Environmental upgrading of irrigation systems to control schistosomiasis

by Mahmoud Abu-Zeid

In Egypt the Ministry of Public Works and Water Resources has prepared short and long-term strategies to eliminate the schistosomiasis problems caused by the High Aswan Dam.

The last century has witnessed a radical change in Egyptian irrigation methods. The ancient system of basin irrigation and cultivation of one crop per year, has been superseded by perennial irrigation since the construction of the High Aswan Dam (HAD).

The total area of cultivated land in Egypt is almost six million acres. This area is artificially irrigated by the Nile through a huge network of canals and drained by a similar network of drains. The total length of both networks exceeds 4,700 kilometres.

The discharge of water from the HAD is under full control, and the release of water for irrigation is adjusted throughout the year to provide all agricultural areas with sufficient water for crop needs. The cross-sections of distributary canals are designed to serve command areas according to specific water duties. *Mesqas* (private canals) are served from the distributary canals which are on a two- or three-turn rotation. The water is typically delivered from 50 to 75cm below the ground surface of the fields, so irrigators must lift the water onto the land by animal-powered *saqias* (water wheels), hand-operated *tambours* (Archimedes' screws), or by diesel-powered pumps. Farmers are not required to pay for water.

After lifting water from the *mesqa*, a farmer is free to distribute it over his field by his own methods. Generally, he distributes the water through the field ditch to small bunded (banked) units called basins. The surface of the fields may be furrowed for row crops or smoothed for basin crops. Excess irrigation water is drained off into tiled or open-field drains.

Drains are classified according to function and size, as follows: collector drains which receive water from field drains; branch drains which receive water from collector drains; main drains which receive water from branch drains, mainly by gravity; and principal drains which receive water from main drains, primarily by lift, and discharge it to the Nile, Northern Delta lakes or the sea.

The basic concept of drainage policy in Egypt is to drain all cultivated lands with sub-surface drainage networks of collectors and laterals to a depth suitable to crop cover and not less than 1.25m below the surface.

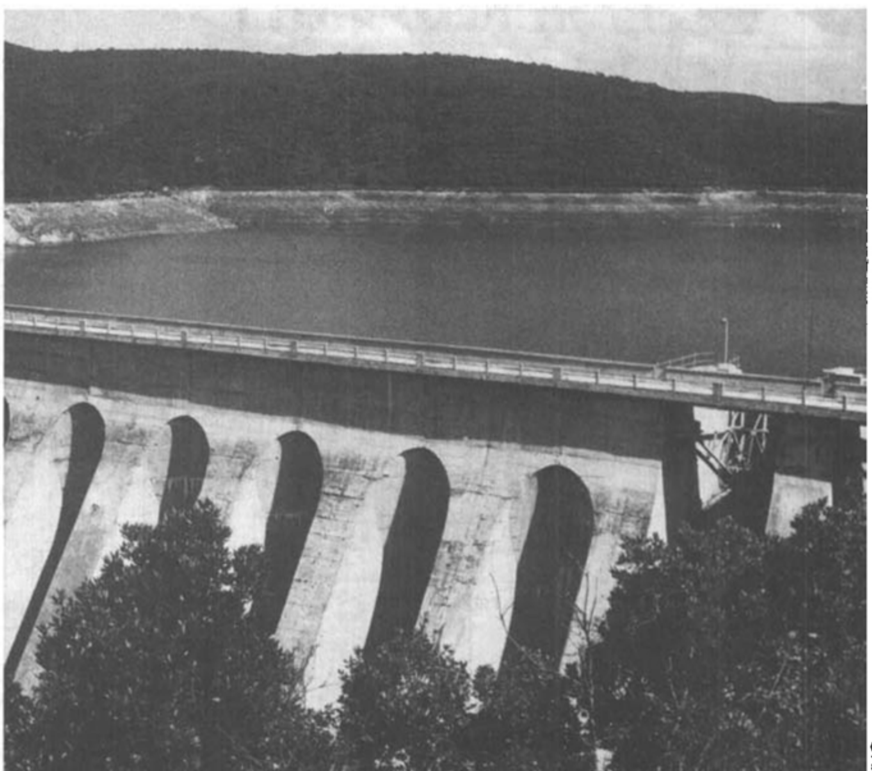
The HAD is a multi-purpose project. It has a great impact on irrigation, the development of the River Nile water, electric power generation, protection against significant floods and droughts, improvement of navigation and fisheries, and many other areas. But although the dam is one of the main supports for national income in Egypt, it has had some side effects on the river's hydrology, changing the regime of irrigation.

Water became clear and free from solid suspension, encouraging the growth of aquatic weeds because of the deeper penetration of sunlight in the water. These weeds cause serious problems by reducing the hydraulic efficiencies, thereby increasing the silting up of canals. Also, the weeds provide a favourable habitat for water snails which are the intermediate hosts for schistosomes.

Additionally, the groundwater level has been raised as a result of the HAD and the availability of water year-round. This availability has encouraged farmers to use excessive water for irrigation, more than the requirements of the plants. Other factors, such as expansion in agricultural land, mostly upstream among the old lands in the Nile Valley, the conversion of about one million acres in Upper Egypt from basin to perennial irrigation, and the increased rice, sugar and plantation areas, all these lead to a greater recharge of water to the ground reservoir.

Schistosomiasis

This disease has probably been present in Egypt since Pharaonic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Dams can make water available all the year round for irrigating agricultural areas — but they have many other environmental side effects.

times. It is only with the introduction of perennial irrigation that it has become a public health problem of great magnitude, adding to the list of endemic diseases.

Research during the past three decades has shown that no single control method is sufficient for effective control of the disease. Efforts have therefore been directed towards four means, in conjunction with one another: mass treatment of infected humans, environmental sanitation, health education, and snail control.

The snail control method, which involves the destruction of the freshwater snails that act as intermediate hosts for schistosomiasis, is carried out by chemical means. Different chemicals were screened for their efficiency as molluscicides, of which only a few have been in use, such as copper sulphate, sodium pentachlorophenate, Frescon and Bayluscide.

The Ministry of Public Health set up a project for schistosomiasis control in the Fayoum Governorate that began in 1967 and ended in March 1972. This was the first time in Egypt, and in Africa in general, that, in a area with more than one million inhabitants and 39,500 km of different water courses, the following three zero values were reached:

- The zero value for infestation of all water courses with *Bulinus truncatus*;
- the zero value for new infection of the population with schistosomiasis;
- the zero value for infection of the newborn.

Recognizing the importance of snail control in irrigation and drainage systems, the Ministry of Public Works and Water Resources (MPWWR) has taken necessary action toward upgrading irrigation and drainage systems to increase irrigation efficiencies which leads to the control of the number of snails. These actions are: managing aquatic weeds, lining the canal with various lining materials, adopting new designs for alluvial canals, and preparing a short- and long-term strategy to eliminate HAD side-effects.

Aquatic weeds

Aquatic weeds are classified into groups according to their life form. There are three main life forms related to the plant's position with respect to the water surface.

Floating weeds have leaves floating on, or slightly emergent above, the water surface. They may not be rooted in the bottom. The common floating weeds in waterways in Egypt are *Eichhornia crassipes* (water hyacinth), *Lemna gibba* and *Nymphea coerulea* (water lily).

Submerged weeds grow mostly below the water surface. They may or may not be rooted in the soil. Types of common submerged weeds in Egyptian water channels are *Potamogeton pectinatus*, *Potamogeton crispus*, *Ceratophyllum demersum*, and filamentous green algae.

Emergent plants are rooted in the soil and have their leaves above the water surface. Types of common ditch bank and emergent weeds in Egypt are *Typha domingensis* (cattail), *Phragmites australis* (reed), *Cyperus alopecuroides*, *Polygonum senegalense*, *Polygonum salicifolium*, and *Echinochloa stagninum*.

The problem of aquatic weeds was not serious in Egypt before the spring of 1975. Now, more than 80 per cent of canals and drains (47,000km) are heavily infested by all types of aquatic weeds.

After the construction of the HAD, the following changes took place:

- The water became free of suspended sediment.
- The annual flush of flood water through the Nile and main canals was stopped.
- The natural fertility of flood-deposited silt was reduced and had to be replaced by heavy applications of fertilizer, increasing the fertility of the aquatic environment.

Traditionally, control involves the regular cutting and removal of vegetation at intervals throughout the growing season. The total eradication of aquatic vegetation is not possible, and may be undesirable to prevent erosion. The aim of aquatic weed control is to keep aquatic vegetation to an acceptably low level at minimum cost.

At present, three major methods of aquatic weed control are carried out in Egypt: manual, mechanical, and chemical. Biological control, using the Chinese grass carp, began in 1977 on a limited scale.

The weed-control programme which gives the best results at the least cost, depends largely on factors such as the type of canals, the infestation, the type of weeds prevailing, and accessibility.

Control methods

Hand weeding is very effective for aquatic weed control. It is practised throughout Egypt on canals and drains of bed widths less than 5m. It is a non-selective method. All kinds of weeds are removed using scythes, scythe chains and manpower.

At present, the use of this method is decreasing and is being replaced gradually by mechanical control because of:

- The possibility of harvested weeds on channel sides sliding back into the water - always a source for new infestation.
- The steady increase in labourers wages.
- The substantial risk of the labourers' catching schistosomiasis.

Weeds are normally removed mechanically in two ways, cutting or dredging, depending on the efficiency of the machine used. Mowing boats are used to control submerged and emerged weeds in channels more than 8m wide. Hydraulic excavators are used to reshape and deepen existing channels that have been silted. The most efficient machine used recently to control weeds in channels less than 5m wide is the side-mounted moving bucket on a four-wheel drive tractor.

Controlling weeds in the main channels of the Nile is carried out by different types of harvesters. In most cases, the harvested plants are collected on the cutting barges, while in others they are passed on to a separate barge that carries them to the shore.

Traction operated rotary mowers attached to hydraulic arms for cutting ditch-bank weeds on the hedges and slopes of water channels are not useful in Egypt as channels are not well shaped.

Submerged weeds may be controlled with chemicals at half the cost of mechanical means. Chemical control is normally recommended for:

- canals more than 5m wide with no road access for machinery, and
- canals where a large infestation of weeds needs to be cleared quickly.

Acrolein, 2-propanol, is used to control all types of common weeds with doses of 5-15ppm. 2-4-D and Ametrun are the most widely used herbicides for controlling the Water Hyacinth with doses of 6kg/acre and 2 litres/acre, respectively. Herbicides for both floating and submerged weeds are usually applied in the spring. Glyphosate and Downpon S. are herbicides commonly used for controlling ditch-banks and emerged weeds with doses of 2litres/acre and 4kg/acre, respectively, to be applied in autumn.

The policy of the Ministry of Public Works and Water Resources is based on reducing chemical control to the minimum to achieve a clean environment.

Biological control of aquatic weeds was introduced in Egypt in 1977, using the Chinese grass carp (*Ctenopharyngodonvidella*). It provides relatively low-cost perpetual control with minimum side-effects in comparison to other methods. The fish, after reaching about 15 cm, becomes purely herbivorous. This makes the species useful and can be an efficient method for controlling submerged aquatic weeds and algae.

The principal benefit of the biological method is that submerged weed control can be maintained for a number of years with a little additional cost for mechanical control. This combined method was found promising for the control of submerged weeds in Egypt. Costs of the combined method are less than half those of conventional methods. Moreover, grass carp has so far caused no manifest damage to the environment.

It is also possible to retard, displace or control aquatic weeds by the following measures:

- Plants compete with one another for space. One of the most practical examples of a harmless aquatic weed that can compete successfully with troublesome rooted weeds is the Pikerush (*Eleocharis*). This short-growing grass can be seeded in the canal or drain bed and will afterwards decrease the establishment of other kinds of weeds without itself hampering the water flow.
- Shading is one of the methods used for retarding the growth of aquatic weeds in watercourses. Shading can be effective specially for narrow canals and drains. This can be achieved by planting trees on one or both sides of the canal or drain banks.
- A more direct approach, which can be included in the design of channels for decreasing weed growth, is lining. The main purpose of canal lining is to reduce both water losses and the growth of rooted weeds; however, velocities should be maintained that are high enough to prevent silting and consequently regrowth of weeds.


P. Almasy/WHO

Washing and bathing in the river are risky activities: this boy's swollen abdomen shows he is already inflicted with schistisomiasis.

Canal lining also has a direct effect on the snail intermediate hosts of schistosomiasis, as discussed later.

Effect of weed control

In Egypt the snails prefer *Potamogeton crispus* followed by *Eichhornia crassipes* (Water Hyacinth) and *Panicum repens*. Water snails depend on aquatic vegetation in a number of ways:

- The presence of aquatic weeds reduces the current; consequently, snails have more opportunity to exist.
- Aquatic weed is an important food supply for snails.
- The leaves of macrophytes offer a good substratum for deposition of eggs, and the oxygen produced by the leaves has a stimulating effect on the oviposition.
- Aquatic weeds offer the snails suitable shelter from molluscivores and, further, omnivores eat more snails if the vegetation

supply is limited.

- The leaves of floating weeds protect snails from bright sunlight and high temperatures; at low water levels, plants also protect snails from drying out.
- Aquatic weeds have a positive effect on the habitat of snails by supplying oxygen and taking up toxicants.

Laboratory experiments were carried out at the Delta Breeding Station to study the relationship between the two intermediate hosts of schistosomiasis (*B. alexandrina* and *B. truncatus*) and macrophytes. Field studies were also carried out in six irrigation canals and three drains at Mansuriya District, Giza, to compare the effects of various methods of weed control (chemical, mechanical and biological — using the Chinese grass carp) on the population of these two snail species and, thus, on the control of the transmission of the disease.

Results of the laboratory studies showed that, in the absence of macrophytes, negative influence was obtained on both the growth and survival of the two intermediate hosts, *Biomphalaria alexandrina* and *Bulinus truncatus*. Both the average number of ovipositions and the hatching rate were higher in the presence than in the absence of macrophytes, and egg production proved to be related to the increasing surface area of the leaves of *Potamogeton nodosus* submerged weed. The same positive correlation could be found in the case of *Eichhornia crassipes*, but only for *Biomphalaria alexandrina*.

Field experiments were carried out using three types of aquatic weed control:

- Chemical, using Acrolein.
- Mechanical, using dragline and hydraulic excavators.
- Biological, using Chinese grass carp.

The field experiments confirmed the strong relationship between the incidence of vegetation on one hand and the incidence of snails, and that the relationship was even stronger in the case of submerged weeds. It was found that:

- Biological weed control using Chinese grass carp resulted in the lowest vegetation coverage.
- Biological aquatic weed control resulted in the lowest number of snails per unit area, estimated for *B. alexandrina* and *B. truncatus* at 36 per cent and 64 per cent of the number encountered in chemical and mechanical control, respectively.

Although each of the three methods of weed control leads to control of the number of intermediate hosts by reducing vegetation, introduction of grass carp for controlling aquatic weeds in canals and drains has a beneficial side effect in controlling schistosomiasis infestation which is better than the other two methods.

Managing aquatic weeds, besides its direct effect on improving irrigation efficiency of the system, can thus also be considered one of the most effective means for schistosomiasis control.

Effects of canal lining

Snail surveys were carried out in two canals in Giza Governorate, Beni Magdul and El-Hammami.

Beni Magdul canal, previously lined in 1977, was relined with concrete in January 1986 because this canal was found to be infected with both *Bulinus* and *Biomphalaria* snails; cracks appeared along its banks; some mud settled on the bottom, and some floating growth of algae appeared on the surface.

Snail surveys were carried out

after relining the canal. All the defects mentioned had almost disappeared, and the stream was found free from both types of snail vectors. Also, some of the non-lined distributaries branching from this main canal were found either completely free from snail vectors or contained only a few specimens. Lining main canals may help to reduce the snail population in branching field-canal channels downstream of the lined section.

This may be explained by the fact that lined water bodies are allowed to dry almost completely (during closure periods of water rotation). Subsequently, field distributaries, branching from them, even if non-lined, will have a better chance to dry before the introduction of water during second water irrigation. Under such environmental conditions, snail breeding is interrupted.

It must be stressed that lining water bodies may not be helpful in reducing snail population unless proper and continuous maintenance is ensured.

Strategies

Since the completion of HAD, the Ministry of Public Works and Water Resources has put forward a short-term and a long-term strategy to eliminate the danger of the dam's side-effects.

The old river course was in equilibrium with the normal high flood discharges. After construction of the dam, the course lost its equilibrium regime, and submerged islands and aquatic weeds of various types appeared and flourished and spread over all the watercourses.

A new design concept is needed to get a non-silting, non-eroding cross section for watercourses. This new design, when developed, will have an indirect effect on schistosomiasis snails as a result of the decreased vegetation and the high-flow velocity gained.

In 1982, investigations were carried out based on a field study of stable alluvial irrigation channels and other available collected data, from which a series of design equations for stable canals has been deduced. These equations have correlated the relationship between the flow parameters and the canal geometrical elements of the water cross-section and the slope of the canal.

Although the computed results have confirmed the general shape of the regime equations, research work was carried out to study the validity and application of such new design criteria. This included additional field and laboratory work in more stable channels to verify and justify the computed relationships and a series of more useful equations was deduced. Regardless of the limitation of the deduced equations, they give a fair accuracy in design criteria to cover a wide range of variables for the uniform flow in stable canal systems in Egypt.

An additional side effect of the HAD is the raised groundwater level. To diminish this problem, the MPWWR, in 1975, outlined a new policy for drainage to ensure a depth of 2.5m in main drains. The principal requirements of this policy were adjustment, regulation, deepening of the main and secondary drains and construction of new pumping stations. Field drainage was given highest priority, the goal being to cover all cultivated lands with tile drainage networks by the end of 1992 and to use vertical drainage whenever feasible.

The new concept of drainage policy in Egypt definitely has a direct effect on controlling schistosomiasis and its snails. Subsurface field drainage, replacing open-field drains, minimizes the open watercourses, decreasing the probability of the existence of snails. The farmer no longer has to drain his land by directing drainage water toward the open drains, thereby eliminating direct contact with drainage water which may be infested with snails. Moreover, better drainage allows for more ground aeration, improving the chance of getting rid of snails or cercariae by flushing them out with the irrigation water. Preliminary studies have shown that the introduction of subsurface drainage has caused a decrease in schistosomiasis transmission.


J. Breitenbach/WHO

Fishermen in developing countries cannot avoid the water, but the water may harbour the parasites that cause river blindness or schistosomiasis.

Summary

- Perennial irrigation has provided new opportunities for more-intensive crop production, but has also intensified the problems of schistosomiasis.
- Research has shown that no single method is sufficient for effective control of schistosomiasis. Efforts have therefore been directed toward several possible means of control, such as the treatment of infested humans, improved sanitation, health education and snail control.
- The Ministry of Public Health Project in the Fayoum Governorate achieved successful results in reducing the disease incidence.
- Ministry of Public Works and Water Resources methods for the control of Schistosomiasis in Egypt include weed control and canal maintenance.
- All weed control methods reduce the number of snails, but the introduction of grass carp to control schistosomiasis is effective and, additionally, has more beneficial side effects than other methods of aquatic weed control.
- Lined watercourses dry almost completely during periods of water rotation; therefore, snail breeding is interrupted and vegetation is decreased.
- A new design concept for a non-silting, non-eroding cross-section for watercourses has an indirect effect on schistosomiasis snails by decreasing production of vegetation and increasing flow velocity.
- Introduction of sub-surface drainage minimizes schistosomiasis transmission by eliminating direct contact of farmers with infested drainage water, by improving ground aeration, and by flushing out snails and cercariae with irrigation water.