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Third report of the
WHO Expert Committee on Vector Biology
and Control

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Geneva, 13–19 November 1979

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ENVIRONMENTAL MANAGEMENT FOR VECTOR CONTROL

Third Report of the WHO Expert Committee on Vector Biology and Control

The WHO Expert Committee on Vector Biology and Control met in Geneva from 13 to 19 November 1979. Dr J. Hamon, Director of the Division of Vector Biology and Control, opened the meeting on behalf of the Director-General. Dr Hamon pointed out that this was the first time that a meeting on this important subject had been convened. Environmental management had, in the past, constituted one of the main tools for the prevention and control of vectorborne diseases. For some time the technique had been relegated to a secondary place in vector control and, on occasions, completely disregarded. Only recently had it been recognized that this reliable method should be reintroduced and applied jointly with all other available procedures for preventing vectorborne diseases. Since the application of well-known measures of environmental management would have to be tested as to their suitability and feasibility under different ecological, epidemiological and socioeconomic conditions, the study of strategies and operational methods would be required before full use could be made of environmental management on a large scale.

1. INTRODUCTION

Vectorborne diseases have been among the most important worldwide health problems for many years and, despite progress made in their control[1] during the past decades by the use of specific chemicals, they still represent a constant and serious risk to the major part of the world's population. These diseases are often linked to poor socioeconomic conditions but some can be associated with projects aimed at economic development. Thus the construction of dams for power generation, irrigation, flood control and water supply

[1] Throughout this report the term "vector control" applies, in a broad sense, to measures used against primary and intermediate vertebrate and invertebrate hosts and animal reservoirs of human and animal diseases.

may lead to an increase in the prevalence of malaria, schistosomiasis and onchocerciasis, while human settlement may increase urban filariasis and domestic rodentborne diseases.

The task of the Expert Committee was to review the known measures which have been developed in the past for the control of many invertebrate and vertebrate hosts and vectors of human and animal diseases; to assess the present application of environmental management techniques in vector control programmes; to estimate the interaction of these measures with agriculture, irrigation and other socioeconomic development schemes; to establish principles for the planning, organization and evaluation of environmental management programmes for vector control; and to make proposals for training the requisite manpower, for organizing an efficient information system, and for conducting research in many areas where knowledge is insufficient, including cost-effectiveness analysis of proposed or future control techniques.

In view of the importance being given to environmental management measures, the Committee has formulated recommendations designed to improve the prevention and control of vectorborne diseases through the application of these measures.

2. BASIC CONSIDERATIONS

The Constitution of the World Health Organization defines health as a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity. This state of health can be achieved primarily through the adjustment of man to his physicochemical, biological and social environment. An understanding of the interrelationship, within the total environment, of vector, pathogen, and man is fundamental to the study of human communicable disease. Even with chronic diseases and injury, the influence of the environment is becoming more apparent, leading to possible preventive measures through management techniques which were so successfully applied to abate vectorborne diseases. The conquest of such diseases as malaria, plague and yellow fever in the developed world was primarily the result of a slow but steady organization of the environment for economic, commercial and social purposes, which, coincidentally, effected a dramatic reduction in the transmission of these diseases. On closer examination, it may be demonstrated that many of the "environmental diseases" are man-induced and that human activities sometimes unwittingly alter and modify the vector habitats in such a way that vectorborne diseases are greatly intensified. Human endeavours must proceed, but in a manner that will avert adverse effects on health. Unfortunately, the rectification of existing problems is difficult and costly, so that attention should first be directed at incorporating preventive measures during the very early stages of any project.

2.1 Definitions

During the past five years or so, environmental management for vector control has been the subject of discussion in several papers prepared by WHO for presentation at various international meetings on malaria control, water resources development, and irrigation and agriculture. The term "environmental management" and some other related terms were defined in these papers, rather broadly to begin with, but later more precisely as their use became established.

To avoid unnecessary misunderstandings, it is important that these terms should be interpreted and used in the same way by all concerned with environmental management for vector control. The Expert Committee considered a number of commonly used terms and agreed on their definitions, which are given below.

(1) *Environmental management for vector control: The planning, organization, carrying out and monitoring of activities for the modification and/or manipulation of environmental factors or their interaction with man with a view to preventing or minimizing vector propagation and reducing man–vector–pathogen contact.*

This approach, which should be carried out prudently and skilfully, is naturalistic and involves an attempt to extend and intensify natural factors which limit vector breeding, survival and contact with man.

(2) *Environmental modification: A form of environmental management consisting in any physical transformation that is permanent or long-lasting of land, water and vegetation, aimed at preventing, eliminating or reducing the habitats of vectors without causing unduly adverse effects on the quality of the human environment.*

Environmental modification includes drainage, filling, land levelling and transformation of impoundment margins. Although these measures are usually of a permanent nature, proper operation and adequate maintenance are essential for their effective functioning.

(3) *Environmental manipulation: A form of environmental management consisting in any planned recurrent activity aimed at producing temporary conditions unfavourable to the breeding of vectors in their habitats.*

Water salinity changes, stream flushing, regulation of the water level in reservoirs, vegetation removal, shading and exposure to sunlight are examples of environmental manipulation activities.

(4) *Modification or manipulation of human habitation or behaviour: A form of environmental management that reduces man-vector-pathogen contact.*

Examples of this kind of approach include the siting of settlements away from vector sources, mosquito- and rodent-proofing of houses, personal protection and hygiene measures against vectors, and provision of such installations as mechanical barriers and facilities for water supply, wastewater and excreta disposal, laundry, bathing and recreation to prevent or discourage human contact with infested waters.

2.2 Reconsideration of environmental management

Emphasis on environmental management for the control of vector and animal reservoirs of disease all but disappeared with the development of spectacular chemical control measures. New persistent and versatile pesticides were apparently so cost-effective that the eventual eradication of the important vectorborne diseases seemed in sight. Unfortunately, this goal was overoptimistic. First there were harmful effects on innocuous species, which were followed by the unexpected development of widespread resistance in the target vectors and then by public objection to repeated application of persistent chemicals. Magnification of trace amounts in the environment—particularly in the food-chain—gave rise to fear of chronic toxicity to man and animals or of severe disturbance in the balance of nature. The narrowing of the economic advantages of chemical control measures due to the recent increase in the cost of raw materials and energy is discouraging the use of repetitive chemical control and favours the consideration of other methods. Environmental management measures offer an alternative approach, which may in the long run bring about lasting control of serious vectorborne diseases with no danger of toxicity or ecological impairment. These measures may prove to be less expensive over the long term and, moreover, produce considerable benefits to agriculture and socioeconomic development.

3. METHODS AND APPLICATIONS OF ENVIRONMENTAL MANAGEMENT

3.1 Environmental modification

Engineering works which greatly influence disease vector potential form part of large-scale undertakings such as irrigation systems, agricultural drainage, water impoundment for a variety of purposes, flood control, and highway and railroad construction. In the past and even today, the engineer has created vector problems by being unaware of the impact of his practices. Not only has vector breeding been promoted, but health problems have been greatly intensified through the presence of human carriers of disease in imported labour forces. In the Americas, the change in approach began in Panama, where, during the building of the Canal, environmental modification and sanitation became linked to large engineering projects, some of which are still functioning. Soon thereafter sanitary engineers became active in the construction, operation and maintenance of railroads, dams and reservoirs in the USA.

The concept of "species sanitation" narrowed the public health objective to reasonably attainable goals. Most vectors are quite fastidious in the selection of their habitat: aquatic forms select either fresh or brackish water, and there is little overlap in their choice. Some prefer lakes, others rivers, with distinctive degrees of shade, temperature, velocity, etc. In the past, many ponds have been drained in ignorance of the fact that the vector concerned preferred running water.

Identification of the vectors incriminated and proper study of their ecology would have permitted the delineation of specific areas in which control interventions were necessary and would have been effective. This implies that a team approach is required to attain the goal of vectorborne disease control.

3.1.1 *Drainage*

Drainage systems may consist of piped drains, open lined or unlined drains, subsoil drains, or vertical drains. Their removal of unwanted water, which will eliminate or restrict breeding places for disease vectors, is normally achieved through gravitational flow. Where this is impossible pumping is used. Such pumping requires energy and entails additional operational and maintenance requirements, which are reflected in considerable increases in costs.

3.1.1.1 *Urban and rural drainage.* The control of urban filariasis transmitted by infected water-breeding culicine mosquitos has been accomplished by providing good urban drainage. Such drainage will also reduce the breeding of other mosquito species, as well as that of snails. Sullage and rainwater accumulating in yards and in roadside ditches are best cleared by an organized piped drainage system, supplemented in some situations by open lined stormwater drains.

In rural situations, piped drainage systems may not be possible on account of cost. Consequently, the appropriate technology for use may be open drains or localized soakaways. Public and private water points should be served with suitable drainage for the removal of spillage. This may be relevant to both rural and certain urban areas.

3.1.1.2 *Agricultural and watershed drainage.* This is usually achieved through open channels, using natural stream courses and drainage lines, sometimes modified by canalization and embanking. In high-value land—for example, that used in intensive agriculture —the channels are usually artificial and generally unlined; where soil characteristics permit and cost is acceptable, piped subsoil drains may be used to prevent an excessive rise of the water-table from damaging the quality of the land and crop production.

While these measures frequently have a directly beneficial effect in the destruction of certain vector habitats, their improper design, operation and, in particular, maintenance may create suitable habitats for other vectors. For example, whereas swamp drainage may eliminate the breeding of certain mosquitos, the drains themselves may provide ideal habitats for other mosquitos or for snails.

The procedure of diking and dewatering has been widely used in agricultural drainage and for flood protection, with some incidental benefit for mosquito control. It was employed rather extensively for mosquito control in the Kentucky Reservoir by the Tennessee Valley Authority in the USA. In general, this method is most applicable to large shallow areas in flooded plains. An advantage of dewatering such areas is the reclamation of fertile land suitable for agricultural use in the area dewatered. Pumping is often necessary to get rid of the volume of water in the diked area. The diking and dewatering method should be viewed in terms of its economic impact on agricultural returns and should not be judged primarily on its merits as a means of achieving mosquito control.

Water held on an impervious stratum overlying a pervious one may be removed by vertical drains, which are boreholes penetrating the impervious layer. As vertical drains may result in groundwater pollution, care must be taken in their construction and use.

Attention should be given to avoid creating an accumulation of water through construction activities. Spoil banks should be broken at intervals to ensure lateral drainage. Culvert pipes under roads should be kept clear to flow and not to create collections of stagnant water suited to the breeding of certain mosquito species. Undrained borrow pits should not be permitted.

A special aspect of watershed drainage is encountered in areas of coastal marshland, where, through the construction of channels and the operation of tidal gates, the salinity of the water can be manipulated to the detriment of target disease vectors.

3.1.2 *Filling*

Filling is one of the most satisfactory methods for the permanent elimination of mosquito- and snail-breeding depressions, provided a source of fill material is available without creating undrained borrow pits. Scattered and small water collections in or around villages and other settlements can be eliminated by hand-filling and grading by vector control staff. Many marshy areas can be filled with stable demolition waste and excavation materials. Refuse and other organic solid wastes may not be desirable as fill material, since they can cause considerable gasification and settlement of the fill. Depressions in coastal areas can be filled with hydraulic spoil from channel and harbour maintenance dredging.

3.1.2.1 *Filling and deepening.* Many vector species breed in shallow waters with emergent vegetation. Filling and deepening is a measure for reducing the extent of such habitats in permanent water bodies. Extensive shallow water can be eliminated by balanced cut and fill. In this manner the shoreline can be considerably shortened and steepened below the depth tolerance of emergent plants. No loss in reservoir storage volume occurs as in complete filling, and maintenance is minimal provided side slopes are stable.

The technique is also applicable to fish-ponds, sewage lagoons, and stock-watering ponds.

3.1.2.2 *Topography alteration.* For the control of snail and mosquito breeding in irrigation fields, careful land grading must be done for both water application and drainage. Surface pools formed from residual irrigation water or rainfall constituting mosquito breeding sites can be eliminated in this way.

3.1.3 *Velocity alteration*

The Expert Committee discussed the importance of water velocity in canals and streams as a factor that may deter the breeding of the snail intermediate hosts of *Schistosoma* and the blackfly vectors of onchocerciasis. Since snails settle and multiply mainly in quiescent and slow-flowing waters, and blackfly larvae need a strong current to reach maturity, an increase in water velocity to dislodge snails[2] or a reduction in velocity to interrupt blackfly larval development[3] could substantially decrease the populations of these species. It was realized, however, that such a measure is, of course, inapplicable where both types of vector are present.

In new projects, branch canals and drains should be located as far as practicable on sloping ground and make the best use of the topographical gradient to maintain command of the land; where possible, they should be designed to convey water at the most convenient velocities for vector control. Canal lining offers the most practicable and effective means for increasing water velocities; it also decreases

[2] According to a laboratory study, a velocity of 0.65 m/s at the top of the shell caused dislodgement of the snails from the surfaces of the Lucite laboratory flume. Laboratory-reared *Biomphalaria glabrata* were used in the study. (Jobin, W. R. & Ippen, A. T. Ecological design of irrigation canals for snail control. *Science*, **145**: 1324-1326 (1964).)

[3] According to field studies carried out in West Africa the larvae of *Simulium damnosum* can tolerate water velocities varying between 0.5 and 2.0 m/s under the best conditions of anchorage, food and aeration. The velocities most commonly tolerated range from 0.7 to 1.2 m/s. (Philippon, B. *L'onchocercose humaine en Afrique de l'Ouest*, Paris, ORSTOM, 1978. Initiations–Documentations techniques N° 37.)

seepage, reduces silting and obstructs the growth of rooted weeds. Regulating water gates in canals and temporary barriers can be used to dam watercourses to retard the flow of water in the upstream stretch and thus interfere with blackfly breeding.

3.2 Environmental manipulation

Proved methods of manipulation, including the control of pond-breeding malaria vectors in impounded water, are based on a sound knowledge of the ecology, or bionomics, of the vector, with particular regard to specific limiting factors. When different species of disease vectors are dealt with it is often difficult to devise a strategy of management using a common body of knowledge. Table 1 lists a number of vectorborne diseases, giving some general information on the reproductive potential and adult behaviour of the vectors concerned, and attempts to illustrate the disparities between the factors which in part determine the relative risk of disease transmission. Habitat and climate are known to be limiting factors in the distribution of vectorborne diseases, influencing not only the vector but the pathogen as well. Man's action and behaviour sometimes help to promote the maintenance and spread of disease and often counteract naturalistic controls by such activities as bringing water to deserts and reordering the regime or natural equilibrium of streams—all interfering with the forces of nature. Manipulation techniques, on the other hand, seek to capitalize on the natural factors unfavourable to the vector and to extend and intensify them.

A WHO Scientific Group on Vector Ecology (WHO Technical Report Series, No. 501, 1972) deliberated extensively on ecological studies which would provide dynamic data appropriate for constructing complex models of disease suitable for computer processing, systems analysis and simulation techniques. Among other uses, these models would allow the simulation of systems and the prediction of the effects of natural changes and man-made interventions in various situations.

The inputs for such models are far from complete for every vector, but include environmental factors, reproductive potential and host factors. At the present time a strong scientific base is often lacking. Therefore, environmental manipulation measures may have to be carried out case by case, utilizing past experiences in one area for application to another with similar vector habitats.

Table 1. Generalized biological information concerning the vectors of some diseases

Disease	Vector or intermediate host	Reproductive potential				Preferred behaviour			
		Number of eggs	Egg-to-egg cycle	Number of broods	Life-span	Feeding time	Resting place	Source of blood	Flight or dispersal range[a]
Malaria	*Anopheles* mosquitos	200	10-14 days	6-10	20 weeks	Night	Indoors and outdoors	Man and animals	1.5 km
Filariasis; viral diseases	*Culex* and *Aedes* mosquitos	200	8-10 days	6-10	20 weeks	Night and day	Indoors and outdoors	Man and animals	0.1-8 km
Onchocerciasis	Blackflies	400	2-3 weeks	3-4	1-2 weeks	Day	Outdoors	Man and animals	4-8 km
Infantile diarrhoea	Houseflies	150	7-14 days	2-3	3 weeks	Day	Indoors and outdoors	—	4 km
Schistosomiasis	Aquatic snails	45	30 days	10-12	50 weeks	—	Outdoors	—	10-30 m
African trypano-somiasis	Tsetse flies	1 pupa	60 days	10	3-12 weeks	Day	Outdoors	Man and animals	2-4 km
Leishmaniasis	Sandflies	50	6-8 weeks	2	12 weeks	Night	Outdoors	Man and animals	50 m
Chagas' disease	Triatomid bugs	200	52 weeks	1-2	50 weeks	Night	Indoors	Man	10-20 m
Plague	Rats	8 per litter	12 weeks	4	32 weeks	Night and day	Indoors and outdoors	—	50-80 m
	Fleas	12	8 weeks	10	15 weeks	Night and day	Indoors and outdoors	Animals and man	—

Note: The figures given are only indicative and illustrate the major factors affecting transmission. They vary widely from species to species and in different environments.

[a] Under normal, static conditions.