Step 6 of the 10-Steps Approach covers such issues as flow velocity and weed control — issues in which canal lining can play an important role. Canal lining, in general, can constitute an extremely valuable part of an irrigation system, and can, directly and indirectly, be a highly beneficial environmental-management measure for vector control. The advantages of lining the entire cross-section of an irrigation canal are:

- It increases water velocities, thus preventing the flow from being sluggish, which favours snail and mosquito breeding;
- If properly maintained, it eliminates rooted growth and facilitates the removal of floating weeds, thus depriving mosquito eggs and larvae of protection and shelter and snails of their main source of food;
- As seepage is less, it reduces the need for drainage. Drains, which always represent an active or potential danger of mosquito and snail production, can be smaller and will be drier most of the time;
- It facilitates the control of residual vectors by water management and/or by the application of chemicals;
- Especially hard-surface linings have a direct effect on disease prevalence because they prohibit the snail vectors from sheltering in the soil against burning when the canal dries out. This only counts when the slope of the canal bottom is sufficient to empty the canal entirely.
- The lining of a canal is an incentive to use planks as bridges over the canals. The better the construction of the lining, the stronger this psychological effect will be;
- Lining the irrigation system is also an incentive for planning and constructing special bathing places for children and drinking places for cattle. These will have a favourable effect on the control of disease transmission. In residential areas, canal stretches should be lined and places selected for the construction of side slopes in the form of steps, which provide easy access for bathing and laundering. (In unlined canals, such concrete steps should also be considered, or else plank bridges close to the waterline.);
- Finally, lining can be regarded as a basic sanitary measure because it will increase the effectiveness of other vector-control measures (e.g. maintenance, mollusciciding) or will reduce their costs.

Other advantages of lining — of a more general kind, but certainly no less important — are:

- Reduced cross-section (smaller value of the roughness coefficient and larger flow velocity), with, as a consequence, lower costs for land acquisition, less loss of land, less earthwork, less evaporation, smaller dimensions of structures and bridges, and fewer structures;
- In flat areas, the opportunity to get a larger land area under command, while maintaining a certain minimum flow velocity;
- Less sedimentation and less growth of aquatic vegetation, which means reduced maintenance costs.

(For References on canal lining, see Kays 1977; Komya 1965; Kraatz 1977; Reuss 1980; Rosenfield and Bower 1979; South 1957; Unrau 1975; Xu 1983; Yokogawa 1972.)
6.9.5 Special Structures

People (and cattle) should be prevented from wading through water to cross a canal. Small, simple bridges (1.50 m wide or less, and thus too narrow for cars) should be installed at an appropriate density. For cattle crossings, such bridges should be provided with a sort of trap to guide the cattle to the bridge and with a closed parapet so that the cattle cannot see the water.

If canals are maintained by mowing boats or small dredgers, ramps will have to be constructed in the canal embankment for the easy release of equipment into the canals.

Provision should also be made for drinking places for cattle. Ramps can be used. A better solution is to select a site in an irrigation canal close to a drain, and to transport the water by siphon across the embankment and into a fenced pond. Excess water from the pond can be evacuated into the drain.

6.9.6 Intermittent Flow

Interrupting the flow in an irrigation canal has a severe impact on aquatic insects and snails. The continuous presence of water is one of the factors that make a canal a suitable habitat for these organisms. If the seasonal population dynamics of the insects and snails are understood, it may be possible to achieve control by the judicious drying of the canals for relatively short periods.

Aquatic snails require a month or two to grow – from hatching to maturity – before they are large enough to shed cercariae and transmit schistosomes to man. So, interrupting the flow every month or less would cause severe disruptions in bilharzia transmission. In canals that flow for two months, the length of dry period needed to control the snails depends on the season of the year and the rapidity and completeness of the drying.

If the canals do not drain well, or if the water is eliminated by evaporation instead of drainage, the ‘dry’ period will have little or no effect except to interrupt reproduction while the snails are out of the water. However, complete drainage of the water within a few days will cause high death rates, depending on the length of time that the canal is kept dry. Although these figures vary with snail species and location, rapid drying will, in general, cause 50 per cent mortality if maintained for 2 weeks and 75 per cent mortality if maintained for 1 month (see Table 6.7). If 1-month-long periods of no flow are scheduled quarterly in a theoretical canal where breeding occurs year-round, the net impact on the snail population would be to eliminate it very quickly.

The requirements for the control of malaria mosquitoes are quite different from those for snails. The mosquito larvae can develop in 1 or 2 weeks after the eggs are deposited in the water, so the flow would have to be interrupted after only one week, depending on the mosquito species and the water temperature. Mortality during the larval stages is very high, even with incomplete drying, so a dry period of a few days is sufficient to kill all of the larvae.
Blackfly larvae deposited on sills, weirs, or other solid objects in the canal are also susceptible to flow interruption or even a lowering of the water level in the canal. Their eggs require about 3 days for maturation, and can be killed with 1 day of drying. Blackfly lay their eggs on fixed objects at the surface of the water, so a lowering of 0.40 or 0.50 m is sufficient to expose and kill most eggs.

In temperate climates, a 4-day interruption in flow every 6 weeks has been found sufficient to control blackfly breeding, but in West Africa or Central America, the interruption would probably have to be repeated every 2 weeks (McMahon 1967).

6.9.7 Design and Operation of Drains

One of the earliest and most effective measures developed against mosquitoes was the rapid drainage of rain or flood waters – the free surface water being removed before the mosquito larvae had time to mature. Such drainage systems must operate repeatedly during the rainy season, whenever water impounds.

Control of bilharzia snails by drainage is much simpler and less costly. The surface waters should be removed in about 1 or 2 months, requiring a much smaller drainage system than that needed for mosquitoes.

Blackfly control is seldom accomplished by drainage because the flies do not breed in flooded areas but only in fast-flowing water.

Unfortunately, providing drains to empty flooded areas is not the end of the problem with mosquitoes and snails. They will quite often populate the drains themselves and such drainage systems, natural or engineered, can often become major transmission sites. So, clearing and maintaining the drains is an important part of the health effort. In general, the same guidelines can be used as those for the operation of canals for mosquito and snail control, but there is an additional option in cases where frequent dredging, weed removal, or drying is not possible: the use of periodic flushes through the drains to dislodge mosquito larvae. The method has been evaluated for snail control also, but it does not appear to be practical in drainage systems because of the high velocities that would be required.

6.9.8 Flushing

Section 6.2.1 described the use of flushing siphons to wash away mosquito larvae and explained how the rise and fall of the flood wave in downstream sections can throw mosquito eggs and larvae up onto stream banks, leaving them stranded.

In drains, too, periodic flushing can be used for mosquito control. Experience in natural streams has shown that flushing due to heavy rains is effective and that this can be simulated by periodically opening flashboards on small impoundments or by installing automatic siphons.

6.9.9 Fluctuation of Pond Levels

Pond-level fluctuations for the control of snails were discussed in Chapter 5.
6.10  Costs of Control Measures

In the process of combining preventive design measures with post-construction op-erational programs for disease control, an important step is estimating the costs of those programs. Engineers and planners usually have access to costs for components of pro-posed irrigation systems, but costs for disease-control programs are not so easily obtained. Since the latter costs are related to chemical control, to chemotherapy, and to the provision of safe water, it seems appropriate to deal with these costs in a Technical Note ('Costs of Control Measures: An Overview') after the other relevant chapters have been considered.

6.11  Practical Examples of Environmental Control of Diseases in Irrigation Systems

Annex 4 (Volume 2) presents four practical examples of the environmental control of malaria, bilharzia, and diarrhoeal diseases associated with water in irrigation schemes. The examples cover a broad range of geographical, agricultural, and social conditions. They include the large Gezira-Managil Irrigation Scheme in Central Sudan, a sugarcane scheme in Puerto Rico, the new Dez Pilot Irrigation Project in Iran, and sanitation works on the island of Java.

These examples demonstrate that considerable experience has been accumulated in recent years in clarifying the importance of environmental factors in the transmis-sion of water-associated diseases. The need to include them in our book bears witness to the fact that designing irrigation schemes to prevent disease transmission is still in a primitive stage, despite the accumulated experience. It is still an art at present, not yet a science.

The examples also provide insights into how environmental factors can be put to use in the development of long-term and stable strategies for disease prevention and control. At another level, they re-assert the value of ecological approaches to disease control – approaches that were initially developed before World War Two. Ecological approaches were discarded with the discovery of the miracle pesticides and drugs, symbolized by DDT and penicillin. They are now being re-introduced and are of par-ticular importance for design engineers, who can provide for them in new irrigation schemes at relatively low cost.

References

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