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ENVIRONMENTAL GUIDELINES FOR

Irrigation in arid and semi-arid areas

Editor: Yusuf J Ahmad

UNITED NATIONS ENVIRONMENT PROGRAMME

IRRIGATION IN ARID AND SEMI-ARID AREAS

Environmental Operational Guidelines

1. Pesticide Use on Industrial Crops
2. Irrigation in Arid and Semi-Arid Areas
3. Watershed Development
4. Pulp and Paper Industry
5. Hides and Skins Industry
6. Coastal Tourism

IRRIGATION IN ARID AND SEMI-ARID AREAS

Prepared by UNEP in consultation with UN specialized agencies — financed by UNEP and UNDP

edited by
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FOREWORD

It has been our concern, shared by other bodies and agencies within and outside the UN family, that development projects and programmes should take due account of basic environmental parameters and constraints. It is, indeed, clear that broad-based sustained development is not feasible, especially in the long-term perspective, without sound environmental assessment and management at the inception.

These guidelines have been prepared by UNEP in close consultation with the United Nations specialized agencies concerned and were jointly financed by UNEP and UNDP. These guidelines were adopted by UNDP and are included in its Policies and Procedures Manual.

As noted in the conclusion to the guidelines for watershed management, but equally applicable to the other guidelines, there are many pitfalls to be avoided in initiating activities in different sectors of development and many opportunities that can be missed. Experience during the last ten years has also shown that remedial measures identified must be incorporated, if they are to be effective, in the very conception and design stage of projects and of planning procedures. Later attempts may prove to be only cosmetic changes as the ecosystems under consideration are particularly fragile and complex and may not recover from the stresses to which they are exposed if they exceed certain limits.

The guidelines for remedial or preventive measures which have been presented in this study are meant to be illustrative rather than exhaustive in character: there are substitutes for local experience, foresight and prudence. We have only attempted to draw attention to the kinds of considerations which must be kept centrally in mind. The objectives for which we strive in this subject area are multidenominational and interrelated, requiring a formidable array of diverse technologies and disciplines. It should be noted that although the guidelines presented here are essentially national in nature and scope, international co-operation and co-ordination to bring into play the different inputs required may often be necessary.

I sincerely hope that the present set of guidelines will be acceptable and meet practical needs, particularly in developing countries. Additional sectors will be examined and further guidelines prepared in collaboration with the United Nations specialized agencies, UNDP and other multilateral and bilateral development financing institutions, taking fully into consideration comments and advice which we expect to receive regarding the present set of guidelines.

Mostafa K. Tolba
Executive Director

PREFACE

At an informal meeting held in Rome in September 1978 the Designated Officials for Environmental Matters (DOEM) of the United Nations Administrative Committee of Co-ordination recommended on the basis of a report prepared by a consultant, Mr. O.M. Ashford, that UNEP undertake, in close collaboration with the United Nations specialized agencies, the preparation of environmental operational guidelines to assess and minimize the possible adverse environmental impact of development activities. The report of the meeting states "that priority should be given to the preparation of guidelines aimed at improving the consideration of environmental aspects at all stages in the planning and execution of projects. It was recognized that the level of sophistication in such guidelines would depend on the audience for which they were intended. Much of the available material was of a general nature which would mainly be of interest to university circles or to senior international and national officials. At the other extreme, detailed guidelines based on in-depth studies of specific projects would be very useful for specialists but difficulties were foreseen in obtaining the necessary information for such analyses, which would take a long time to complete. The meeting agreed that at this stage the primary need was for guidelines which would be useful at the operational level. For this purpose each of the major categories used in the consultant's report (e.g. agriculture) would have to be broken down into a number of subareas (e.g. crop pest control and rangeland management). A first list of subareas on which guidelines should be prepared soonest was agreed on as follows:

1. pesticide use on industrial crops
2. irrigation in arid and semi-arid areas
3. watershed development
4. pulp and paper industry
5. hides and skins industry
6. coastal tourism

At a subsequent meeting the DOEM determined that the operational guidelines should "avoid undue technicalities. They should be clear-cut statements of the environmental concerns, environmental parameters and environmental constraints arising in the area of interest. A distinction should be made between what would be useful for informed laymen, such as UNDP resident representatives or officials in the Ministry of Planning or Ministry of Economic Affairs of a developing country, to reach a decision on the need for and nature of environmental considerations in a given project at a very early stage of its formulation on the one hand, and the analytical tools required by engineers, economists and other scientific consultants in the form of coefficients, etc., to implement a project on the other. The latter should not be a part of the operational guidelines but on manuals of implementation." In the event, the six guidelines that have been prepared vary in the nature of the material assembled and the technical details analysed. This has been done deliberately.

In order to afford an opportunity to assess the practical utility of different approaches to the preparation of guidelines, it was considered necessary to establish models which could be compared and evaluated in terms of practical utility. UNEP would gratefully receive views on the analytical frameworks and approaches adopted in the different guidelines as well as suggestions for their improvement or amendment.

The environmental operational guidelines in this series are not intended to be prescriptions for corrective action or constraints on the methods, nature and scope of development activites. They are presented in the belief that dynamics and change induced by development aims are not without environmental hazards and risks; it is necessary to identify such hazards and risks where they arise and take early steps, in so far as prevailing circumstances permit, to contain or reduce them. It is necessary to take early steps, because later attempts at remedial action may be illusory, and always more costly than preventive action taken at the outset, and, as has been stated in the Conclusion to the Guidelines on Irrigation in Arid and Semi-arid Regions, "in some cases may be so costly as to bring into question the overall economic viability of the project".

We acknowledge with gratitude the contribution received from the United Nations specialized agencies, particularly the Food and Agriculture Organization, for the preparation of guidelines. Without financial assistance from UNDP, the operational guidelines could not have been completed effectively within the short time available. We are also dependent upon the assessment of the Resident Representatives and

the Headquarter staff of UNDP in regard to whether guidelines meet specific needs in the field.

Within UNEP, a number of colleagues have assisted in the preparation and editing of the operational guidelines. I wish to thank in particular Mr. Nat Htun (for the guidelines on the pulp and paper industry and on the hides, skins and leather industry) and Mr. Mohamed Tangi (for the guidelines on coastal tourism). Ms. Merran Van der Tak, Ms. Shahida Chaudhary and Mr. Mark Aeron-Thomas have assisted in the research and editing of the series.

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INTRODUCTION

Since the dawn of civilization irrigation has played an important role in helping man satisfy the most basic of all his needs—the need for food. However, the impact of irrigation projects is not exclusively beneficial, and when assessing the viability of such a project the adverse consequences must also be taken into consideration. The purpose of this document is to highlight the most serious of these consequences, which can be most damaging to the fragile and delicately balanced ecosystems that characterize the arid and semi-arid regions, so that full account may be taken of the necessary preventive or remedial actions that must be incorporated into any well-planned irrigation scheme, if the benefits gained are not to prove illusory.

In this document the semi-arid region will be defined as any region having a dry season of three to four months, regardless of the total annual precipitation. Such an area would need supplementary or seasonal irrigation. The arid region is taken as one in which the usual dry season will last longer than four months, and sometimes the whole year. Such regions must be designated for perennial irrigation.

REASONS FOR IRRIGATION

The beneficial effects of irrigation can be enormous, and the investments in most cases have been well justified economically. The primary benefit is the increase in agricultural production that irrigation makes possible. In a number of developing countries the increases in food production have failed to keep pace with demographic growth. The reasons for this failure are complex; however, one important constraint to the expansion of agricultural production (especially in the arid and semi-arid zones) has been the lack of moisture. Irrigation can supply that moisture.

Other secondary benefits include accelerated modernization; improved soil conservation due to greater permanence of the vegetative cover; an improved micro-climate with lower rates of evaporation, and sometimes favourably modified temperatures; and improved habitat, supplies of drinking water, and cover for certain types of wildlife.

ENVIRONMENTAL IMPACTS OF PRIMARY WATER SOURCES

The environmental impacts from a programme to develop a region for irrigation begin not with the consequence of irrigation practice, but with the development of primary water resources.

Diversion

Diversion irrigation schemes are usually built upon streams which have perennial or nearly perennial flow, and are sometimes referred to as "run of the river diversion". Diversion of such streams can cause a variety of problems downstream, including damage to fish stocks, navigational hazards, and dislocation of water supplies for domestic use. However, what is often the most serious problem is the inability of the reduced flow to deal adequately with the levels of chemical and human pollution deposited into it. The reduction of the base flow in the stream may be insufficient to flush out these wastes in the dry season, and the river bed may become fetid and act as a breeding place for pests and disease.

Methods of dealing with these problems

a) The government can ensure minimum flow levels based on careful hydrological studies that will allow sufficient volume of water to prevent some, if not all, of these problems arising.

b) Alternatively the problem of pollution can be dealt with by preventing the discharge of untreated wastes into the stream, thereby reducing the base flow required for dilution. This approach, however logical, is difficult to apply due to the necessity of legal instruments, monitoring apparatus, etc.

Storage in surface reservoirs

The storage of intermittent stream flows and flood peaks in surface reservoirs is one of the most basic techniques in primary water source development for irrigation. The potential impairment to the environment caused by large reservoirs falls into two broad categories: damage to the reservoir area itself, and damage downstream. Possible damage to the reservoir basin itself includes the following factors:

a) *Inundation of land*: The flooding of lands to create a reservoir may not only cause the loss of agricultural land and the destruction of habitat for wildlife, but will also involve the translocation of whole populations to other sites; for instance the Mekong River Development Project may involve the movement of up to half a million people. This may cause unanticipated degrees of hardship in some cases due to cultural and sociological problems related to abandoning of burial sites of ancestors, breaking up of kinship groups and neighbourly relationships that had existed for generations, etc. Indifference upon the part of planners to such elements of human ecology could cause serious disruption and hardship to the very population which the water project was intended to benefit.

b) Silt entrapment within the dam can cause a number of major problems which should be recognized in the project design if a fair appraisal is to be made. These include progressive depletion of the storage capacity of the dam, the more erosive action of silt-free water on the river bed and distribution canals, the loss of the silt which, depending on its composition, may be a source of renewing fertility to the irrigated lands downstream, and the upset of the delicate balance between shore erosion and sedimentary deposition—as occurred in the Nile Delta necessitating expensive control measures.

c) *Proliferation of aquatic weeds*: Another very important type of ecological problem resulting from the large dams, which has already begun to appear in the Mekong Basin, is the proliferation in the reservoirs of aquatic weeds, particularly the water hyacinth. These transmit water diseases, inhibit fishing and compete with plankton (the principal food of fish) for nutrients. Though not entirely without its uses (it can be used as a substitute for wood pulp or as cattle feed, and helps in the task of water purification) the water hyacinth is particularly problematic due to its prolific growth rate. Methods for controlling the water hyacinth include the use of herbicides, biological control using the water hyacinth weevil, foams, mechanical harvesting, and the manipulation of water levels, all of which have been tried with relative degrees of success in the southern United States.

d) *Effects of river fish:* The greatest inland fisheries in the world (apart from the Great Lakes) are the flood plains of the great river systems. Some of these produce in excess of 100,000 tons annually. The height of the flood and the extent of the flood plain have a direct influence on the feeding and breeding of these river fish, and consequently on the size and quality of the catch. When the irrigation project reclaims these flood plains the fish population is either greatly reduced or destroyed. To some extent losses may be compensated by catches in the reservoir by the deliberate incorporation of intensive aquaculture into the irrigation development plan with both fish ponds and the stocking of canals, or by the rotation of fish crop with flooded rice paddies which has been very successful in parts of Asia.

e) *Diseases:* The general aspects of public health will be dealt with in detail in the section entitled "Impacts on Public Health". However, there are certain public health problems specific to the creation of surface reservoirs in relation to those living nearby. Waste disposal is a particular problem, since, due to topography, there is rarely an alternative outlet other than the reservoir itself, and with the absence of currents there may be a considerable build up of pollution in the vicinity of the village. Since the reservoir will probably be used by the villagers for drinking, laundering and washing, this may become a serious health hazard. To avoid this, adequate waste outlet pipes must be provided. Furthermore, a host of water-related pests may develop readily in the ideal conditions created at the water margins. Though none of these are unique to reservoirs extra attention should be paid to the prevention of disease proliferation in these circumstances.

Pumping of ground water

The third major source of water for irrigation is pumping of ground water. This is of growing importance in those arid zones which have underlying aquifers. The principal environmental problems encountered are those associated with overpumping. Overpumping, in simple terms, may be defined as the extraction of water from an aquifer beyond the "safe yield"

The first important form of ecological damage resulting from overpumping is simply the depletion of the resource beyond its renewability. This means that the acceptance of an over-ambitious irrigation scheme may exhaust the aquifer relatively quickly, in a situation where a smaller project compatible with the "safe yield" could have continued indefinitely.

The second form of ecological damage caused by overpumping is contamination. This is particularly important in coastal areas, where there is danger of the intrusion of sea water into the aquifer, hence ruining it as a water source.

To guard against overpumping it is essential to establish what the "safe yield" is. This is a complex problem of hydrology, geology and economics to be determined by an expert. Furthermore, it must be ensured that this rate is not exceeded. Ability to do this presupposes the existence of a water law which enables the authorities to regulate pumping rates and to deny permission to drill new wells. As such laws do not exist in many countries their establishment is a pre-condition of protection against this hazard. In the case where the intrusion by sea water is a severe hazard provision should be made for recharging through injection wells.

ENVIRONMENTAL IMPACTS OF IRRIGATION PRACTICES

The way in which an irrigation project is planned, developed and maintained is of fundamental importance for both the long-term viability of the project itself and the health of all those living in or near the irrigated area. Failure to give adequate recognition at the outset to either of these can lead to disastrous consequences.

Impacts that can threaten the project's long-term viability

Siltation

In irrigation projects based upon direct diversion of water from a river there may be a high sediment load in the flow which is deposited on the surface of the irrigated fields. In some cases such as the Nile overflow, this silt is a renewing source of fertility. However, the deposited sediments may not always be so fertile and can cause damage to the land. This siltation may not only reduce fertility and necessitate constant cleaning of the clogged distribution canals, but over time may also raise the level of the field's surface to such an extent that the gravity system can no longer function properly. This occurred in many of the ancient irrigation schemes, and in some cases led to their total destruction. The best control measure is, of course, to prevent erosion upstream, but even if possible this may be prohibitively expensive. Alternatively the use of the river water for irrigation at times of high sediment load should be avoided. This may be difficult, and would require constant monitoring of the stream.

Soil erosion

The opposite process, that of erosion, may also create problems in an irrigated area in the following ways:

a) *Canal erosion*: Clear water is much more erosive than muddy water, and may cause significant deepening of earthen distribution canals. If this occurs, especially if it is in conjunction with siltation on the irrigated fields, the growing difference between the water levels and the surface level may eventually make the whole system inoperative. This can be avoided by the use of concrete-lined canals, but the solution is costly.
b) *Furrow erosion*: When irrigation furrows are run down the slope at gradients that are too steep, or discharges that are too great, the furrows become eroded, particularly at the upper end. This can result in a serious loss of valuable topsoil. The solution is the proper design and layout of a furrow irrigated field, something which is not often achieved by non-experts, and/or land levelling which, though expensive, is often worth the cost.
c) *Surface erosion*: With sprinkler irrigation on sloping hillsides erosion may occur if the soil is not properly covered with vegetation, or if the intensity of irrigation exceeds the infiltration rate of the soil surface. With gravity irrigation on terraced hillsides, if water flows from one step onto another it can cause significant soil loss through erosion. The best way of preventing this hazard is by having the sprinkler system designed by an expert, or in the case of gravity irrigation on terraced hillsides to ensure that the system is properly designed and that adequate provision is made within the project plan for continual maintenance.

Over-irrigation and salinity

Either over-irrigation or salinity can be a significant problem on its own, and indeed salinity frequently occurs in irrigation schemes even when over-irrigation has not taken place; however they frequently appear together, and the adverse consequences of each are magnified by the presence of the other. They will therefore be treated together in the section below.

One of the basic hazards of irrigation is the over-use of water. When the quantity of water applied exceeds the capacity of the upper layers of the soil to retain it, a water surplus occurs which can be disposed of in two ways. With adequate drainage it moves laterally to a suitable outlet such as the sea or some inland waterway, but otherwise it permeates into the ground-water table which, with gravity irrigation, then rises with various undesirable consequences. For example:

a) If the ground-water surface rises far enough it can create water-logged soils and swamps which reduce the depth of the soil profile in which the plant roots can develop. This is especially serious for deep-rooted crops such as alfalfa and many varieties of tree.

b) The ground water under large gravity irrigation projects tends to be more saline than that of similar unirrigated areas. Therefore, its rising level can cause damage to local wells, and if it rises far enough may result in what is known as the "tea-kettle effect", (this occurs when, due to capillarity, the brackish water reaches ground level and evaporates, resulting in a continual deposition of saline or alkaline residue on the land surface). This latter effect has been responsible throughout history for the destruction of extensive irrigated areas.

There are a number of measures that can be taken to avoid the problems of over-irrigation and salinity.

Over-irrigation

a) Application of the correct amounts of water based upon local research into the soil conditions, crop needs and climatic factors. However, since this presupposes the willingness and ability of farmers to measure the rate of flow and to abide by the recommendations, and an efficient supervisory organization, this may not be easy to achieve, especially in developing countries. Some motivation may be provided by a steeply inclined rate of payment for water which penalizes over-application, however, this will often go against the local tradition that water is "free", or at least unlimited after a basic tax per hectare has been paid. Much explanation and education will often be required to convey the notion that restricted use of water (within the correct scientifically determined limits) is to the advantage of the farmer.

b) Most importantly, it must be ensured that deep drainage systems are included in the irrigation plan, or added if the project has already been established.

Salinity

Where alternative or additional water sources are available the least saline should always be used.

Impacts on public health

Irrigation projects, if planned correctly, can bring about an improvement in public health in a number of ways. However, these benefits are not automatic, and indeed irrigation schemes have all too frequently been associated with a deterioration in public health.

Beneficial effects

Of the possible benefits to public health the provision of an abundant supply and wide distribution of water in regions where there is little water is the most important. This will allow an increase in personal and domestic hygiene, which will often help control certain communicable diseases, such as trachoma and scabies, and solves the problem of drinking water, at least when water is pumped from tube wells. Any such improvements are of major public health importance and, if allowed for in the planning stage, excellent results are obtained at minimal expense. However, when these basic precautions are neglected, a great opportunity is lost.

Deleterious effects and ways to combat them

Establishment of an irrigation scheme may render a region more vulnerable to diseases. Water can carry toxic chemicals and many communicable diseases, serving both as a transfer medium and as a habitat for vectors and intermediate hosts. Diseases which did not exist in an area may appear after irrigation. Their prevalence and the intensity of infections that existed previously at a reasonable level can grow to continuous and massive infections. Severe and debilitating infection then reduces the workers' capacity with socio-economic consequences.

The major diseases under consideration are the following:

i) Transmitted by mosquitoes:
- malaria
- filariasis
- arthropod-borne viruses: yellow fever, dengue (and dengue haemorrhagic fever), equine encephalitis

ii) Transmitted by the Simulium fly:
- onchocerciasis (river blindness)

iii) Transmitted by the tsetse fly:
- African trypanosomiasis (sleeping sickness)

iv) Borne by snails:
- schistosomiasis (urinary intestinal bilharziasis)
- paragonimiasis (lung fluke)
- distomatosis (liver fluke)
- clonorchiasis (human liver fluke)

v) Borne by freshwater crustacean:
- dracunculosis (guinea worm)

Of these diseases, malaria, schistosomiasis and onchocerciasis have caused the greatest damage in countries where irrigation has been developed with no consideration for public health effects. No attempt will be made to analyse the causes and effects of all these diseases; however, some of the more important ones will be discussed below:

a) *Malaria*: Malaria is carried by mosquitoes of the genus *Anopheles*; it is a danger in any warm arid region where there is irrigation. In arid zones, breeding places are generally small in size, and often dry out, which interrupts transmission in the dry season. Such regions are particularly vulnerable to man-induced environmental perturbations, such as the introduction of perennial irrigation, or changing from dry farming and irrigation of winter crops to wet cultivation. These environmental changes in arid countries tend to transform a seasonal and moderate malaria into a permanent hyperendemic situations.

b) *Filariasis:* Filariasis, a disease affecting the human lymphatic system, is borne by a parasite worm transmitted by several species of mosquitoes. It may result in elephantiasis, commonly known as brain fever, which not only severely affects human work capacity but also causes permanent mental disability in children.

c) *Schistosomiasis:* Schistosomiasis in its urinary and intestinal forms is transmitted by aquatic or amphibious snails. It is the predominant disease associated with irrigation schemes in hot arid lands and it is a typically debilitating infection which may result in reduced working capacity. If irrigation schemes are built in lands where the disease occurs, the infection may quickly reach epidemic proportions by introduction of snails into the irrigation system or by introduction of the disease by the immigration of infected people. Mollusciciding and periodic desiccation have proved remarkably successful in eradicating these snails, especially when used on lined water-ways. In the case of all the mosquito-borne diseases, including malaria and filariasis, it is not so much the practice of irrigation that is harmful, as the poorly planned, operated, and maintained irrigation schemes, with stagnant water in the canals, badly maintained drains, seepage and permanent residual weed-filled pools which provide a suitable habitat and breeding ground for the mosquitoes. Since the aquatic snails that act as vectors for schistosomiasis and various other diseases also flourish in such an environment every effort should be made to ensure that due recognition is given to the problems associated with such conditions, and that the project plan incorporates provision for adequate maintenance, etc.

d) *Onchoceriasis:* Onchoceriasis is a type of filariasis common in Africa and some parts of South America, and is transmitted by the bite of the simulium fly. If the bites are frequent, eye disease may result, culminating in so-called "river-blindness". As many as 30 per cent of the inhabitants of some African villages are blind, and some villages and fertile lands are therefore abandoned by the inhabitants. The simulium fly lives in well-oxygenated turbulent waters, rapid brooks, streams and waterfalls. It is important in areas where this disease is a problem that the irrigation project does not create additional breeding sites of this type.

e) *African trypanosomiasis*: African trypanosomiasis, also known as sleeping sickness, may appear in a population relocated in a tsetse fly area, as in the Kariba reservoir in Zambia. Alternatively, changes of floral composition, growth of trees along irrigation canals, increased air humidity or extensive introduction of cattle may result in tsetse fly proliferation as occurred in southern Sudan. If proper medical attention is provided, treatment can be very effective, but the long-term approach must involve the control of the tsetse fly. A variety of methods have been used in attempting to do this, and expert assistance or advice should be sought if the disease is thought to be a potential problem.

Pollution and public health

Pollution from irrigation with sewage water

With the growing shortage of water there is an increasing tendency in the arid and semi-arid regions to recycle sewage waters for the purpose of irrigation. While this is a praiseworthy measure for the conservation of resources it may create serious health hazards by accelerating the transmission of viral, bacterial and parasitic soil-borne diseases associated with fecal pollution.

a) Hazards

Contamination of food crops

The hazard to public health arising from irrigation with sewage effluent is due to the possible survival of pathogens in the soil of the irrigated crops. In 1970 a dramatic outbreak of cholera in Jerusalem was attributed to this cause. The best method of dealing with this problem is to ensure that the sewage is "properly treated". The definition of "properly treated" is, of course, the key issue here; the standard ultimately adopted must rely on a compromise between the resources available to the project and the relative likelihood under alternative standards of disease occurring from the consumption of the crops concerned.

Direct contamination

Farm workers may be directly contaminated by infections such as hookworm, as the result of direct contact with the sewage water. Where possible, practices such as walking barefoot should be discouraged, and an increased awareness of personal hygiene should be fostered.

Dispersion in the air

With the use of sprinkler irrigation there is the possibility of spreading contamination either through the direct inhalation of the airborne micro-organisms, or via other crops located downwind. If disinfection of the water is not feasible, the creation of a buffer zone between fields irrigated in this way and residential areas has been suggested (though this does not protect workers in the irrigated fields).

Sewage irrigation of pastures

Irrigation of pastures with raw sewage water can present a serious health hazard to the grazing animals, and in turn to humans via beef tapeworm and such diseases as tuberculosis. Disinfection is recommended to stop the spread of tubercul bacilli but special measures are required to eliminate completely the tapeworm eggs.

b) Regulation

Because of the hazards to health indicated above it is important for every country practicing irrigation with sewage effluent to establish adequate standards of treatment prior to irrigation. WHO has proposed a set of standards that could be adopted by any country. The basic principle underlying these standards is that the degree of treatment required of sewage water to be used for irrigation depends upon the type of crop to be irrigated. Since the crops vary greatly in this requirement and the higher types of treatment are relatively expensive, it is more economical to restrict certain types of water to certain types of uses. Crops have been divided into three categories: crops not for direct human consumption (forage and fibre crops), crops eaten cooked (potatoes, corn, grain), and crops eaten raw (vegetables and fruits). The required treatments vary from primary through secondary, tertiary and disinfection.

Before a country or district adopts a set of standards of this type, two important points must be kept in mind:

The economic factor

Extremely rigorous standards call for expensive tertiary and disinfection treatment of sewage. This may make the cost of recycled water so expensive as to place it beyond the limit which agriculture can pay. If this happens the whole project becomes inoperational. It has been found advisable in developing countries to begin the control with less rigorous standards, and, as the need becomes evident and as the agricultural economy becomes stronger, the standards become gradually raised. This requires alertness on the part of the health authorities to recognize unfavourable developments as early as possible.

The problem of enforcement

If sewage effluent of a certain standard is permitted only on certain types of crops, supervision must be provided to ensure this will not be violated in the course of subsequent crop rotations. Moreover great care must be taken to prevent cross connections and any possibility that effluent of low standard be used for drinking, laundering or other domestic purposes. Not all developing countries have adequately staffed supervision agencies to ensure compliance with the standards. For these reasons the first projects undertaken in sewage irrigation should be carefully selected with respect to the type of crop, standard of effluent, and location in relation to other fields and residential areas so as to minimize the hazards described above. During the period of development of such projects, the supervising agencies can gain experience and improve their organizational abilities to handle more problematic and hazardous situations. See Ref. WHO 1973 'Re-use of effluents: Methods of Wastewater Treatment and Health Safeguards' Tech. Rep. Series No. 517.

Water pollution

The use of irrigation, especially gravity irrigation and/or leaching, can cause pollution of the aquatic environment, due to the entry of nitrogen compounds and, if used, pesticides into both ground-water and river systems. The presence of either of these can lead to adverse public health impacts.

a) Nitrogen compounds

The most common form of water pollution with nitrogen is by inorganic compounds of nitrates, nitrites, and to a lesser extent, ammonia. Nitrates are the most commonly monitored parameter of this type of pollution and are known to cause methemoglobinaemia or nitrate cyanosis in both infants and livestock. Standards for nitrate limitation in drinking water are not uniform, and a degree of scientific uncertainty remains with respect to what levels of concentration can be considered 'safe'. However, the U.S. Public Health Service in 1962 recommended a limit of 45 ppm (parts per million) nitrate or 10 ppm, nitrogen though such levels have been exceeded without causing major problems.

b) Pesticides

The pollution of water sources with pesticides is a problem usually associated with surface runoff but can also occur as the result of the chemicals seeping into the ground water following heavy irrigation or leaching of the soil. On reaching the river system the pesticides may accumulate in fish thus rendering them unfit for human consumption, pollute drinking water or destroy the balance of the aquatic ecosystem. Wells should be monitored to avoid the dangers associated with the pollution of ground water, when it is thought that this might be occurring. To avoid the dangers associated with the pollution due to surface runoff efforts should be made to minimize the drainage flow. This can be achieved by reducing the inflow to a level which balances with the infiltration rate of the soil. When using sprinklers for irrigation this may be comparatively straightforward, but with the use of the more primitive gravity system this may be much more difficult to achieve. In such cases it may be provident, if the danger is thought to be acute, to make provision for the monitoring of residues in drinking water and/or fish.

General comments of irrigation and public health

In as much as health problems in irrigation schemes are entirely dependent on the design, functioning and management of the irrigation system, their solution, or better, prevention, may be found only in close co-operation between workers from several fields such as public health specialists, planners, hydrologists, engineers, agronomists and economists. It must be ensured that this co-operation begins with the planning phase and will continue through the life of irrigation development scheme.

Concerning the control of diseases associated with irrigation, a few general and important principles may be stated.

Individual or mass treatment of a population when used as the only method of control rarely leads to long-term improvement. This seems evident, but many public health problems are still dealt with by a narrow therapeutic approach.

Specific methods directed against a pathogenic agent, vector, or intermediate host are different for the various diseases. The common attempts at controlling mosquito-borne or snail-borne diseases use insecticides, molluscicides, mass chemotheraphy and mass eradication of snails. Environmental measures have the advantage of being efficient against several diseases at the same time. Thus the construction and utilization of latrines and of appropriate waste-disposal systems protect the environment against contamination, particularly fecal pollution, and at the same time hinder the transmission of viral, bacterial and parasitic soil-borne diseases. Provision of safe water supplies inhibits transmission of numerous diseases through drinking polluted water (mainly bacterial and viral diseases and dracunculosis) and also avoids skin penetration by schistosomes, hookworm and eelworm infective larvae.

Hydrologic engineering is an important component. Where relevant, drainage, stream channelization, lining of streams and canals, land levelling and filling to eliminate low spots, seepage control, piped or covered canals and drains, weed control, improved water management and strict discipline in the use of water promote community health. Sprinkler and drip irrigation, while extremely costly, deserve consideration in view of possible savings in public health expenses as well as saving water. Little may be expected from a programme of disease prevention without establishing broad contact with the population.

A sanitary education programme should be incorporated into the project design, and should enlist the assistance of local leaders in conjunction with sanitary experts if the propaganda is to be effective.

SOCIO-ECONOMIC IMPACTS OF IRRIGATION

One important area on which irrigation projects can have a significant impact which is sometimes overlooked is the social environment. By changing agricultural methods, increasing the density of population, and altering the distribution of wealth, irrigation can have a profound influence upon traditional social patterns, and indeed this may be one of the objectives of the scheme itself. However, such changes and their possible repercussions must be anticipated.

Changes in agricultural methods

It is often argued that people who are introduced to new farm practices will readily adopt modernized forms of behaviour. In some cases this may be true; however, the difficulties of adjusting to strange environments and agricultural methods should not be underestimated. Farmers new to irrigation may have enough trouble surviving, let alone forging new habits and linkages. They may find the obstacles to adopting irrigation so obdurate that they never settle into the irrigation routine and leave the project lands partly uncultivated. The record of such difficulties is especially clear among semi-nomadic peoples. It is essential, therefore, that the aims which the project planners have in mind are realistic in relation to the adaptive capacity of the peoples concerned.

Increased density of population

With enhanced food supplies, increased employment opportunities, improved health amenities, etc., powerful forces for rapid population growth may come into play. If the initial objective of the irrigation project was to bring about an increase in per capita living standards, then the management of birth rates is a strategic step that may have to be considered.

Distribution of wealth

Both the decision to undertake the project itself and the way it is financed and run will have a significant impact on the distribution of wealth between regions and social groups. A new scheme in one part of the country may adversely affect economic welfare in another by reducing markets, and contributing to unemployment and excess capacity. Whether productivity will be shared by the bulk of the population or concentrated among the few will depend in part on other economic circumstances that surround the financing and operation of the project.

Such considerations as these must be recognized in the original project design, and, where possible, ameliorative action taken if the inequalities are thought to be too large. In state owned projects the desired distribution can be brought about administratively. Where projects are developed for privately owned land a number of devices may be used to spread aggregate wealth more evenly. These include the limitation of the size of holdings, control over prices and wages, and the application of taxes that recover speculative gains.

The above-mentioned categories cover only a small proportion of the possible socio-economic impacts of an irrigation project, and therefore should be regarded, not as a comprehensive survey, but as a reminder that the project document should give due recognition to this type of impact, and that failure to do this can lead as easily to the project's failure as any error in agronomical or hydrological calculations.

CONCLUSIONS

It is not the purpose of this document to provide the basis of a full project appraisal for an irrigation scheme; however, it is hoped that by identifying some of the more important environmental impacts (which can be as important to the determination of potential welfare gains and losses as say the expected increased in crop yield, or the costs of digging canals), it will be possible to ensure that adequate allowance has been made for them in the project plan. If these environmental repercussions are not considered and included at the planning stage then the later use of "fire brigade" methods of rectifying the problem caused will almost always prove to be more costly than preventive action taken at the outset and in some cases may be so costly as to bring into question the overall economic viability of the project.

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