *Plasmodium* *falciparum* *vivax* *malariae*	Mosquito Anopheles spp.	Standing water (pools, ponds, borrow pits, etc)	Worldwide in hot climates	150 million clinical cases per year. Estimated fatalities (pre 14 years): 1 million per year	High risk generally of providing new vector habitats, introducing reservoirs of disease among immigrants and introducing new mosquito species.
Filariasis (Bancroftian Filariasis, Onchocerciasis etc)	Helminth (nematode, filarial worms) Onchocerca spp.	Various insects Simulium spp. (Onchocerciasis) Culex spp. Anopheles spp. Aedes spp. Mansonia spp. (Bancroftian filariasis and other filarial diseases)	Simulium spp. fast flowing oxygenated water Mosquitos: standing water, floating vegetation, polluted water, etc	Worldwide in the tropics Onchocerciasis especially in West Africa	300 million approx.	Simulium habitats are often destroyed by dam development; mosquito habitats are likely to be increased by dam and irrigation projects
Dracontiasis	Helminth (Guinea worm) Dracunculus spp.	Arthropod (water flea) Cyclops spp.	Small pools of open water, wells etc	Sub-Saharan & N.E. Africa; Arabian peninusla; Iran; India; Pakistan	*ca* 20 million cases annually	Risk can be high where domestic water supplies for drinking are inadequate
Trypanosomiasis (sleeping sickness)	Protozoa: Trypanosoma Spp.	Tsetse fly Glossina spp.	Riverine bush-shady vegetation near water, High humidity	Tropical Africa		The possibility of creating suitable habitats in vegetation along irrigation canals, etc is significant

entirely in the abstract, but must be scheme-related because of the wide variation in geographic, ecological, and social conditions between countries and even between projects in close proximity. A number of examples illustrate this point.

On the coastal lands of Indonesia where rice irrigation is practised, special dykes are constructed to control salinity levels in tidal areas and so control mosquito breeding [9]. Intermittent irrigation is also encouraged to control mosquito breeding in the rice fields, thus necessitating the construction of an adequate drainage system, which might otherwise not have been needed.

An example of a scheme in a more arid region is an irrigated sugar cane/citrus estate in South Africa [10]. The canal system is lined and fenced; drains are deep with almost perpendicular banks; and labour is housed away from the irrigation and drainage system and provided with adequate water for domestic use. With no other measures taken, there was less than 2 per cent schistosomiasis infection on the project.

Projects in Puerto Rico highlight the difficulty in deciding what are the most appropriate measures to take [11]. Irrigation schemes in close proximity varied greatly in their schistosomiasis problems. Schemes on sandy soils, with few water-logged areas and good hydraulic control over water distribution, had few problems, whereas schemes on heavier land with swampy conditions had many. Although canals were concrete lined in each scheme, some canals with quite high design velocities harboured snails, whilst others with lower velocities did not. This is an interesting observation, because lining is thought by many to be one of the major contributions that engineering can make to snail control in irrigation schemes.

Many other examples could be quoted to illustrate the complex interaction of measures which are applicable only to the particular project being considered.

Two important points emerge from the literature. The first is that many of the more important measures that are effective in vector control may already form part of the physical works normally associated with water storage and control. The main reason for their inclusion, however, is unlikely to be for improved vector control, but more strongly linked to economic advantages in terms of better water use or improved crop production. For example, a decision to line a canal with concrete, rightly or wrongly, would undoubtedly be based on the benefits gained from greater water availability, from reduced seepage, or savings in future maintenance costs. A change from conventional surface irrigation to sprinklers or trickle methods would be based on soils, topography, and cropping conditions. Although there are benefits to community health, these are likely to be secondary issues or considered a bonus.

The second point is that many of the items listed by the various authors are concerned with the standard to which the engineering works are carried out, rather than to special features. E. F. McJunkin [10] points out that although there are obvious links between schistosomiasis and irrigation, the link is most strongly associated with defective and inefficient irrigation, poor land preparation, and lack of field drainage than with irrigation per se. 'Schistosomiasis engineering in considerable degree is just *good* irrigation practice'. It is in this context that many developing countries experience problems. They often lack the skills or equipment to carry out work in a proper manner.

A common example of this is that of canal construction, where spoil for embankments often leaves extensive borrow pits which fill with water and create excellent habitats for vector breeding. By careful construction, borrow can be sought from land out of command, by broad stripping, or from spoil excavated from drainage channels. Similarly, improved construction methods and supervision of canal construction would lead to more compact embankments, less seepage, and hence a reduction in the 'wet areas' around canals.

This means providing more highly skilled staff to carry out design and construction tasks, and more time and effort spent by construction contractors working to achieve higher standards of workmanship.

Operation and maintenance is one of the most neglected areas of project development as most attention, and indeed funding, is generally devoted to the more prestigious activities of constructing new projects. It is this neglect which has led to the need for extensive rehabilitation of many schemes and reference is made to this aspect of development later.

The problem of maintenance depends very much on how well the scheme was constructed in the first place and the care taken in its planning and design. The same can be said for the maintenance of any environmental control measures introduced during earlier stages. As was pointed out above, when such measures are delayed to a later stage they can be extremely difficult to rectify.

Operation of irrigation schemes provides an opportunity to practice various environmental manipulation measures. These could include flushing and/or draining canals or improved scheduling. To carry out these and other tasks implies that the necessary physical works have been provided and that sufficient operators and managers with the necessary skills are available.

Rehabilitation. Throughout the world many irrigation schemes have failed in some way to meet planned production targets and a common cause often cited is poor water management practices, with resulting low irrigation efficiencies, often much less than 50 per cent.

Physical improvement strategies have ranged from the use of structures to control water distribution more effectively to the re-organisation of field irrigation by improving field layouts and water management practices, land levelling, and field drainage. There is now considerable emphasis on the latter, which is concerned with the application of engineering at field level; it is an area which has been greatly neglected in the past. Rehabilitation is usually carried out for improved agriculture and water use and not primarily for vector control. However, it can be seen that such improvements can create potential for both.

Training. One of the major problems of introducing such strategies appears to be a general lack of awareness of health problems and how to deal with them among many of those who influence decision-making in water-development projects, such as the construction of dams and irrigation schemes. Those with experience in the developing countries know only too well the desperate shortage of properly trained people and of those who understand the full implications of the work in which they are involved. An immediate requirement is a greatly increased programme of training so that currently available knowledge can be put to practical use in the field.

In the developing countries, many of which are within the tropics, a detailed awareness of the health problems associated with water is a vital part of a civil engineer's training. This requires a detailed course of study so that young engineers are not only aware of the problems of vectors and the diseases they carry, but are able to do something positive about them when they arise.

Conclusions and recommendations

A number of conclusions emerge from the foregoing:

(i) Many irrigation schemes of all sizes have had significant and largely adverse effects on human health through the creation of new vector habitats and the increase of man-vector-pathogen contact.

(ii) Deliberate measures can be taken to manipulate the physical environment in such a way that these adverse health effects are minimised.

(iii) Unfortunately, the present knowledge of environmental management techniques has not been implemented to the extent that it might have been, and this is in large part due to a lack of inter-disciplinary communication and training.

(iv) The inclusion of improved environmental management into new and existing schemes would generally have a minor effect on project costs, because most of the more significant and costly measures—such as canal lining—can be defended on grounds other than merely the health advantages to be gained.

In view of these conclusions the following recommendations are made:

(i) Authoritative planning, design, and maintenance procedures should be drawn up to relate known and tried environmental management techniques to future developments. The engineers and others who are involved need such guidelines in this as in other non-engineering fields of knowledge.

(ii) Further to bridge the communications gap between the engineers and medical/biological specialists, in-service education and training courses should be established.

(iii) Further work needs to be done to establish the true costs to the community of the adverse health effects of many projects. This is a necessary basis for the allocation of funds to environmental management work.

(iv) Finally, engineers and planners should work towards the integration, as a matter of course, of health and vector ecological studies into planning, design, construction, and operation and maintenance phases of irrigation development.

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